

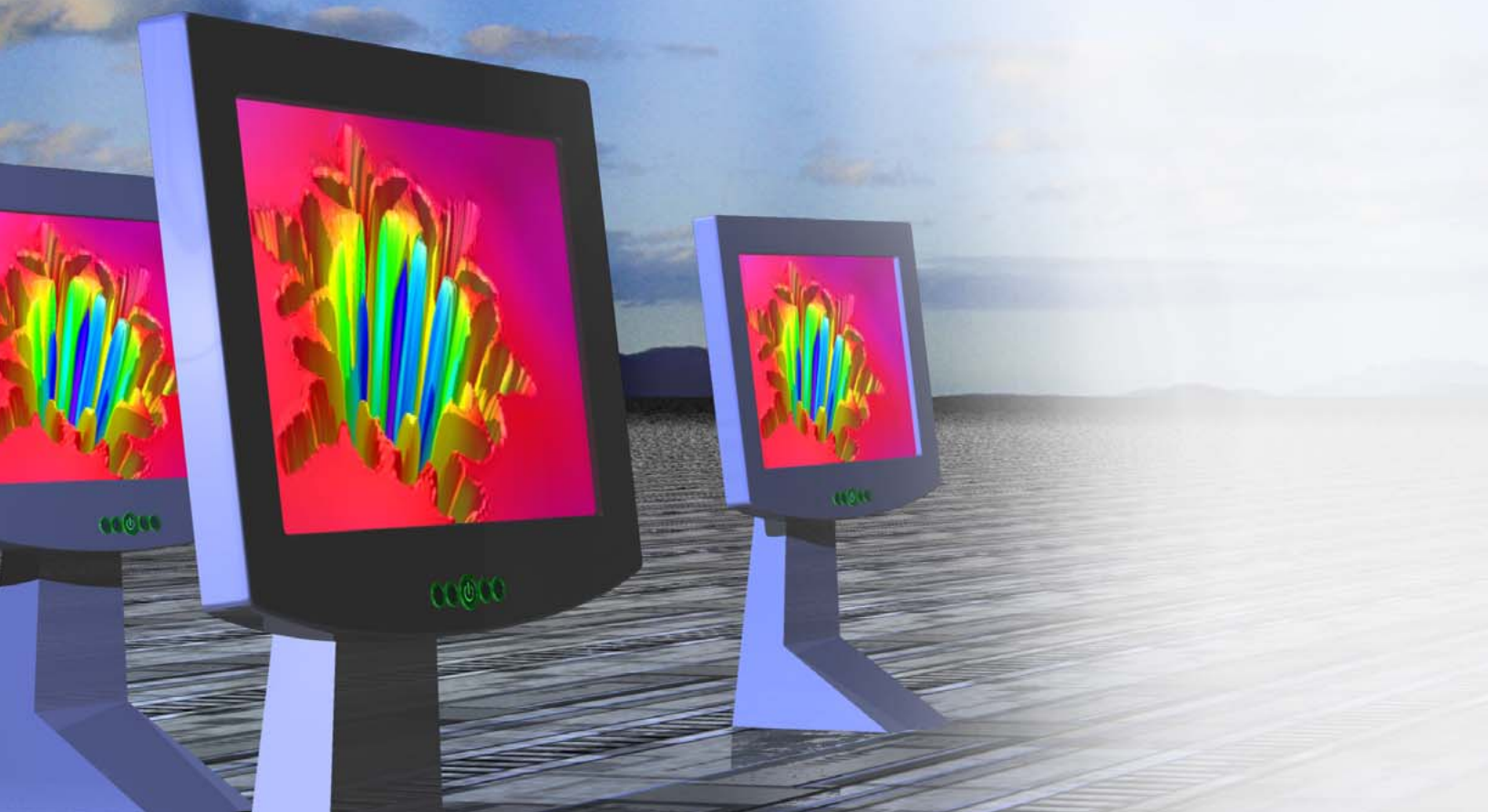
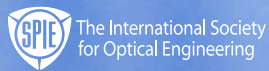
IS&T/SPIE 18th Annual Symposium

Electronic Imaging

Science and Technology

15-19 January 2006 San Jose Marriott and San Jose Convention Center • San Jose, California USA

Sponsored by:



Technical Program

IS&T/SPIE 18th Annual Symposium

Electronic Imaging

Science and Technology

15–19 January 2006 San Jose Marriott and San Jose Convention Center • San Jose, California USA

Conferences • Continuing Education • Technical Exhibition • Demonstrations

Welcome

We are all too busy. If your jobs are like ours, then you are expected to produce more innovation, more products, more research, more students, more money, but all with less time. So how does participating in EI 2006 fit into this picture?

Well, here is the straight answer as to why the Electronic Imaging Symposium is a great investment of your time and resources.

- **Defines the cutting edge in imaging research** - The EI symposium, and its associated publication the *Journal of Electronic Imaging*, have been defining the envelope of high impact digital imaging research since their inception. Because of its leading role, EI is where the innovation leaders in imaging research go to find out about the newest imaging systems, methods, instrumentation, and algorithms.
- **Provides broad coverage with tremendous technical depth** - The unique structure of EI leads to a rich marketplace of ideas where a broad range of topics are discussed in great technical depth. Each year, the EI symposium starts new conferences on important new topics and reinvigorates highly respected existing conferences through the incorporation of new research and participants.
- **Promotes an atmosphere for professional networking** - Because of its organization into primarily single-tracked conferences, the symposium has a very personal and friendly atmosphere that gives technical experts and researchers an opportunity to learn what they need and also, to efficiently network on a professional level.
- **Enhances your professional value** - EI gives you great opportunities to publish high-quality research, meet widely recognized experts in your field, and keep up on "hot" technical trends. All these things enhance the value of both you and your organization.
- **Provides opportunities for professional participation** - Each year new people get involved and infuse EI with fresh new ideas. There are numerous opportunities to participate, and we want both your input and your participation! If you have ideas, feel free to speak to your conference chair, or other EI representatives about getting involved.
- **Leverages the Silicon Valley community** - Every year EI is held in San Jose, the heart of Silicon Valley and the hub of the international information technology industry. Each year we look forward to visiting the institutions that are shaping the future of the imaging industry, and we also don't mind the warm weather!

We look forward to seeing you both this year and for years to come.

IS&T/SPIE would like to express their deepest appreciation to the symposium chairs, conference chairs, and program committees who have so generously given of their time and advice to make this symposium possible. The symposium, like our other conferences and activities, would not be possible without the dedicated contribution of our participants and members.

2006 Symposium Chairs



Charles A. Bouman,
Purdue Univ.



Gabriel G. Marcu,
Apple Computer, Inc.

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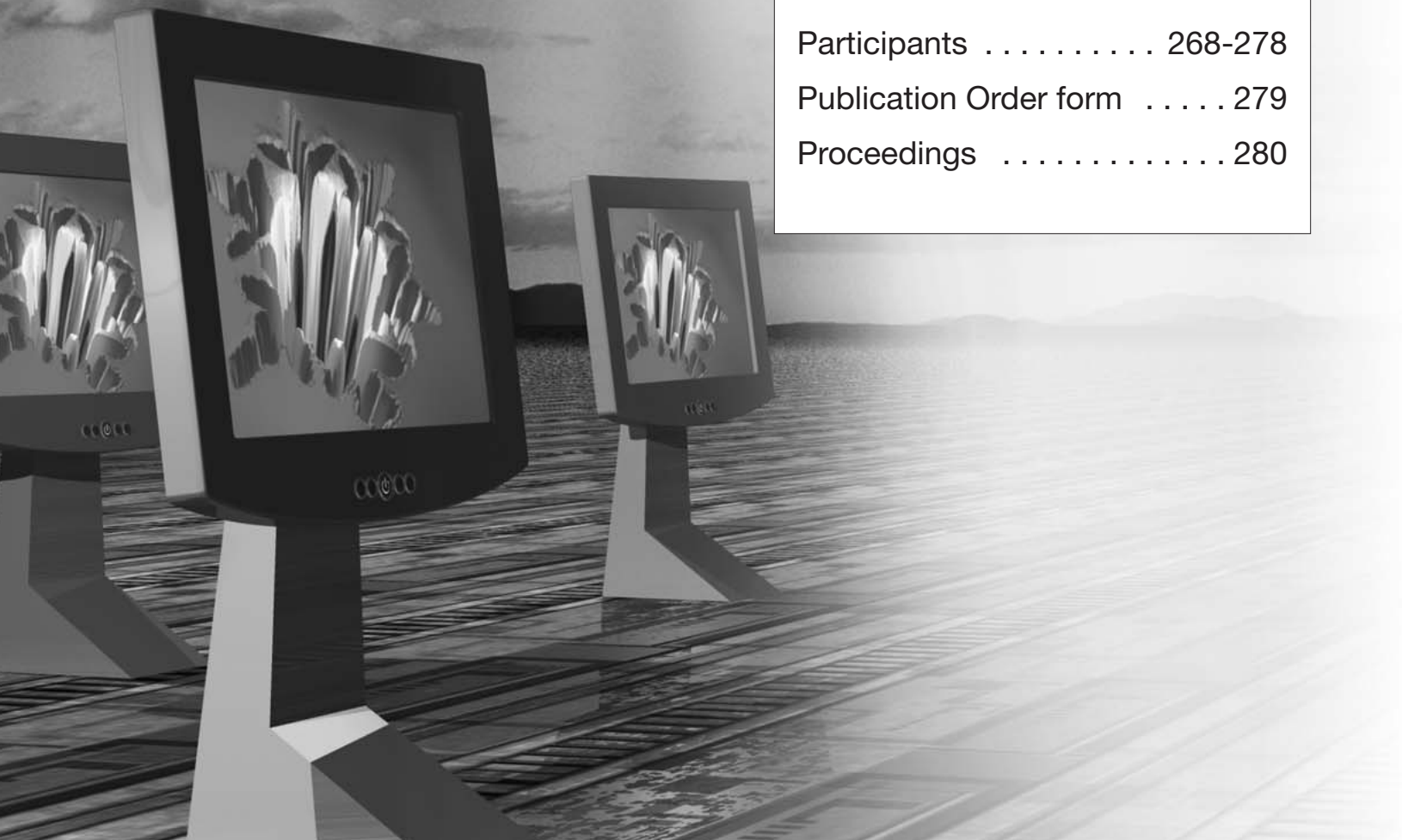
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Electronic Imaging

Symposium Chairs

Charles A. Bouman, Purdue Univ.
Gabriel G. Marcu, Apple Computer, Inc.

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Andrew J. Woods, Ctr. for Marine Science and Technology/Curtin Univ. of Technology (Australia)

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Nasser M. Nasrabadi, Army Research Lab.
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Mitchell Rosen, Rochester Institute of Technology
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Simone Santini, Univ. of California/San Diego
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Kazem Taghva, Univ. of Nevada/Las Vegas
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Matthew Tocheri, Arizona State Univ.
Shoji Tominaga, Osaka Electro-Communication Univ. (Japan)
Rudolf L. van Renesse, VanRenesse Consulting (Netherlands)
Ping Wah Wong, IDzap LLC
Andrew J. Woods, Ctr. for Marine Science and Technology/Curtin Univ. of Technology (Australia)
Angela Y. Wu, American Univ.

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3D Imaging, Interaction, and Measurement

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Imaging, Visualization, and Perception

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Image Processing

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(Nasrabadi, Rizvi) ... p. 34
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- Weds-Thurs 6071 **Multimedia Computing and Networking 2006**
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Optical Security and Anti-Counterfeiting

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Program on

Visual Communications and Image Processing

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Visual Communications and Image Processing			
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Sunday	Monday	Tuesday	Wednesday	Thursday
Digital Imaging				
<p>SC753 Image Quality Evaluation for Digital Cameras Based on Existing ISO Standards (<i>Wueller, Matherson</i>) 8:30 am to 5:30 pm</p> <p>SC504 Introduction to CCD and CMOS Imaging Sensors and Applications (<i>Janesick</i>) 8:30 am to 5:30 pm</p>	<p>SC760 CCD Technology/ Digital Photographic Systems Technology (<i>Theuwissen</i>) 8:30 am to 5:30 pm</p> <p>SC762 Device Simulation for Image Quality Evaluation (<i>Farrell</i>) 8:30 am to 5:30 pm</p> <p>SC772 High Dynamic Range Techniques: From Acquisition to Display (<i>Heidrich, Hoefflinger, Myszkowski</i>) 8:30 am to 5:30 pm</p> <p>SC513 Practical MTF and Noise Performance Measurement for Digital Cameras and Scanners (<i>Burns, Williams</i>) 8:30 am to 5:30 pm</p>		<p>Students: Save 50% on course registrations!</p> <p>Register for Courses at the registration desk.</p>	
Electronic Imaging Technology				
<p>SC066 Fundamentals of Electronic Image Processing (<i>Weeks</i>) 8:30 am to 5:30 pm, \$450 / \$53</p> <p>SC589 Video Compression: Standards and Trends (<i>Rabbani</i>) 8:30 am to 5:30 pm</p>	<p>SC590 Advanced Digital Image and Video Enhancement Algorithms (<i>Rabbani</i>) 8:30 am to 5:30 pm</p> <p>SC763 Subband/Wavelet Scalable Video Coding (<i>Woods</i>) 8:30 am to 12:30 pm, \$220 / \$260</p>	<p>SC761 Novel Spatially Adaptive Anisotropic Local Approximation Techniques in Image Processing (<i>Katkovnik, Egjazarian, Astola</i>) 8:30 am to 12:30 pm</p> <p>SC685 Content-based Image and Video Retrieval (<i>Gevers, Sebe</i>) 1:30 to 5:30 pm</p>	<p>SC491 Neural Networks Applications in Image Processing (<i>Nasrabadi</i>) 8:30 am to 5:30 pm</p>	
Electronic Imaging Applications				
<p>SC084 An Introduction to Cryptography and Digital Watermarking with Applications to Multimedia Systems and Forensics (<i>Delp, Dittmann</i>) 8:30 am to 5:30 pm</p> <p>SC060 Stereoscopic Display Application Issues (<i>Merritt, Woods</i>) 8:30 am to 5:30 pm</p> <p>SC766 Video Surveillance (<i>Ebrahimi, Dufaux</i>) 8:30 am to 5:30 pm</p>	<p>SC764 Filter Banks and Wavelets: Design and Use in Perceptual Coding (<i>Schuller</i>) 1:30 to 5:30 pm</p>		<p>SC767 Practical Implementations of Machine Vision Systems within Technical Processes (<i>Niel</i>) 8:30 am to 12:30 pm</p>	
Biometrics and Security				
<p>SC686 Biometrics: Applications, Technologies, Standards and Evaluation (<i>Vielhauer</i>) 8:30 am to 5:30 pm</p> <p>SC759 Ownership of the Electronic Image: Overview of Copyright, Privacy, and Liability Issues (<i>Williams</i>) 1:30 to 5:30 pm</p>		<p>SC087 Optical Document Security (<i>van Renesse</i>) 8:30 am to 12:30 pm</p>		
Color and Perception				
<p>SC754 Human Shape Perception (<i>Pizlo, Latecki</i>) 8:30 am to 5:30 pm</p>	<p>SC765 The Biology, Physics, and Metrology of Color Perception (<i>Appell</i>) 8:30 am to 5:30 pm</p> <p>SC516 Color Considerations for Liquid Crystal Displays (<i>Marcu</i>) 8:30 am to 12:30 pm</p> <p>SC075 Effective Color Computing (<i>Marcu</i>) 1:30 to 5:30 pm</p>			

Special Events

Technical Group Meeting

Members and nonmembers alike are invited to attend this informative meeting that provides excellent networking opportunities.

Electronic Imaging

Marriott Ballroom 3

Monday 16 January 7:30 to 9:30 pm

Chair: Gabriel Marcu, Apple Computer, Inc.

This group addresses diverse research, engineering, and specialized applications of electronic imaging devices or systems. Because of the diverse topical areas within electronic imaging, the technical group covers image processing, image capture, display and hardcopy, system integration and visualization. Application areas are just as far-reaching. They include industrial automation, graphic arts, aerospace sensing, remote sensing, document processing, high-resolution television, medical imaging, and all areas of digital image processing, including analysis, compression and restoration. The group members are strongly encouraged to propose topics of interest for the next meeting and to submit short articles for publications in the Electronic Imaging Newsletter which serves to promote the topics of interest to the Group.

About the IS&T/SPIE Electronic Imaging Technical Group

Joint sponsorship by the IS&T and SPIE provides even more benefits and contacts for members of the technical group through the close partnership of the two societies. Both IS&T and SPIE members may join the technical group at the member rate of just \$15 per year.

Technical group benefits include:

- a twice-yearly newsletter covering events in the field
- an annual directory of members
- discounts on selected publications, including the SPIE/IS&T copublished quarterly *Journal of Electronic Imaging*.

Poster Session

San Jose Convention Center, Exhibit Hall 1

Tuesday, 17 January 5:30 to 7:00 pm

Conference attendees are invited to the poster session. Authors of poster papers will be on hand during this session to answer questions and provide in-depth discussion concerning their papers. Attendees are requested to wear their conference registration badges to the poster session.

Authors can set up posters after 10:00 am on Tuesday. Poster supplies (pushpins) will be available. Other supplies can be obtained from the Speakers' Audio Visual Desk.

Posters can be previewed during the day of the event before the formal poster session begins at 5:30 pm.

Authors must remove their papers at the conclusion of the poster reception. It is the author's responsibility to remove their posters immediately after the session. Papers not removed will be considered unwanted and will be discarded. The Societies assume no responsibility for posters left up after the end of the poster reception.

All-Conference Reception

Marriott Ballroom 4-6

Wednesday 18 January 7:30 pm to 9:30 pm

Plan to join us for this great opportunity to get to know your Electronic Imaging colleagues. All attendees are invited to relax and enjoy a pleasant evening with friends old and new!

Symposium Demonstration Session

San Jose Convention Center, Exhibit Hall 1

Tuesday 17 January 5:30 to 8:30 pm

Conference Chair: Neil A. Dodgson, Univ. of Cambridge (United Kingdom)

The highly-successful, interactive, hands-on demonstration of stereoscopic hardware, software, and display—traditionally a component of the Stereoscopic Display and Applications Conference—will be expanded this year to include research demonstrations and products related to the entire Electronic Imaging Symposium.

3D Phantogram Exhibit

San Jose Convention Center, Concourse 1 Lobby

Tuesday 17 January 10:00 am to 8:30 pm

Wednesday 18 January 10:00 am to 4:00 pm

Phantograms are a relatively new "3D art form" which place realistic three-dimensional images within hand's reach of the observer. In some ways like a hologram, but in other ways not, phantograms use conventional stereoscopic display technology in a special way to present images that are enchanting. Be prepared to experience a new reality with this innovative combination of art and technology.

Exhibition and Bookfair Hours

Tuesday 17 January 10:00 am to 5:00 pm

Select exhibitors may choose to stay open to 8:30 pm during the Demonstration and Poster Sessions

Wednesday 18 January 10:00 am to 4:00 pm

2006 Exhibitors

**Ukrainian Chapter of SPIE—The International Society
for Optical Engineering**

3D Consortium

Photron USA

Institute for Microelectronics Stuttgart

ABBYY USA Software House

Photonics Spectra

Vision Systems Design

Wiley

Morgan Kaufman/Elsevier

Vision Gates 360°

Plenaries

Marriott Ballroom 1-6

Tuesday 17 January 8:30 to 9:15 am

Image Processing: Interconnections



Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign, Recipient of the 2006 Electronic Imaging Scientist of the Year Award

We live in a complex world. To solve complex problems, we need to combine knowledge and technologies from diverse fields. Image processing often plays a key role in these interdisciplinary problems. In a narrow sense, image processing comprises three areas: coding, enhancement/restoration/reconstruction, and analysis (measurement/detection/recognition). These three areas are, of course, intimately related to each other. Many 2D images are perspective views of 3D objects and scenes. When we try to relate a 2D image to its originating 3D objects/scene, we enter the realm of computer vision. Computer vision techniques are increasingly being used in computer graphics and animation. One may take the position that in a broad sense, image processing subsumes computer vision and computer graphics. Finally, to solve many important problems, it may be advantageous, or necessary to use multimodal (especially, audio and visual) information. In this talk, we shall give two examples of interconnections. First: very low bitrate video coding using a 3D model-based approach, which combines computer vision and computer graphics. Second: audio-visual speech recognition, which combines the audio and the visual modalities.

Biography: **Thomas S. Huang** received his BS from National Taiwan University, and SM and SC.D. from the Massachusetts Institute of Technology, all in Electrical Engineering. He was on the Faculties of MIT and Purdue University before joining the University of Illinois at Urbana-Champaign in 1980, where he is currently William L. Everitt Distinguished Professor of Electrical and Computer Engineering, Professor of the Center for Advanced Study, Research Professor at Coordinated Science Laboratories, and Cochair of the Human Computer Intelligent Interaction major research theme at the Beckman Institute for Advanced Science and Technology. Huang's research interests lie in the broad area of Information Technology, but especially Multidimensional and Multimodal Signal Processing, with applications to human computer interaction, and multimedia data indexing, retrieval, and mining. He has published 21 books and more than 600 journal and conference papers in 2D digital filtering, digital holography, image and video compression, multimodal human computer interfaces, and multimedia data retrieval. He is a member of the National Academy of Engineering, a Fellow of SPIE, OSA, IAPR, and IEEE; and has received numerous awards, including: IEEE Jack S. Kilby Signal Processing Medal (co-recipient with Arun Netravali), and the King-Sun Fu Prize of the Int'l. Association of Pattern Recognition.

Wednesday 18 January 8:30 to 9:15 am

Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging



Richard M. Leahy, Univ. of Southern California

The combined revolutionary advances in recent years in molecular biology, imaging science and computing power make this a golden age for biomedical imaging. Central to modern biomedical imaging is the requirement for new computational imaging methods for noninvasive studies of human and animal anatomy and function. Computational tools are needed both for optimizing resolution and noise properties in reconstructed images and for the interpretation and statistical analysis of these images across modalities, subjects, and populations. I will describe some recent work on image formation and analysis in functional brain mapping and molecular imaging, and attempt to highlight common themes and open research questions relevant to computational imaging.

Biography: **Richard M. Leahy** received the B.Sc. and Ph.D. degrees in Electrical Engineering from the University of Newcastle upon Tyne, England. In 1985 he joined the University of Southern California where he is a Professor of Electrical Engineering, Radiology and Biomedical Engineering and was Director of the Signal and Image Processing Institute from 1997 until 2003. He was General Chair of the 2004 IEEE International Symposium on Biomedical Imaging and is a Fellow of the IEEE. His research interests lie in the application of signal and image processing theory to anatomical and functional imaging with applications in neuroimaging, oncology, and gene expression.

General Information

Electronic Imaging 2006

San Jose Convention Center
408 S. Almaden Boulevard, San Jose, CA 95110
San Jose Marriott Hotel
301 S. Market Street, San Jose, CA 95113

Registration Location and Information Hours

San Jose Convention Center, Concourse 1 Lobby

Courses Only:

Sunday 15 January 7:00 am to 10:00 am

Conference Registration:

Sunday 15 January 10:00 am to 4:00 pm

Monday-Wednesday 16-18 January 7:00 am to 4:00 pm

Thursday 19 January 7:00 am to Noon

Speakers Audiovisual Desk Hours

San Jose Convention Center, Room E

Monday-Thursday 16-19 January 7:30 am to 4:30 pm

Speakers who have requested to use LCD projection from their laptop, 35mm slide projection, a VHS video player, or an overhead projector are encouraged to preview their materials at the Audiovisual Desk prior to their presentation. Speakers who have requested special equipment beyond the standard equipment noted here are asked to report to the EI '06 Audiovisual Desk upon arrival at the meeting to confirm equipment requests. Speakers will be responsible for delivering visual materials to the conference room and may retrieve their presentation materials from the room monitor in the conference room immediately following the session.

Course Notes

Courses will take place in various meeting rooms at the San Jose Marriott Hotel and the San Jose Convention Center. Your room assignment will be given to you with a ticket in your registration materials. Registrants for courses must exchange each course ticket received for their course notes in the course meeting room at the beginning of your class.

Video/Digital Recording Policy

For copyright reasons, video or digital recording of any conference session, short course, or poster session is strictly prohibited without written prior consent from each specific presenter to be recorded. Individuals not complying with this policy will be asked to leave a given session and to surrender their film or disc. It is the responsibility of the presenter to notify the conference sponsors if such consent is given.

Messages for Attendees

Messages for attendees at Electronic Imaging 2006 Symposium can be left by calling the IS&T/SPIE Message Center at 408-271-6100. Messages will be taken during registration hours Sunday through Thursday.

Attendees should check the message boards at the message center daily to receive their messages.

Complimentary Internet Wireless Access

IS&T/SPIE are pleased to provide complimentary wireless access to the Internet for all conference attendees bringing 802.11b wireless-enabled laptops or PDAs.

Properly secure your computer before accessing the public wireless network. Failure to do so may allow unauthorized access to your laptop.

Coverage locations and connection settings will be posted at the Registration desk.

Please configure your wireless settings as follows:

SSID: EI2006 (case-sensitive - all capital letters)

WEP: Disabled

Network Card Settings: DHCP

SPIE Bookstore and Membership Booth

Monday through Thursday, Open during registration hours.

SPIE publishes a variety of technical books designed to meet diverse research, reference, and educational needs. Proceedings of SPIE technical conferences from this and related meetings may be purchased at the bookstore. Also available are related books in the SPIE PRESS Series, including Tutorial Texts, Milestone Series of Selected Reprints, Critical Reviews in Science & Technology, and Monographs & Handbooks.

IS&T Bookstore and Membership Booth

Monday through Thursday, Open during registration hours.

IS&T publishes a variety of books to meet your needs. Proceedings of past IS&T conferences including Digital Printing Technologies, Color Imaging as well as Recent Progress series books will be available. IS&T also distributes selected titles from cooperating publishers of science and technology books in the imaging field. Information about upcoming IS&T conferences and IS&T membership benefits, sample journals, and newsletters are available.

Cash Cart: Breakfast Breads, Snacks and Quick Lunch

San Jose Convention Center, Concourse 1 Lobby

Monday-Thursday 16-19 January 7:30 am to 2:30 pm

The Cash Cart will offer breakfast breads, yogurt, fruit, coffee, juice and other beverages each morning of the conference. Luncheon and snack service will include deli-style sandwiches, salads, snacks and pastries, and beverage.

Attendees will need to make their own breakfast arrangements for Monday.

Copy & Computer Services

Marriott San Jose Hotel - Business Center. Self-service computers/printers, fax, copiers and internet access is available on 24 hr basis. Access is by your sleeping room key. All Marriott guest rooms include T-1 internet connections.

San Jose Convention Center - Business Center at the administration office. Open 8:00 am to 5:00 pm daily. Services available include computers/printers, fax, and copiers.

Child Care

A few child sitting services available in San Jose are as follows.

1. Bay Area 2nd MOM Inc.

Hotel Nanny Service

Toll Free Phone: 1-888-926-3666, or (650) 858-2469, ext. 109.,

Monday-Friday 9:00 am to 5:00 pm.

At other times phone (650) 858-4984

Fax: (650) 493-6598

E-mail: info@2ndmom.com or oncall@2ndmom.com

Website: www.2ndmom.com

2. Sitters Unlimited

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Monday-Wednesday 16-18 January 2006 • Part of Proceedings of SPIE Vol. 6055
Stereoscopic Displays and Virtual Reality Systems XIII

Stereoscopic Displays and Applications XVII

Conference Chairs: **Andrew J. Woods**, Ctr. for Marine Science and Technology/Curtin Univ. of Technology (Australia); **Neil A. Dodgson**, Univ. of Cambridge (United Kingdom); **John O. Merritt**, The Merritt Group

Program Committee: **Gregg E. Favalora**, Actuality Systems, Inc.; **Nicolas S. Holliman**, Univ. of Durham (United Kingdom); **Janusz Konrad**, Boston Univ.; **Shojiro Nagata**, InterVision (Japan); **Steven L. Smith**, Consultant; **Vivian K. Walworth**, Jasper Associates; **Michael A. Weissman**, Micro Vision Systems Inc.

Monday 16 January

SESSION 1

Conv. Ctr. Room A8 Mon. 8:30 to 10:10 am
Entertainment, Visualization, and Training: Applications of Stereoscropy

Chair: **Andrew J. Woods**, Curtin Univ. of Technology (Australia)

- 8:30 am: **The use of stereoscopic visualization in chemistry and structural biology**, M. Hušák, Institute of Chemical Technology Prague (Czech Republic) [6055A-01]
- 8:50 am: **Using stereoscopic real-time graphics to shorten training time for complex mechanical tasks**, F. Tecchia, M. Carrozzino, F. Rossi, M. Bergamasco, Scuola Superiore Sant'Anna (Italy); M. Vescovi, SIG Simonazzi (Italy) [6055A-02]
- 9:10 am: **Stereoscopic display of 3D models for design visualization**, K. J. Gilson, Parsons Brinckerhoff [6055A-03]
- 9:30 am: **Stereoscopic image production: live, CGI, and integration**, E. Criado, Enxebre Entertainment (Spain) [6055A-04]
- 9:50 am: **Cosmic cookery: making a stereoscopic 3D animated movie**, N. S. Holliman, C. Baugh, C. Frenk, A. Jenkins, B. Froner, D. Hassaine, J. Helly, N. Metcalfe, T. Okamoto, Univ. of Durham (United Kingdom) [6055A-05]
- Coffee Break 10:10 to 10:40 am

SESSION 2

Conv. Ctr. Room A8 Mon. 10:40 am to 12:00 pm
Medical Applications of Stereoscropy

Chair: **Michael A. Weissman**, Micro Vision Systems, Inc.

- 10:40 am: **Evaluation of stereoscopic medical video content on an autostereoscopic display for undergraduate medical education**, J. F. R. Ilgner, Univ. Hospital Aachen (Germany); T. Kawai, T. Shibata, T. Yamazoe, Waseda Univ. (Japan); M. Westhofen, Univ. Hospital Aachen (Germany) [6055A-06]
- 11:00 am: **Stereoscopic visualization and editing of automatic abdominal aortic aneurysms (AAA) measurements for stent graft planning**, L. Zhou, Y. P. Wang, C. Goh, R. Kockro, L. Serra, Volume Interactions Pte. Ltd. (Singapore) [6055A-07]
- 11:20 am: **A hybrid virtual environment for training of radiotherapy treatment of cancer**, R. Phillips, The Univ. of Hull (United Kingdom) [6055A-08]
- 11:40 am: **Blur spot limitations in distal endoscope sensors**, A. Yaron, Visionsense Inc.; M. Shechterman, N. Horesh, U. Ronen, Visionsense Ltd. (Israel) [6055A-09]
- Lunch Break 12:00 to 1:30 pm

SESSION 3

Conv. Ctr. Room A8 Mon. 1:30 to 3:10 pm
Perception and Performance: Stereoscopic Human Factors

Chair: **John O. Merritt**, The Merritt Group

- 1:30 pm: **Visual comfort with mobile stereoscopic gaming**, J. P. Häkkinen, Nokia Research Ctr. (Finland) and Univ. of Helsinki (Finland); M. Liinasuo, Nokia Research Ctr. (Finland); J. Takatalo, G. S. Nyman, Univ. of Helsinki (Finland) [6055A-10]
- 1:50 pm: **Effect of disparity and motion on visual comfort of stereoscopic images**, F. Speranza, J. W. Tam, R. Renaud, Communications Research Ctr. Canada (Canada); N. Hur, Electronics and Telecommunications Research Institute (South Korea) [6055A-11]
- 2:10 pm: **Analysis of an autostereoscopic display: the perceptual range of the three-dimensional visual fields and saliency of static depth cues**, P. R. Havig, Air Force Research Lab.; J. P. McIntire, Consortium Research Fellows Program; R. McGruder, U.S. Air Force Academy [6055A-12]
- 2:30 pm: **Effects of gender, application, experience, and constraints on interaction performance using autostereoscopic displays**, Z. Y. Alpaslan, S. Yeh, A. A. Rizzo III, A. A. Sawchuk, Univ. of Southern California [6055A-13]
- 2:50 pm: **Examination of asthenopia recovery using stereoscopic 3D display with dynamic optical correction**, T. Shibata, T. Kawai, K. Ohta, L. Jae Lin, Waseda Univ. (Japan); M. Otsuki, N. Miyake, Nikon Corp. (Japan); Y. Yoshihara, Arisawa Manufacturing Co., Ltd. (Japan); T. Iwasaki, Univ. of Occupational and Environmental Health (Japan) [6055A-14]
- Coffee Break 3:10 to 3:40 pm

SESSION 4

Conv. Ctr. Room A8 Mon. 3:40 to 5:00 pm
Stereoscopic Projection and Stereoscopic Cinema

Chair: **Vivian K. Walworth**, Jasper Associates

- 3:40 pm: **High-resolution insets in projector-based stereoscopic displays: principles and techniques**, G. Godin, P. Massicotte, L. Borgeat, National Research Council Canada (Canada) [6055A-15]
- 4:00 pm: **Stereo projection using interference filters**, H. Jorke, M. Fritz, Infitec GmbH (Germany) [6055A-16]
- 4:20 pm: **Development of the real-time stereoscopic error corrector and convergence controller**, S. Nam, C. Park, Korean Broadcasting System (South Korea); Y. S. Yu, K. Lee, TVLogic Co. Ltd. (South Korea) [6055A-55]
- 4:40 pm: **3D in digital cinema**, W. J. Husak, Dolby Labs. [6055A-18]

3D Theatre 5:20 to 7:20 pm
*Chairs: Andrew J. Woods, Curtin Univ. of Technology (Australia);
 Chris Ward, Lightspeed Design, Inc.*
 See large-screen examples of how 3D video is being used and produced around the world.

SD&A Dinner 7:30 pm to Late
 A no-host informal dinner open to all SD&A attendees will be held at a local San Jose restaurant. Details will be available at the conference.

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am
Marriott Ballroom 1-6
Image Processing: Interconnections
Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign
See p. 7 for details.

SESSION 5

Conv. Ctr. Room A8 Tues. 9:30 to 10:30 am
Stereoscopic Image Processing
Chair: Janusz Konrad, Boston Univ.

- 9:30 am: **Platelet-based coding of depth maps for the transmission of multiview images**, Y. Morvan, D. Farin, P. H. N. de With, Technische Univ. Eindhoven (Netherlands) [6055A-19]
- 9:50 am: **Efficient view synthesis from uncalibrated stereo**, R. A. C. Braspenning, M. Op de Beeck, Philips Research Labs. (Netherlands) [6055A-20]
- 10:10 am: **A fast image multiplexing method robust to viewer's position and lens misalignment in lenticular 3D displays**, Y. Lee, J. B. Ra, Korea Advanced Institute of Science and Technology (South Korea) [6055A-21]
- Coffee Break 10:30 to 11:00 am

SESSION 6

Conv. Ctr. Room A8 Tues. 11:00 am to 12:00 pm
Making Pictures: Stereoscopic Rendering
Chair: Neil A. Dodgson, Univ. of Cambridge (United Kingdom)

- 11:00 am: **Real-time rendering for multiview displays**, R. M. Berretty, F. J. Peters, Philips Research Labs. (Netherlands); G. Volleberg, Philips Applied Technologies (Netherlands) [6055A-22]
- 11:20 am: **Anisotropic scene geometry resampling with occlusion filling for 3DTV applications**, J. Kim, T. Sikora, Technische Univ. Berlin (Germany) [6055A-23]
- 11:40 am: **Distributed rendering for multiview parallax displays**, T. Annen, Max-Planck-Institut für Informatik (Germany); W. Matusik, H. Pfister, Mitsubishi Electric Research Labs.; H. Seidel, Max-Planck-Institut für Informatik (Germany); M. Zwicker, Massachusetts Institute of Technology [6055A-24]
- Lunch/Exhibition Break 12:00 to 1:30 pm

SESSION 7

Conv. Ctr. Room A8 Tues. 1:30 to 3:10 pm
Autostereoscopic Displays I
Chair: Gregg E. Favalora, Actuality Systems, Inc.

- 1:30 pm: **On the number of viewing zones required for head-tracked autostereoscopic display**, N. A. Dodgson, Univ. of Cambridge (United Kingdom) [6055A-25]
- 1:50 pm: **Multiview LCD wall system**, I. Relke, Opticality GmbH (Germany) [6055A-26]
- 2:10 pm: **Flatbed-type autostereoscopic display system and its image format for encoding**, T. Saishu, S. Numazaki, K. Taira, R. Fukushima, A. Morishita, Y. Hirayama, Toshiba Corp. (Japan) [6055A-27]
- 2:30 pm: **Autostereoscopic 3D display**, A. Schwerdtner, SeeReal Technologies GmbH (Germany) [6055A-28]
- 2:50 pm: **The HoloVizio system**, T. Balogh, Holografika Kft. (Hungary) [6055A-29]
- Coffee Break 3:10 to 3:40 pm

SESSION 8

Conv. Ctr. Room A8 Tues. 3:40 to 5:20 pm
Autostereoscopic Displays II
Chair: Shojiro Nagata, InterVision (Japan)

- 3:40 pm: **Development of autostereoscopic display system for remote manipulation**, T. Honda, Y. Kuboshima, K. Iwane, T. Shiina, Chiba Univ. (Japan) [6055A-30]
- 4:00 pm: **Ray-space acquisition and reconstruction within cylindrical objective space**, T. Yendo, T. Fujii, M. Tanimoto, Nagoya Univ. (Japan) [6055A-31]
- 4:20 pm: **72-directional display having VGA resolution for high-appearance image generation**, Y. Takaki, T. Dairiki, Tokyo Univ. of Agriculture and Technology (Japan) [6055A-32]
- 4:40 pm: **Combining volumetric edge display and multiview display for expression of natural 3D images**, R. Yasui, I. Matsuda, H. Kakeya, Univ. of Tsukuba (Japan) [6055A-33]
- 5:00 pm: **Adaptive parallax control for multiview stereo panoramas**, C. Wang, A. A. Sawchuk, Univ. of Southern California [6055A-34]

✓ Posters and Demonstrations-Tuesday

*Chairs: Neil A. Dodgson, Univ. of Cambridge (United Kingdom);
 Andrew J. Woods, Curtin Univ. of Technology (Australia)*

Demonstrations 5:30 to 8:30 pm

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters 5:30 to 7:00 pm

- Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.*
- ✓ **Real-time stereographic display of volumetric datasets in radiology**, X. H. Wang, G. S. Maitz, J. K. Leader, W. F. Good, Univ. of Pittsburgh [6055A-46]
- ✓ **Ergonomic evaluation system for stereoscopic video production**, T. Kawai, S. Kishi, T. Yamazoe, T. Shibata, Waseda Univ. (Japan); T. Inoue, Kanagawa Institute of Technology (Japan); Y. Sakaguchi, K. Okabe, Y. Kuno, Let's Corp. (Japan); T. Kawamoto, Chukyo TV Broadcasting Corp. (Japan) [6055A-47]
- ✓ **Wide-viewing-angle three-dimensional display system using HOE lens array**, H. Takahashi, H. Fujinami, Osaka City Univ. (Japan); K. Yamada, Hiroshima Institute of Technology (Japan) [6055A-48]

- ✓ **Depth map-based disparity estimation technique using multiview and depth camera**, G. Um, Electronics and Telecommunications Research Institute (South Korea); S. Kim, K. Kim, Gwangju Institute of Science and Technology (South Korea); N. Hur, Electronics and Telecommunications Research Institute (South Korea); K. Lee, Gwangju Institute of Science and Technology (South Korea) [6055A-50]
- ✓ **A uniform metric for anaglyph calculation**, Z. Zhang, D. F. McAllister, North Carolina State Univ. [6055A-51]
- ✓ **Multiview autostereoscopic display with double-sided reflecting scanning micromirrors**, A. Nakai, K. Hoshino, K. Matsumoto, I. Shimoyama, The Univ. of Tokyo (Japan) [6055A-53]
- ✓ **Depth-enhanced floating display system based on integral imaging**, J. Kim, Seoul National Univ. (South Korea); S. Min, Information and Communications Univ. (South Korea); Y. Kim, S. Cho, H. Choi, B. Lee, Seoul National Univ. (South Korea) [6055A-54]
- ✓ **Three-dimensional sprites for lenticular-type three-dimensional display**, T. Dairiki, Y. Takaki, Tokyo Univ. of Agriculture and Technology (Japan) [6055A-56]
- ✓ **Optical design considerations for a beam combiner in a StereoMirror (TM) 3D display**, A. Hochbaum, VAV Consulting; J. L. Ferguson, Ferguson Patent Properties [6055A-57]
- ✓ **Horizontal parallax distortion in toe-in camera systems with fisheye lens**, H. Kang, D. Kim, N. Hur, Electronics and Telecommunications Research Institute (South Korea) [6055A-58]
- ✓ **Implementation of 3DTV broadcasting system for realistic broadcasting services**, B. Bae, S. Cho, K. Yun, H. Kang, N. Hur, C. Ahn, Electronics and Telecommunications Research Institute (South Korea) [6055A-59]
- ✓ **Performance analysis of a compact electro-optical 3D adapter with a wide capturing angle**, S. Kim, J. Lee, E. Kim, Kwangwoon Univ. (South Korea) [6055A-61]
- ✓ **New method of zoom-convergence interlocked control in the moving parallel-axes style stereoscopic camera**, J. Lee, S. Nam, J. Lee, C. Park, S. Chung, Korean Broadcasting System (South Korea) [6055A-62]

Wednesday 18 January

Plenary Speaker Wed. 8:30 to 9:15 am

Marriott Ballroom 1-6

Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging

Richard Leahy, Univ. of Southern California

See p. 7 for details.

SESSION 9

Conv. Ctr. Room A8 Wed. 9:30 to 10:30 am

Integral 3D Imaging

Chair: Shojiro Nagata, InterVision (Japan)

9:30 am: **Integral videography of high-density light field with spherical layout camera array**, T. Koike, M. Oikawa, N. Kimura, F. Beniyama, T. Moriya, M. Yamasaki, Hitachi, Ltd. (Japan) [6055A-35]

9:50 am: **Imaging properties of microlens arrays for integral imaging system**, J. Arai, M. Okui, Y. Nojiri, F. Okano, NHK Science & Technical Research Labs. (Japan) [6055A-36]

10:10 am: **Comparative study on 3D-2D convertible integral imaging systems**, B. Lee, H. Choi, J. Kim, Y. Kim, Seoul National Univ. (South Korea) [6055A-37]

Coffee Break 10:30 to 11:00 am

**Discussion Forum: Stereoscopic Digital Cinema:
The Way of the Future or a 9-Day Wonder?**

Moderator: Charles Swartz, Entertainment Technology Ctr./Univ. of Southern California

Panel Members: Lenny Lipton, CTO, REAL D; **Ray Zone**, The 3-D Zone; **John Rupkalvis**, StereoScope International; **Walter Husak**, Dolby Labs Inc.; **Neil Feldman**, In-Three, Inc.

Lunch/Exhibition Break 12:00 to 1:50 pm

SESSION 10

Conv. Ctr. Room A8 Wed. 1:50 to 2:10 pm

Stereoscopic Software

Chair: Nicolas S. Holliman, Univ. of Durham (United Kingdom)

1:50 pm: **Application of 3DHiVision: a system with a new 3D HD renderer**, P. Sun, Sun Advanced Engineering, Inc. (Japan); S. Nagata, InterVision (Japan) [6055A-39]

SESSION 11

Conv. Ctr. Room A8 Wed. 2:20 to 3:20 pm

Keynote Presentation

Chair: Andrew J. Woods, Curtin Univ. of Technology (Australia)

Keynote

3D animation in three dimensions: the rocky road to the obvious, Hugh Murray, IMAX Corp. (Canada) [6055A-40]

That animation created using CG modeling and animation tools is inherently three-dimensional is well known. In the middle to late nineties IMAX Corporation began actively exploring CG animated features as a possible source of economically viable content for its rapidly growing network of stereoscopic IMAX(r) 3D theatres. The journey from there to the spectacular success of the IMAX(r) 3D version of The Polar Express is an interesting mix of technical, creative and production challenges. For example 3D animations often have 2D elements and include many sequences that have framing, composition and lens choices that a stereographer would have avoided had 3D been part of the recipe at the outset. And of course the decision to ask for a second set of deliverables from an already stressed production takes nerve. The talk will cover several of these issues and explain why the unique viewing experience enabled by the wide-angle geometry of IMAX(r) 3D theatres makes it worth all the pain.

Biography: **Hugh Murray** is Vice President, Technical Production at IMAX Corporation and for the past 10 years he has worked on most of IMAX Corporation's film productions as a technical expert, particularly in 3D and special effects. Hugh was the instigator and producer, with Steve Hoban, of the computer animated film Cyberworld 3D. Hugh led the team that identified the key technologies for the IMAX DMR(r) process and was IMAX(r) Producer on Apollo 13 (with Lorne Orleans), Star Wars Episode II: Attack of the Clones (with Lorne Orleans), Matrix Reloaded, Matrix Revolutions, and the IMAX(r) 3D version of The Polar Express. He was most recently an Executive Producer on Magnificent Desolation: Walking On The Moon 3D and is currently working on the 3D versions of two animated features for release in 2006.

Coffee Break 3:20 to 3:50 pm

SESSION 12

Conv. Ctr. Room A8 Wed. 3:50 to 5:30 pm

Stereoscopic Developments

Chair: Steven L. Smith, Consultant

3:50 pm: **A method of real-time construction of full parallax light field**, K. Tanaka, S. Aoki, Sony Corp. (Japan) [6055A-41]

4:10 pm: **Depth maps created from blur information using images with focus at near and at far**, S. Cho, Electronics and Telecommunications Research Institute (South Korea); J. W. Tam, F. Speranza, R. Renaud, Communications Research Ctr. Canada (Canada); N. Hur, S. Lee, Electronics and Telecommunications Research Institute (South Korea) [6055A-49]

4:30 pm: **Simulation of 3D image depth perception in a 3D display using two stereoscopic displays at different depths**, K. Uehira, Kanagawa Institute of Technology (Japan) [6055A-43]

4:50 pm: **Innovative stereoscopic display using variable polarized angle**, J. E. Gaudreau, PolarScreens, Inc. (Canada) and MacNaughton, Inc.; M. Bechamp, PolarScreens, Inc. (Canada); B. MacNaughton, V. S. Power, MacNaughton, Inc. [6055A-44]

5:10 pm: **A novel walk-through 3D display**, S. DiVerdi, A. Olwal, I. K. Rakkolainen, T. Höllner, Univ. of California/Santa Barbara . . . [6055A-45]

Thursday 19 January 2006 • Part of Proceedings of SPIE Vol. 6055
Stereoscopic Displays and Virtual Reality Systems XIII

The Engineering Reality of Virtual Reality 2006

Conference Chairs: **Mark T. Bolas**, Univ. of Southern California; **Ian E. McDowall**, Fakespace Labs., Inc.

Program Committee: **Nick England**, 3rdTech, Inc.; **Guillaume Moreau**, CNRS Aeronmie (France); **Shojiro Nagata**, InterVision (Japan); **Daniel J. Sandin**, Univ. of Illinois/Chicago; **Andreas Simon**, Fraunhofer Institute for Media Communication (Germany); **Henry A. Sowizral**, Sun Microsystems, Inc.

Thursday 19 January

SESSION 13

Conv. Ctr. Room B3 Thurs. 8:30 to 9:50 am

Procedures

Chair: **Ian E. McDowall**, Fakespace Labs., Inc.

- 8:30 am: **Texturing of continuous LoD meshes with the hierarchical texture atlas**, H. Birkholz, Univ. Rostock (Germany) [6055B-63]
- 8:50 am: **Optimal approximation of head-related transfer function's zero-pole model based on genetic algorithm**, J. Zhang, Southeast Univ. (China) [6055B-64]
- 9:10 am: **Multiprojector image distortion correction scheme for curved screens on the example of the Cybersphere**, B. V. Shulgin, J. Ye, V. H. Raja, Univ. of Warwick (United Kingdom) [6055B-65]
- 9:30 am: **3D workflow for HDR image capture of projection systems and objects for CAVE virtual environments authoring with wireless touch-sensitive devices**, M. J. Prusten, Optical Design Labs.; M. K. McIntyre, Total Eclipse Studios; M. Landis, The Univ. of Arizona [6055B-66]
- Coffee Break 9:50 to 10:20 am

SESSION 14

Conv. Ctr. Room B3 Thurs. 10:20 to 11:40 am

Applications

Chair: **Ian E. McDowall**, Fakespace Labs., Inc.

- 10:20 am: **Examination of corner vane estrangement evaluation method for a circular tunnel**, H. Yokoyama, O. Fujishima, Hitachi, Ltd. (Japan) [6055B-67]
- 10:40 am: **Virtual technical support for field engineers in the water and ventilation hygiene industry**, I. A. Nicholas, Cardiff Univ. (United Kingdom); D. Kim, Aqua Marc Ltd. (United Kingdom) [6055B-68]
- 11:00 am: **Virtual reality in construction industry: a requirement compatibility analysis approach**, J. Ye, B. V. Shulgin, V. H. Raja, Univ. of Warwick (United Kingdom) [6055B-69]
- 11:20 am: **Adding tactile realism to a virtual reality laparoscopic surgical simulator with a cost-effective human interface device**, I. W. Mack, Queen's Univ. Belfast (United Kingdom); S. Potts, The Royal Group of Hospitals (United Kingdom); K. R. McMenemy, R. S. Ferguson, Queen's Univ. Belfast (United Kingdom) [6055B-70]
- Lunch Break 11:40 am to 1:10 pm

SESSION 15

Conv. Ctr. Room B3 Thurs. 1:10 to 2:30 pm

The Medium

Chair: **Mark T. Bolas**, Fakespace Labs., Inc.

- 1:10 pm: **Inverse perspective**, M. Dolinsky, Indiana Univ. . . . [6055B-71]
- 1:30 pm: **Virtual reality and the unfolding of higher dimensions**, J. C. Aguilera, Univ. of Illinois at Chicago [6055B-72]
- 1:50 pm: **Framing the magic**, D. Tsoupiakova, Univ. of Illinois at Chicago [6055B-73]
- 2:10 pm: **Virtual reality, immersion, and the unforgettable experience**, J. F. Morie, Univ. of Southern California [6055B-74]

SESSION 16

Conv. Ctr. Room B3 Thurs. 2:30 to 4:40 pm

Viewpoints

Chair: **Mark T. Bolas**, Fakespace Labs., Inc.

- 2:30 pm: **Teleoperation interface for mobile robot with perspective-transformed virtual 3D screen on PC display**, T. Kimura, H. Kakeya, Univ. of Tsukuba (Japan) [6055B-75]
- 2:50 pm: **An orientation sensing interface for portable situation awareness displays**, J. Bleecker, Univ. of Southern California [6055B-76]
- Coffee Break 3:10 to 3:40 pm
- 3:40 pm: **An interactive camera placement and visibility simulator for image-based VR applications**, A. State, G. Welch, A. Ilie, The Univ. of North Carolina at Chapel Hill [6055B-77]
- 4:00 pm: **Overview of virtual camera mechanisms for collaborative virtual environments: an application to the VRIMOR project**, E. E. Alvarez, A. A. De Antonio, Univ. Polit cnica de Madrid (Spain) [6055B-78]
- 4:20 pm: **Synthecology: 'sound' use of audio in teleimmersion**, G. A. Baum, SUNY/Univ. at Buffalo; M. Gotsis, Univ. of Southern California; B. Chang, R. Drinkwater, D. St. Clair, Art Institute of Chicago . . . [6055B-79]

Panel Discussion 4:40 to 5:40 pm

Three-Dimensional Image Capture and Applications VI

Conference Chairs: **Brian D. Corner**, U.S. Army Natick Soldier Ctr.; **Peng Li**, GEO-Centers, Inc.; **Matthew Tocheri**, Arizona State Univ.

Monday 16 January

SESSION 1

Conv. Ctr. Room C1 Mon. 8:40 to 10:00 am

3D Scanning Hardware

Chair: **Brian D. Corner**, U.S. Army Natick Soldier Ctr.

8:40 am: **A novel design of grating projecting system for 3D reconstruction of wafer bumps**, Y. Shu, Xi'an Jiaotong Univ. (China); R. C. Chung, J. Cheng, The Chinese Univ. of Hong Kong (Hong Kong China); E. Y. Lam, The Univ. of Hong Kong (Hong Kong China); K. S. M. Fung, F. Wang, ASM Assembly Automation Ltd. (Hong Kong China) [6056-01]

9:00 am: **Measurement of discontinuities on 3D objects using digital moiré**, J. Liao, L. Cai, The Hong Kong Univ. of Science and Technology (Hong Kong China) [6056-02]

9:20 am: **High-speed and high-sensitive demodulation pixel for 3D imaging**, B. Büttgen, T. Oggier, Ctr. Suisse d'Electronique et de Microtechnique SA (Switzerland); P. Seitz, Swissnex; F. Lustenberger, Ctr. Suisse d'Electronique et de Microtechnique SA (Switzerland) ... [6056-03]

9:40 am: **A QVGA-size CMOS time-of-flight range image sensor with background light charge draining structure**, T. Ushinaga, I. Abdul Halin, T. Sawada, S. Kawahito, Shizuoka Univ. (Japan); M. Homma, Sharp Corp. (Japan); Y. Maeda, Suzuki Motor Corp. (Japan) [6056-04]

Coffee Break 10:00 to 10:30 am

SESSION 2

Conv. Ctr. Room C1 Mon. 10:30 am to 12:00 pm

3D Object Capture from Static Scans and Video I

Chair: **Brian D. Corner**, U.S. Army Natick Soldier Ctr.

10:30 am: **Overview of 3D surface digitization technologies in Europe (Invited Paper)**, N. D'Apuzzo, Homometrica Consulting (Switzerland) [6056-05]

11:00 am: **Automatic 3D real world surface texture mapping using perspective projection methods**, C. Shih, MingDao Univ. (Taiwan) [6056-06]

11:20 am: **Virtual confocal macroscopy**, P. M. Hanna, U.S. Air Force; B. D. Rigling, Wright State Univ. [6056-07]

11:40 am: **A robust algorithm for estimation of depth map for 3D shape recovery**, A. Malik, T. Choi, Gwangju Institute of Science and Technology (South Korea) [6056-08]

Lunch Break 12:00 to 1:30 pm

SESSION 3

Conv. Ctr. Room C1 Mon. 1:30 to 5:00 pm

3D Object Capture from Static Scans and Video II

Chair: **Peng Li**, GEO-Centers, Inc.

1:30 pm: **Formation of stereoscopic image pairs from a sequence of frames**, M. A. Wessels, Dimensional Imaging, LLC [6056-09]

1:50 pm: **3D model generation using unconstrained motion of a hand-held video camera**, C. Baker, C. H. Debrunner, M. Whitehorn, PercepTek, Inc. [6056-10]

2:10 pm: **3D from arbitrary 2D video**, I. A. Ideses, L. P. Yaroslavsky, Tel-Aviv Univ. (Israel) [6056-11]

2:30 pm: **Nonintrusive viewpoint tracking for 3D for perception in smart video conference**, X. Desurmont, I. Ponte, J. Meessen, J. Delaigle, Multitel A.S.B.L. (Belgium) [6056-12]

2:50 pm: **Internal shape-deformation invariant 3D surface matching using 2D principal component analysis**, M. Celenk, I. Al-Jarrah, Ohio Univ. [6056-13]

Coffee Break 3:10 to 3:40 pm

3:40 pm: **Digital Hammurabi: design and development of a 3D scanner for cuneiform tablets**, D. V. Hahn, D. Duncan, K. Baldwin, J. Cohen, B. Purnomo, Johns Hopkins Univ. [6056-14]

4:00 pm: **Three-dimensional surface reconstruction for evaluation of the abrasion effects on textile fabrics**, A. O. Mendes, P. T. Fiadeiro, R. A. Miguel, Univ. da Beira Interior (Portugal) [6056-15]

4:20 pm: **3D environment capture from monocular video and inertial data**, R. Clark, M. Lin, C. J. Taylor, Acuity Technology [6056-16]

4:40 pm: **The effects of different shape-based metrics on identification of military targets from 3D ladar data**, G. J. Meyer, J. Weber, Air Force Research Lab. [6056-18]

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 4

Conv. Ctr. Room C1 Tues. 9:30 am to 12:10 pm

3D Scans of the Human I

Chair: **Matthew Tocheri**, Arizona State Univ.

9:30 am: **Digital 3D reconstruction of George Washington (Invited Paper)**, A. Razdan, Arizona State Univ. [6056-19]

10:00 am: **The study of craniofacial growth patterns using 3D laser scanning and geometric morphometrics**, M. Friess, Anthrotech Inc. [6056-20]

Coffee Break 10:20 to 10:50 am

- 10:50 am: **A three-dimensional analysis of the geometry and curvature of the proximal tibial articular surface of hominoids**, E. K. Landis, P. A. Karnick, Arizona State Univ. [6056-21]
- 11:10 am: **New approach in curve matching technique and its implications on human evolution research**, H. Vahdati, P. A. Karnick, Arizona State Univ. [6056-22]
- 11:30 am: **Point cloud-based 3D head model classification using optimized EGI**, X. Tong, H. Wong, B. Ma, City Univ. of Hong Kong (Hong Kong China) [6056-23]
- 11:50 am: **3D face structure extraction using shape matching morphing model**, F. Xue, X. Ding, Tsinghua Univ. (China) [6056-24]
- Lunch/Exhibition Break 12:10 to 1:40 pm

SESSION 5

Conv. Ctr. Room C1 Tues. 1:40 to 2:40 pm

3D Scans of the Human II

Chair: Brian D. Corner, U.S. Army Natick Soldier Ctr.

- 1:40 pm: **Posture and re-positioning considerations of a torso imaging system for assessing scoliosis**, P. O. Ajemba, N. G. Durdle, Univ. of Alberta (Canada); D. L. Hill, J. V. Raso, Glenrose Rehabilitation Hospital (Canada) [6056-25]
- 2:00 pm: **Reverse engineering and rapid prototyping techniques to innovate prosthesis socket design**, G. Magrassi, G. Colombo, M. Bertetti, D. Bonacini, Politecnico di Milano (Italy) [6056-26]
- 2:20 pm: **Measuring human movement for biomechanical applications using markerless motion capture**, L. Mündermann, S. Corazza, A. M. Chaudhari, T. P. Andriacchi, Stanford Univ.; A. Sundaresan, R. Chellappa, Univ. of Maryland/College Park [6056-28]

Posters and Demonstrations-Tuesday

Chair: Peng Li, GEO-Centers, Inc.

Demonstrations 5:30 to 8:30 pm

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters 5:30 to 7:00 pm

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Development of measurement system of three-dimensional shape and surface reflectance**, T. Miyasaka, K. Araki, Chukyo Univ. (Japan) [6056-29]
- ✓ **Use of laser 3D digitizer in data collection and 3D modeling of anatomical structures**, K. Tse, Univ. of New South Wales (Australia); H. Van Der Wall, Concord Repatriation General Hospital (Australia); D. H. Vu, Univ. of New South Wales (Australia) [6056-30]
- ✓ **Volume intersection with imprecise camera parameters**, S. Sakamoto, K. Shoji, H. Iwase, F. Toyama, J. Miyamichi, Utsunomiya Univ. (Japan) [6056-31]
- ✓ **Development of ultrathin three-dimensional image capturing system**, K. Yamada, H. Mitsui, T. Asano, Hiroshima Institute of Technology (Japan); H. Takahashi, Osaka City Univ. (Japan); J. Tanida, Osaka Univ. (Japan) [6056-32]

- ✓ **Run-based volume intersection for shape recovery of objects from their silhouettes**, K. Shoji, S. Sakamoto, H. Iwase, F. Toyama, J. Miyamichi, Utsunomiya Univ. (Japan) [6056-33]
- ✓ **A prototype system for 3D measurement using flexible calibration method**, M. Fukuda, T. Miyasaka, K. Araki, Chukyo Univ. (Japan) [6056-34]
- ✓ **Estimation of object motion with known structure in moving camera**, H. J. Kwon, N. Hur, S. Lee, Electronics and Telecommunications Research Institute (South Korea) [6056-35]
- ✓ **Synthesizing wide-angle and arbitrary view-point images from a circular camera array**, N. Fukushima, T. Yendo, T. Fujii, M. Tanimoto, Nagoya Univ. (Japan) [6056-36]
- ✓ **3D urban scene reconstruction from high-resolution IKONOS stereo images**, M. Fedi, T. Riadh, B. Ziad, SUPCOM (Tunisia) [6056-37]
- ✓ **Procedure and algorithm of 3D reconstruction of large-scale ancient architecture**, S. Xia, Y. Zhu, X. Li, Wuhan Univ. (China) [6056-38]
- ✓ **Real-time 3D image-guided patient positioning in radiation therapy**, D. Liu, Henry Ford Health System; G. Yin, Genex Technologies, Inc. (China); S. Li, Henry Ford Health System [6056-41]

Human Vision and Electronic Imaging XI

Conference Chairs: **Bernice E. Rogowitz**, IBM Thomas J. Watson Research Ctr.; **Thrasylvoulos N. Pappas**, Northwestern Univ.; **Scott J. Daly**, Sharp Labs. of America, Inc.

Program Committee: **Albert J. Ahumada, Jr.**, NASA Ames Research Ctr.; **Jan P. Allebach**, Purdue Univ.; **Walter R. Bender**, MIT Media Lab.; **Michael H. Brill**, Datacolor; **John C. Dalton**, Synthetik Software; **Huib de Ridder**, Technische Univ. Delft (Netherlands); **Gunilla A. M. Derefeldt**, Swedish Defence Research Agency (Sweden); **Miguel P. Eckstein**, Univ. of California/Santa Barbara; **Elena A. Fedorovskaya**, Eastman Kodak Co.; **Jennifer Gille**, Raytheon Co.; **Laurent Itti**, Univ. of Southern California; **Stanley A. Klein**, Univ. of California/Berkeley; **Jan J. Koenderink**, Univ Utrecht (Netherlands); **John J. McCann**, McCann Imaging; **Jeffrey B. Mulligan**, NASA Ames Research Ctr.; **Karol Myszkowski**, Max-Planck-Institut für Informatik (Germany); **Adar Pelah**, The Univ. of York (United Kingdom); **Hawley K. Rising III**, Sony Electronics; **Robert J. Safraneck**, Benevue, Inc.; **Christopher W. Tyler**, Smith-Kettlewell Institute; **Andrew B. Watson**, NASA Ames Research Ctr.

Note: Please see room sign for papers added after program was printed.

Monday 16 January

SESSION 1

Conv. Ctr. Room A3 Mon. 9:00 am to 12:00 pm

Keynote Session

10:00 am: **Computational Neuroimaging: maps and Tracks in the Human Brain**, B. Wandell, Stanford University

11:00 am: **Learning where to look**, Mary Hayhoe, University of Rochester

Lunch Break 12:00 to 1:30 pm

SESSION 2

Conv. Ctr. Room A3 Mon. 1:30 to 3:30 pm

Mechanisms of Luminance, Color, and Temporal Sensitivity

1:30 pm: **Local luminance effect on spatial summation in the foveal vision and its implication on image artifact classification**, C. Chen, S. Y. Lin, H. G. Han, National Taiwan Univ. (Taiwan) [6057-01]

1:50 pm: **Evaluating contrast sensitivity**, S. Kitagura, L. W. MacDonald, London College of Communication (United Kingdom) [6057-02]

2:10 pm: **Spatio-velocity CSF as a function of retinal velocity using unstabilized stimuli**, J. L. Laird, M. R. Rosen, J. B. Pelz, E. D. Montag, Rochester Institute of Technology; S. J. Daly, Sharp Labs. of America, Inc. [6057-03]

2:30 pm: **A basis for cones**, B. V. Funt, W. Xiong, Simon Fraser Univ. (Canada) [6057-04]

2:50 pm: **High-dynamic range scene compression in humans**, J. J. McCann, McCann Imaging [6057-47]

3:10 pm: **Computational model of lightness perception in HDR imaging**, G. Krawczyk, K. Myszkowski, H. Seidel, Max-Planck-Institut für Informatik (Germany) [6057-05]

Coffee Break 3:30 to 4:00 pm

SESSION 3

Conv. Ctr. Room A3 Mon. 4:00 to 6:00 pm

Eye Movements, Visual Search, and Attention: A Tribute to Larry Stark

4:00 pm: **Larry Stark and scan path**, S. R. Ellis, NASA Ames Research Ctr. [6057-46]

4:20 pm: **A new metrics for definition of gaze area from the geometrical structures of picture composition**, M. Yamazaki, M. Kameda, Iwate Prefectural Univ. (Japan) [6057-06]

4:40 pm: **Target salience and visual search on novel and familiar backgrounds**, K. McDermott, Univ. of Nevada/Reno; J. Mulligan, NASA Ames Research Ctr.; G. Bebis, M. Webster, Univ. of Nevada/Reno [6057-43]

HVEI Banquet 7:30 to 10:30 pm

The annual Human Vision and Electronic Imaging Banquet will be held Monday evening, 16 January, 7:30 to 10:30 pm. The banquet will take place in a local restaurant or wine cellar. For tickets and more information, please visit the Electronic Imaging Registration Desk.

Banquet Speaker: **Jack Tumblin**, Northwestern Univ.

Rethinking Photography: Digital Devices to Capture Appearance

Tuesday 17 January

SESSION 6

Plenary Speaker **Tues. 8:30 to 9:15 am**
Marriott Ballroom 1-6
Image Processing: Interconnections
Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign
See p. 7 for details.

SESSION 4

Conv. Ctr. Room A3 **Tues. 9:30 am to 12:00 pm**

Perceptual Image Quality and Applications

- 9:30 am: **Effects of spatial correlations and global precedence on the visual fidelity of distorted images**, D. M. Chandler, K. H. S. Lim, S. S. Hemami, Cornell Univ.[6057-07]
 9:50 am: **Pseudo no reference image quality metric using perceptual data hiding**, A. Ninassi, P. Le Callet, F. Autrusseau, Univ. de Nantes (France)[6057-08]
 10:10 am: **Attention-based color correction**, F. W. M. Stentford, Univ. College London (United Kingdom)[6057-09]
 Coffee Break 10:30 to 11:00 am
 11:00 am: **Contrast enhancement of medical images using multiscale decomposition**, M. A. Trifas, J. M. Tyler, O. S. Pinykh, Louisiana State Univ.[6057-10]
 11:20 am: **Human visual alpha stable models for digital halftoning**, A. J. González, J. Bacca Rodríguez, G. R. Arce, Univ. of Delaware; D. L. Lau, Univ. of Kentucky[6057-11]
 11:40 am: **Study of asthenopia caused by the viewing of stereoscopic images**, H. Hagura, Tokyo Institute of Technology (Japan)[6057-12]
 Lunch Break 12:00 to 1:30 pm

SESSION 5

Conv. Ctr. Room A3 **Tues. 1:30 to 2:50 pm**

Visually Tuned Algorithms for the Design and Analysis of Flat-Panel Displays

- 1:30 pm: **Perceptual image quality improvement for large screen displays**, F. Lebowsky, Y. Huang, H. Wang, STMicroelectronics (France)[6057-13]
 1:50 pm: **LCD motion-blur analysis, perception, and reduction using synchronized backlight flashing**, X. Feng, Sharp Labs. of America, Inc.[6057-14]
 2:10 pm: **Human vision-based algorithm to hide defective pixels in LCDs**, T. R. Kimpe, S. Coulier, Barco N.V. (Belgium)[6057-15]
 2:30 pm: **Using optimal rendering to visually mask defective subpixels**, D. S. Messing, L. J. Kerofsky, Sharp Labs. of America, Inc.[6057-16]
 Coffee Break 2:50 to 3:20 pm

Conv. Ctr. Room A3 **Tues. 3:20 to 5:40 pm**

Perceptual Issues in Video Quality

- 3:20 pm: **Perceptual study of the impact of varying frame rate on motion imagery interpretability quality**, C. P. Fenimore, National Institute of Standards and Technology; J. M. Irvine, Science Applications International Corp.; D. Cannon, National Geospatial-Intelligence Agency; J. W. Roberts, I. Aviles, National Institute of Standards and Technology; S. A. Israel, Science Applications International Corp.; M. Brennan, The Boeing Co.; L. Simon, J. R. Miller, D. S. Haverkamp, Science Applications International Corp.; P. F. Tighe, M. Gross, Booz Allen Hamilton Inc.[6057-17]
 3:40 pm: **Color preference and perceived color naturalness of digital videos**, C. C. Koh, J. M. Foley, S. K. Mitra, Univ. of California/Santa Barbara[6057-18]
 4:00 pm: **Stabilizing viewing distances in subjective assessments of mobile video**, M. D. Brotherton, British Telecommunications plc (United Kingdom); K. Brunnström, Acreo AB (Sweden); D. Hands, British Telecommunications plc (United Kingdom)[6057-19]
 4:20 pm: **Predicting subjective video quality from separated spatial and temporal assessment**, R. R. Pastrana-Vidal, J. Gicquel, J. Blin, France Telecom R&D (France); H. Cherifi, Univ. de Bourgogne (France) [6057-20]
 4:40 pm: **Handling of annoying variations of performances in video algorithm optimization**, M. M. Nicolas, STMicroelectronics (France)[6057-21]
 5:00 pm: **Structural similarity quality metrics in a coding context: exploring the space of realistic distortions**, A. Brooks, T. N. Pappas, Northwestern Univ.[6057-22]
 5:20 pm: **Lossy compression of high dynamic range images and video**, R. Mantiuk, K. Myszkowski, H. Seidel, Max-Planck-Institut für Informatik (Germany)[6057-23]

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Psychophysical measurement for perceptual image brightness enhancement based on image classification**, I. Kim, W. Choe, S. Lee, SAMSUNG Advanced Institute of Technology (South Korea) .[6057-34]
- ✓ **Visual deficiency and image recognition: an image semantic cartography related to visual performance**, A. Scherlen, J. Da Rugna, Univ. Jean Monnet Saint-Etienne (France)[6057-35]
- ✓ **Simple color conversion method to perceptible images for color vision deficiencies**, M. Meguro, C. Takahashi, T. Koga, Yamagata Univ. (Japan)[6057-36]
- ✓ **Toward a taxonomy of textures for image retrieval**, J. S. Payne, Buckinghamshire Chilterns Univ. College (United Kingdom); T. J. Stonham, Brunel Univ. (United Kingdom)[6057-38]

- ✓ **Using words as lexical basis functions for automatically indexing face images in a manner that correlates with human perception of similarity**, M. Phielipp, J. A. Black, Jr., S. Panchanathan, Arizona State Univ.[6057-39]
- ✓ **Subjective video quality evaluation for multimedia applications**, Q. Huynh-Thu, Psytechnics Ltd. (United Kingdom); M. Ghanbari, Univ. of Essex (United Kingdom); D. Hands, M. D. Brotherton, British Telecommunications plc (United Kingdom)[6057-40]
- ✓ **Texture segmentation using adaptive Gabor filters based on HVS**, S. Bi, D. Liang, Dalian Maritime Univ. (China)[6057-41]
- ✓ **Image stability analysis on the human retina**, M. I. Baritz, Univ. Transilvania din Brasov (Romania)[6057-42]

Wednesday 18 January

Plenary Speaker **Wed. 8:30 to 9:15 am**
Marriott Ballroom 1-6
Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging
Richard Leahy, Univ. of Southern California
See p. 7 for details.

SESSION 7

Conv. Ctr. Room A3 **Wed. 9:30 am to 12:00 pm**

Perceptual Approaches to Image Analysis

- 9:30 am: **A closer look at texture metrics**, H. H. Shenae, V. Interrante, Univ. of Minnesota[6057-24]
- 9:50 am: **M-HinTS: mimicking humans in texture sorting**, E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands); T. Kok, T. E. Schouten, Radboud Univ. Nijmegen (Netherlands); E. M. van Rikxoort, Univ. Medisch Ctr. Utrecht (Netherlands)[6057-25]
- 10:10 am: **Inference and segmentation in cortical processing**, Y. Liu, G. A. Cecchi, A. R. Rao, J. Kozloski, C. Peck, IBM Thomas J. Watson Research Ctr.[6057-26]
- Coffee Break 10:30 to 11:00 am
- 11:00 am: **Subjective segmentation evaluation methods: a survey**, E. Drelie Gelasca, T. Ebrahimi, École Polytechnique Fédérale de Lausanne (Switzerland)[6057-27]
- 11:20 am: **Perceptually based techniques for semantic image classification and retrieval**, D. Depalov, T. N. Pappas, Northwestern Univ.[6057-28]
- 11:40 am: **Is Wölfli's system for characterizing art possible to validate by methods used in cognitive-based image-retrieval (CBIR)?**, G. A. M. Derefeldt, S. Nyberg, J. Alfredson, H. U. Allberg, Swedish Defence Research Agency (Sweden)[6057-29]
- Lunch/Exhibition Break 12:00 to 1:40 pm

SESSION 8

Conv. Ctr. Room A3 **Wed. 1:40 to 2:40 pm**

Detection, Recognition, and Navigation in Complex Environments

- 1:40 pm: **Symbol discriminability models for improved flight displays**, A. J. Ahumada, Jr., M. Trujillo San-Martin, J. Gille, NASA Ames Research Ctr.[6057-30]
- 2:00 pm: **Is haptic watermarking worth it?**, M. Barni, D. Prattichizzo, G. Menegaz, A. Formaglio, M. Franzini, Univ. degli Studi di Siena (Italy); H. Z. Tan, Purdue Univ.[6057-32]
- 2:20 pm: **Display conditions that influence wayfinding in virtual environments**, R. A. Browse, D. W. S. Gray, Queen's Univ. (Canada)[6057-33]

Natural Image Statistics

Conv. Ctr. Room A3 **Wed. 2:40 to 4:30 pm**

Color Imaging XI: Processing, Hardcopy, and Applications

Conference Chairs: **Reiner Eschbach**, Xerox Corp.; **Gabriel G. Marcu**, Apple Computer, Inc.

Program Committee: **A. Ufuk Agar**, Garanti Technology (Turkey); **Jan P. Allebach**, Purdue Univ.; **Jan Bares**, NexPress Solutions, LLC; **Phil J. Green**, London College of Communication (United Kingdom); **Roger David Hersch**, École Polytechnique Fédérale de Lausanne (Switzerland); **Patrick G. Herzog**, GretagMachbeth (Germany); **Choon-Woo Kim**, Inha Univ. (South Korea); **Michael A. Kriss**, Consultant; **Shaun T. Love**, Lexmark International, Inc.; **Alessandro Rizzi**, Univ. Degli Studi di Milano (Italy); **Shoji Tominaga**, Osaka Electro-Communication Univ. (Japan); **Chris Tuijn**, Agfa-Gevaert NV (Belgium)

Tuesday 17 January

<p>Plenary Speaker Tues. 8:30 to 9:15 am</p> <p><i>Marriott Ballroom 1-6</i></p> <p>Image Processing: Interconnections</p> <p>Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign</p> <p><i>See p. 7 for details.</i></p>

SESSION 1

Conv. Ctr. Room A2 **Tues. 3:30 to 6:00 pm**

Color and Color Transforms

Chair: Reiner Eschbach, Xerox Corp.

- 3:30 pm: **Ideal illuminants for rod/L-cone color**, J. J. McCann, McCann Imaging [6058-01]
- 4:00 pm: **Accuracy of color transforms**, P. J. Green, London College of Communication (United Kingdom) [6058-02]
- 4:20 pm: **Color image dequantization by constrained diffusion**, D. Keysers, T. M. Breuel, DFKI GmbH (Germany) and Univ. of Kaiserslautern (Germany) [6058-03]
- 4:40 pm: **Spring-primary mapping: a fast color mapping method for primary adjustment and gamut mapping**, H. Zeng, Hewlett-Packard Co. [6058-04]
- 5:00 pm: **A framework for image-dependent gamut mapping**, J. Giesen, E. Schuberth, ETH Zürich (Switzerland); K. Simon, EMPA (Switzerland); D. Zeiter, ETH Zürich (Switzerland); P. Zolliker, EMPA (Switzerland) . [6058-05]
- 5:20 pm: **Perceptual gamut mapping algorithm development based upon image quality and preference factors**, B. Kang, M. Cho, H. Choh, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea) [6058-06]
- 5:40 pm: **Gamut estimation using 2D surface splines**, M. Q. Shaw, Hewlett-Packard Co. [6058-07]

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

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Posters **5:30 to 7:00 pm**

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- ✓ **High-resolution image viewing on multiprojector distributed parallel rendering display wall**, J. Meng, H. Lin, J. Shi, Zhejiang Univ. (China) [6058-40]
- ✓ **The application of wavelet transforms and mathematics morphology on the processing of infrared satellite cloud image**, J. Xue, Z. Liu, P. Wang, Tianjin Univ. (China) [6058-41]
- ✓ **Simulation and parameter optimizing of multielectrode capacitive transducers based on finite element method**, D. Chen, Harbin Univ. of Science and Technology (China) [6058-42]
- ✓ **Digital watermarking of color image**, S. C. Chao, Ta Hwa Institute of Technology (Taiwan); H. M. Huang, Tung Nan Institute of Technology (Taiwan); C. Y. Chen, Institute of Nuclear Energy Research (Taiwan) [6058-43]
- ✓ **Subjective assessment of printed color image quality as saturation of the primary colors RGB decreases**, W. Song, H. Seki, Naltec Inc. (Japan); G. Ohashi, Y. Shimodaira, Shizuoka Univ. (Japan) ... [6058-45]

Wednesday 18 January

<p>Plenary Speaker Wed. 8:30 to 9:15 am</p> <p><i>Marriott Ballroom 1-6</i></p> <p>Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging</p> <p>Richard Leahy, Univ. of Southern California</p> <p><i>See p. 7 for details.</i></p>
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SESSION 2

Conv. Ctr. Room A2 **Wed. 9:30 to 10:20 am**

Color Adjustment

Chair: Phil J. Green, London College of Communication (United Kingdom)

- 9:30 am: **Uncalibrated color (Invited Paper)**, N. Moroney, Hewlett-Packard Co. [6058-08]
- 10:00 am: **Geometrical methods for lightness adjustment in YCC color spaces**, R. Samadani, G. Li, Hewlett-Packard Labs. [6058-09]
- Coffee Break 10:20 to 10:50 am

SESSION 3

Conv. Ctr. Room A2 Wed. 10:50 am to 12:10 pm

Digital Photography and Applications

Chair: Michael A. Kriss, Consultant

- 10:50 am: **Measuring gloss by digital photography**, P. Kumar, L. W. MacDonald, London College of Communication (United Kingdom)[6058-10]
- 11:10 am: **Ubiquitous image processing: a novel image-enhancement facility for consumers**, R. Shaw, P. Johnson, White Rose Digital [6058-11]
- 11:30 am: **Color constancy on Japanese animation**, Y. G. Ichihara, Hosen-Gakuen College (Japan)[6058-12]
- 11:50 am: **Convincing non-printers to become future customers**, R. Fageth, W. Schmidt-Sacht, CeWe Color AG & Co. OHG (Germany)[6058-13]
- Lunch/Exhibition Break 12:10 to 1:30 pm

SESSION 4

Conv. Ctr. Room A2 Wed. 1:30 to 3:00 pm

Displays I

Chair: Choon-Woo Kim, Inha Univ. (South Korea)

- 1:30 pm: **DTV color and image processing: past, present, and future (Invited Paper)**, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)[6058-14]
- 2:00 pm: **Subpixel rendering method for color error minimization on subpixel structured display**, W. Choe, S. Lee, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)[6058-15]
- 2:20 pm: **Compensation method for color defects in PDP due to different time responses of phosphors**, H. Oh, H. Lee, D. Park, S. Kim, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)[6058-16]
- 2:40 pm: **Six-primary-color LCD monitor using six-color LEDs with an accurate calibration system**, H. Sugiura, H. Kaneko, S. Kagawa, J. Someya, H. Tanizoe, Mitsubishi Electric Corp. (Japan)[6058-17]
- Coffee Break 3:00 to 3:30 pm

SESSION 5

Conv. Ctr. Room A2 Wed. 3:30 to 5:30 pm

Displays II

Chair: Gabriel G. Marcu, Apple Computer, Inc.

- 3:30 pm: **A color control method for image output with projection displays**, S. Tominaga, K. Kumamoto, Osaka Electro-Communication Univ. (Japan)[6058-18]
- 3:50 pm: **Illuminant-adaptive color reproduction for a mobile display**, J. M. Kim, K. Park, M. Lee, Y. Cho, Y. Ha, Kyungpook National Univ. (South Korea)[6058-19]
- 4:10 pm: **Skin color reproduction algorithm for portrait images shown on the mobile display**, Y. Kwak, S. Lee, D. Park, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)[6058-20]
- 4:30 pm: **Estimating displays' color fidelity based on classified image statistics**, P. Sun, C. Lee, Shih Hsin Univ. (Taiwan)[6058-21]
- 4:50 pm: **End-user display calibration via support vector regression**, B. Bastani, Hewlett-Packard Co.; B. V. Funt, W. Xiong, Simon Fraser Univ. (Canada)[6058-22]
- 5:10 pm: **The calibration accuracy of display white point by visual calibrator under various illuminations**, T. Sugiyama, Y. Kudo, Dai Nippon Printing Co., Ltd. (Japan)[6058-23]

Thursday 19 January

SESSION 6

Conv. Ctr. Room A2 Thurs. 8:40 to 10:00 am

Printing

Chair: A. Ufuk Agar, Garanti Technology (Turkey)

- 8:40 am: **Black extraction method using gamut boundary descriptors**, M. Cho, B. Kang, H. Choh, SAMSUNG Advanced Institute of Technology (South Korea)[6058-24]
- 9:00 am: **Colorimetric characterization based on color correlation in CMYKGO printer**, I. Jang, C. Son, T. Park, K. Ko, Y. Ha, Kyungpook National Univ. (South Korea)[6058-25]
- 9:20 am: **Hardcopy global color correction**, Y. Bang, Y. Kim, H. Choh, Samsung Advanced Institute of Technology (South Korea)[6058-26]
- 9:40 am: **Efficient document rendering with enhanced run length encoding**, G. Feng, Ricoh Innovations, Inc.; C. A. Bouman, Purdue Univ.[6058-28]
- Coffee Break 10:00 to 10:30 am

SESSION 7

Conv. Ctr. Room A2 Thurs. 10:30 to 11:50 am

Halftoning I

Chair: Jan P. Allebach, Purdue Univ.

- 10:30 am: **Model-based clustered-dot screening**, S. H. Kim, SAMSUNG Electronics Co., Ltd. (South Korea)[6058-29]
- 10:50 am: **AM-FM hybrid color screen design to reduce brightness variation**, B. M. Kang, B. T. Ryu, C. Kim, Inha Univ. (South Korea); S. H. Kim, SAMSUNG Electronics Co., Ltd. (South Korea)[6058-30]
- 11:10 am: **Frequency domain design of cluster dot screens**, M. Fischer, D. Shaked, Hewlett-Packard Labs. (Israel)[6058-31]
- 11:30 am: **A spatial domain optimization method to generate plan-dependent masks**, Y. Wu, Hewlett-Packard Co.[6058-32]
- Lunch Break 11:50 am to 1:30 pm

SESSION 8

Conv. Ctr. Room A2 Thurs. 1:30 to 3:30 pm

Halftoning II

Chair: Reiner Eschbach, Xerox Corp.

- 1:30 pm: **Using errors in halftoning to increase reproduction accuracy**, S. Herron, Global Graphics Software Inc.[6058-33]
- 1:50 pm: **Analysis of misregistration-induced color shifts in the superposition of periodic screens**, B. Oztan, G. Sharma, Univ. of Rochester; R. P. Loce, Xerox Corp.[6058-35]
- 2:10 pm: **Analysis of color error diffusion with vector error filters**, Z. Z. Fan, Xerox Corp.[6058-36]
- 2:30 pm: **New halftoning method combining the best of masking and error diffusion algorithms**, F. Cittadini, Océ Print Logic Technologies (France) and Univ. Pierre et Marie Curie (France); J. Pervillé, S. Berche, Océ Print Logic Technologies (France); M. Ben Chouikha, G. Alquié, Univ. Pierre et Marie Curie (France)[6058-37]
- 2:50 pm: **Graph order dither**, A. Hausner, Univ. of New Hampshire[6058-38]
- 3:10 pm: **Optimal halftoning over hexagonal grids**, J. Bacca Rodriguez, A. J. Gonzalez Lozano, G. R. Arce, Univ. of Delaware; D. L. Lau, Univ. of Kentucky[6058-39]

Tuesday-Thursday 17-19 January 2006 • Proceedings of SPIE Vol. 6059

Image Quality and System Performance III

Conference Chairs: **Luke C. Cui**, Lexmark International, Inc.; **Yoichi Miyake**, Chiba Univ. (Japan)

Program Committee: **Peter D. Burns**, Eastman Kodak Co.; **Mark D. Fairchild**, Rochester Institute of Technology; **Susan Farnand**, Eastman Kodak Co.; **Frans Gaykema**, OCE Technologies BV (Netherlands); **Dirk W. Hertel**, Polaroid Corp.; **Robin B. Jenkin**, Cranfield Univ. (United Kingdom); **Nathan Moroney**, Hewlett-Packard Co.; **Rene Rasmussen**, Xerox Corp.; **Eric K. Zeise**, NexPress Solutions, Inc.

Tuesday 17 January

Wednesday 18 January

<p>Plenary Speaker Tues. 8:30 to 9:15 am <i>Marriott Ballroom 1-6</i> Image Processing: Interconnections Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign <i>See p. 7 for details.</i></p>

<p>Plenary Speaker Wed. 8:30 to 9:15 am <i>Marriott Ballroom 1-6</i> Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging Richard Leahy, Univ. of Southern California <i>See p. 7 for details.</i></p>
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✓ Posters and Demonstrations-Tuesday

Demonstrations 5:30 to 8:30 pm

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters. 5:30 to 7:00 pm

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Image quality assessment based on textual structure and noise normalization**, C. Zhang, Z. Qiu, Beijing Jiaotong Univ. (China)[6059-36]
- ✓ **Quality models for audiovisual streaming**, T. C. Thang, Y. S. Kim, C. S. Kim, Y. M. Ro, Information and Communications Univ. (South Korea)[6059-37]
- ✓ **Research on the analysis and measurement of MTF of staring imaging system**, D. Lu, Q. Chen, G. Gu, Nanjing Univ. of Science & Technology (China)[6059-38]
- ✓ **Quantification method of the color break-up phenomena: evaluation of next-generation color wheels for field sequential color displays**, J. Thollot, K. Sarayedine, Thomson R&D France (France); A. Trémeau, Univ. Jean Monnet Saint-Etienne (France)[6059-39]
- ✓ **No-reference jerkiness evaluation method for multimedia communications**, M. Carli, D. Guida, A. Neri, Univ. degli Studi di Roma Tre (Italy)[6059-40]

SESSION 1

Marriott San Carlos Room Wed. 9:30 to 10:10 am

Image Quality Understanding

Chair: Luke C. Cui, Lexmark International, Inc.

- 9:30 am: **Fundamental questions related to print quality**, P. J. Mangin, M. Dubé, Univ. du Québec à Trois-Rivières (Canada) [6059-01]
- 9:50 am: **What do users really perceive: probing the subjective image quality**, G. S. Nyman, J. Radun, T. Leisti, Univ. of Helsinki (Finland); J. Oja, H. J. Ojanen, J. Olives, T. Vuori, Nokia Research Ctr. (Finland); J. P. Häkkinen, Univ. of Helsinki (Finland) and Nokia Research Ctr. (Finland) [6059-02]
- Coffee Break 10:10 to 10:40 am

SESSION 2

Marriott San Carlos Room ... Wed. 10:40 am to 12:00 pm

Perceptual Attributes and Psychometrics

Chair: Nathan Moroney, Hewlett-Packard Co.

- 10:40 am: **The effect of image sharpness on quantitative eye-movement data and on image quality evaluation while viewing natural images**, T. Vuori, M. Olkkonen, Nokia Corp. (Finland) [6059-03]
- 11:00 am: **Assessing the enhancement of image sharpness**, S. Bouzit, Univ. of St. Andrews (United Kingdom); L. W. MacDonald, London College of Communication (United Kingdom) [6059-04]
- 11:20 am: **Reference-free quality metric using a region-based attention model for JPEG2000 compressed images**, R. Barland, A. Saadane, Univ. de Nantes (France) [6059-05]
- 11:40 am: **Comparison of various subjective video quality assessment methods**, C. Lee, H. Choi, E. Lee, S. Lee, J. Choe, Yonsei Univ. (South Korea) [6059-06]
- Lunch/Exhibition Break 12:00 to 1:20 pm

SESSION 3

Marriott San Carlos Room Wed. 1:20 to 2:20 pm

Perceptual Image Quality Modeling

Chair: Susan Farnand, Eastman Kodak Co.

- 1:20 pm: **Selecting significant colors from a complex image for image quality modeling**, K. J. Leeming, P. J. Green, London College of Communication (United Kingdom) [6059-07]
- 1:40 pm: **Comparison of three full-reference color image quality measures**, E. Girshel, V. Slobodyan, J. S. Weissman, A. M. Eskicioglu, The City Univ. of New York [6059-08]
- 2:00 pm: **Influence of ambient illumination on adapted and optimal white point**, I. Vogels, J. Berentsen, Philips Research Labs. (Netherlands) [6059-09]
- Session Break 2:20 to 2:30 pm

SESSION 4

Marriott San Carlos Room Wed. 2:30 to 3:30 pm

Objective Attributes Characterization I

Chair: Rene S. Rasmussen, Xerox Corp.

- 2:30 pm: **Characterization of digital image noise properties based on RAW data**, H. H. Hytti, Tampereen Teknillinen Yliopisto (Finland) [6059-10]
- 3:00 pm: **An evaluation of sharpness in different image displays used for medical imaging**, M. Ukishima, T. Nakaguchi, Chiba Univ. (Japan); K. Kato, Canon Inc. (Japan); Y. Fukuchi, Chiba Univ. Hospital (Japan); N. Tsumura, Chiba Univ. (Japan); K. Matsumoto, Canon, Inc.; N. Yanagawa, H. Morita, Chiba Univ. Hospital (Japan); Y. Miyake, Chiba Univ. (Japan) [6059-12]
- Coffee Break 3:30 to 4:00 pm

SESSION 5

Marriott San Carlos Room Wed. 4:00 to 5:20 pm

Objective Attributes Characterization II

Chair: Peter D. Burns, Eastman Kodak Co.

- 4:00 pm: **Characterization of printer MTF**, W. Jang, Hewlett-Packard Co.; J. P. Allebach, Purdue Univ. [6059-13]
- 4:20 pm: **PSF estimation by gradient descent fit to the ESF**, E. H. Barney Smith, Boise State Univ. [6059-14]
- 4:40 pm: **Printer banding estimation using the generalized spectrum**, N. A. Rawashdeh, I. Shin, K. D. Donohue, Univ. of Kentucky; S. T. Love, Lexmark International, Inc. [6059-15]
- 5:00 pm: **Scanner-based macroscopic color variation estimation**, C. Kuo, L. Di, E. K. Zeise, NexPress Solutions, Inc. [6059-16]

Thursday 19 January

SESSION 6

Marriott San Carlos Room Thurs. 8:20 to 10:00 am

Standardization I: Progress

Chair: Eric K. Zeise, NexPress Solutions, Inc.

- 8:20 am: **Viewing conditions, colorimetric measurements, and profile making: the conundrum of standards vs. practical realities**, D. Q. McDowell, Standards Consultant [6059-17]
- 8:40 am: **Progress in digital color workflow understanding in the ICC workflow WG**, A. L. McCarthy, Lexmark International, Inc. and International Color Consortium [6059-18]
- 9:00 am: **Recent progress in the development of ISO 19751**, S. Farnand, Eastman Kodak Co.; E. N. Dalal, Xerox Corp.; Y. S. Ng, NexPress Solutions, Inc. [6059-19]

- 9:40 am: **ISO 19751 macro-uniformity**, R. S. Rasmussen, Xerox Corp.; K. D. Donohue, Univ. of Kentucky; Y. S. Ng, NexPress Solutions, Inc.; W. C. Kress, Toshiba America DSE; S. Zoltner, Xerox Corp.; F. Gaykema, OCE Technologies BV (Netherlands) [6059-20]
- Coffee Break 10:00 to 10:30 am

SESSION 7

Marriott San Carlos Room Thurs. 10:30 to 11:30 am

Standardization II: Breakthroughs

Chair: Robin B. Jenkin, Cranfield Univ. (United Kingdom)

- 10:30 am: **Edge-raggedness evaluation using slanted-edge analysis**, P. D. Burns, Eastman Kodak Co. [6059-21]
- 11:00 am: **Statistical interpretation of ISO TC42 dynamic range: risky business**, D. R. Williams, P. D. Burns, Eastman Kodak Co. [6059-22]
- Lunch Break 11:30 am to 1:10 pm

SESSION 8

Marriott San Carlos Room Thurs. 1:10 to 2:10 pm

System Image Quality Characterization and Modeling I

Chair: Dirk W. Hertel, Consultant

- 1:10 pm: **The influence of statistical variations on image quality**, B. O. Hultgren, D. W. Hertel, Consultant; J. Bullitt, Polaroid Corp. [6059-25]
- 1:30 pm: **The use of a virtual printer model for the simulation of imaging systems**, B. O. Hultgren, Consultant [6059-26]
- 1:50 pm: **Improved pen alignment for bidirectional printing**, E. Bernal, J. P. Allebach, Z. Pizlo, Purdue Univ. [6059-27]
- Session Break 2:10 to 2:20 pm

SESSION 9

Marriott San Carlos Room Thurs. 2:20 to 3:30 pm

System Image Quality Characterization and Modeling II

Chair: Frans Gaykema, OCE Technologies BV (Netherlands)

- 2:20 pm: **Further image quality assessment in digital film restoration**, M. Chambah, Univ. de Reims Champagne-Ardenne (France); C. Saint Jean, Univ. de La Rochelle (France); F. Helt, Independent Consultant (France) [6059-28]
- 2:50 pm: **Development of picture quality monitoring system for IPTV service based on the reduced reference framework**, O. Sugimoto, R. Kawada, A. Koike, KDDI R&D Labs. (Japan) [6059-29]
- 3:10 pm: **An image quality evaluation method for DOE-based camera lenses**, S. Lee, Y. Jin, H. Jeong, Samsung Electro-Mechanics Co., Ltd. (South Korea); S. Song, Hanyang Univ. (South Korea) [6059-30]
- Coffee Break 3:30 to 4:00 pm

SESSION 10

Marriott San Carlos Room Thurs. 4:00 to 5:20 pm

Image Defects Characterization and Modeling

Chair: Yoichi Miyake, Chiba Univ. (Japan)

- 4:00 pm: **Visibility and annoyance of LCD defective subpixels of different colors and surrounds at different positions**, H. Ho, J. M. Foley, S. K. Mitra, Univ. of California/Santa Barbara [6059-32]
- 4:20 pm: **Robust detection of defects in imaging arrays**, J. Dudas, C. G. Jung, G. H. Chapman, Simon Fraser Univ. (Canada); Z. Koren, I. Koren, Univ. of Massachusetts/Amherst [6059-33]
- 4:40 pm: **Objective video quality assessment method for freeze distortion based on freeze aggregation**, K. Watanabe, J. Okamoto, T. Kurita, NTT Service Integration Labs. (Japan) [6059-34]
- 5:00 pm: **Film grain synthesis and its applications for re-graining**, P. Schallauer, R. Mörzinger, JOANNEUM RESEARCH GmbH (Austria) [6059-35]

Visualization and Data Analysis 2006

Conference Chairs: **Robert F. Erbacher**, Utah State Univ.; **Jonathan C. Roberts**, Univ. of Kent (United Kingdom); **Matti T. Gröhn**, CSC-Scientific Computing Ltd. (Finland); **Katy Börner**, Indiana Univ.

Cochairs: **Ming C. Hao**, Hewlett-Packard Labs.; **Pak C. Wong**, Pacific Northwest National Lab.

Program Committee: **Uwe Brinkschulte**, Univ. Karlsruhe (Germany); **Philip C. Chen**, Future, Inc.; **L. E. Greenwade**, Idaho National Engineering and Environmental Lab.; **Hans-Georg Pagendarm**, German Aerospace Research Establishment DLR (Germany); **Alex T. Pang**, Univ. of California/Santa Cruz; **Christopher D. Shaw**, Georgia Institute of Technology; **Kalpathi R. Subramanian**, Univ. of North Carolina/Charlotte; **Yinlong Sun**, Purdue Univ.; **J. E. Swan II**, Naval Research Lab.; **Craig M. Wittenbrink**, NVIDIA; **Yingcai Xiao**, Univ. of Akron; **William J. Yurcik**, Univ. of Illinois at Urbana-Champaign

Monday 16 January

SESSION 1

Conv. Ctr. Room B1 Mon. 8:30 to 9:30 am

Flow Visualization

Chair: **Robert F. Erbacher**, Utah State Univ.

8:30 am: **Multiscale image based flow visualization**, A. C. Telea, Technische Univ. Eindhoven (Netherlands); R. Strzodka, Research Ctr. Caesar (Germany) [6060-01]

8:50 am: **Visualizing oceanic and atmospheric flows with streamline splatting**, Y. Sun, E. Ess, D. Sapirstein, M. Huber, Purdue Univ. . [6060-02]

9:10 am: **View-dependent multiresolutional flow texture advection**, L. Li, H. Shen, The Ohio State Univ. [6060-03]

Session Break 9:30 to 9:40 am

SESSION 2

Conv. Ctr. Room B1 Mon. 9:40 to 11:10 am

Volume Visualization

Chair: **Matti T. Gröhn**, Ctr. for Scientific Computing (Finland)

9:40 am: **Volumetric depth peeling for medical image display**, D. M. Borland, J. P. Clarke, J. R. Fielding, R. M. Taylor II, The Univ. of North Carolina at Chapel Hill [6060-04]

Coffee Break 10:00 to 10:30 am

10:30 am: **Adaptive border sampling for hardware texture-based volume visualization**, E. C. LaMar, Institute for Scientific Research, Inc. [6060-05]

10:50 am: **Ray-casting time-varying volume data sets with frame-to-frame coherence**, D. Tost, S. Grau, Univ. Politècnica de Catalunya (Spain); M. Ferre, Univ. Rovira i Virgili (Spain); A. Puig, Univ. de Barcelona (Spain) [6060-06]

Session Break 11:10 to 11:20 am

SESSION 3

Conv. Ctr. Room B1 Mon. 11:20 am to 12:00 pm

Visualization Theory

Chair: **Pak C. Wong**, Pacific Northwest National Lab.

11:20 am: **Theoretical analysis of uncertainty visualizations**, T. D. Zuk, M. S. T. Carpendale, Univ. of Calgary (Canada) [6060-07]

11:40 am: **A visualization framework for design and evaluation**, B. J. Blundell, S. Pettifer, The Univ. of Manchester (United Kingdom); G. Ng, Cerebra, Inc. [6060-08]

Lunch Break 12:00 to 1:30 pm

SESSION 4

Conv. Ctr. Room B1 Mon. 1:30 to 2:00 pm

Invited Paper I

Chair: **Robert F. Erbacher**, Utah State Univ.

1:30 pm: **Visual analytics and the NVAC (Invited Paper, Presentation Only)**, P. C. Wong, Pacific Northwest National Lab. [6060-09]

Session Break 2:00 to 2:10 pm

SESSION 5

Conv. Ctr. Room B1 Mon. 2:10 to 3:10 pm

Lighting

Chair: **Matti T. Gröhn**, Ctr. for Scientific Computing (Finland)

2:10 pm: **Maximum entropy lighting for physical objects**, T. Malzbender, E. Orndlich, Hewlett-Packard Labs. [6060-10]

2:30 pm: **Pre-computed illumination for isosurfaces**, K. M. Beason, Florida State Univ.; J. Grant, Pixar Animation Studios; D. C. Banks, B. Futch, M. Y. Hussaini, Florida State Univ. [6060-11]

2:50 pm: **Retro-rendering with vector-valued light: producing local illumination from the transport equation**, D. C. Banks, K. M. Beason, Florida State Univ. [6060-12]

Coffee Break 3:10 to 3:40 pm

SESSION 6

Conv. Ctr. Room B1 Mon. 3:40 to 4:20 pm

Image Processing

Chair: **Ming C. Hao**, Hewlett-Packard Labs.

3:40 pm: **Bit-plane based analysis of integer wavelet coefficients for image compression**, A. F. Abu-Hajar, Digitavid, Inc. [6060-13]

4:00 pm: **Two-dimensional reduction PCA: a novel approach for feature extraction, representation, and recognition**, R. M. Mutelo, W. L. Woo, S. S. Day, Univ. of Newcastle Upon Tyne (United Kingdom) [6060-14]

Session Break 4:20 to 4:30 pm

SESSION 7

Conv. Ctr. Room B1 Mon. 4:30 to 5:10 pm

Terrain/GIS Visualization

Chair: **Edward Suvanaphen**, Univ. of Kent (United Kingdom)

4:30 pm: **Energetically optimal travel across terrain: visualizations and a new metric of geographic distance with archaeological applications**, B. Wood, Harvard Univ.; Z. Wood, California Polytechnic State Univ. [6060-15]

4:50 pm: **Real-time 3D visualization of DEM combined with a robust DCT-based data-hiding method**, A. Martin, Univ. Montpellier II (France); G. Gesquiere, Univ. de Provence (France); W. Puech, Univ. Montpellier II (France); S. Thon, Univ. de Provence (France) [6060-16]

Session Break 5:10 to 5:20 pm

SESSION 8

Conv. Ctr. Room B1 Mon. 5:20 to 6:00 pm

Applications

Chair: Katy Börner, Indiana Univ.

5:20 pm: **Hierarchical causality explorer: making complementary use of 3D/2D visualizations**, S. Azuma, Ochanomizu Univ. (Japan); I. Fujishiro, Tohoku Univ. (Japan); H. Horii, The Univ. of Tokyo (Japan) [6060-17]

5:40 pm: **InvIncements: incremental software to support visual simulation**, D. C. Banks, W. Blanco, Florida State Univ. [6060-18]

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am
Marriott Ballroom 1-6
Image Processing: Interconnections
Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign
See p. 7 for details.

SESSION 9

Conv. Ctr. Room B1 Tues. 9:40 to 10:20 am

Interaction Techniques

Chair: Ming C. Hao, Hewlett-Packard Labs.

9:40 am: **Plot of plots and selection glass**, H. Chen, SAS Institute Inc. [6060-19]

10:00 am: **Navigation techniques for large-scale astronomical exploration**, C. Fu, The Hong Kong Univ. of Science and Technology (Hong Kong China); A. J. Hanson, E. A. Wernert, Indiana Univ. . . . [6060-20]

Coffee Break 10:20 to 10:50 am

SESSION 10

Conv. Ctr. Room B1 Tues. 10:50 to 11:50 am

InfoVis

Chair: Ketan K. Mane, Indiana Univ.

10:50 am: **Reducing InfoVis cluttering through non uniform sampling, displacement, and user perception**, E. Bertini, G. Santucci, L. Dell'Aquila, Univ. degli Studi di Roma/La Sapienza (Italy) [6060-21]

11:10 am: **Diverse information integration and visualization**, S. L. Havre, A. R. Shah, C. Posse, B. M. Webb-Robertson, Pacific Northwest National Lab. [6060-22]

11:30 am: **WordSpace: visual summary of text corpora**, U. Brandes, M. Hofer, J. Lerner, Univ. of Konstanz (Germany) [6060-23]

Lunch/Exhibition Break 11:50 am to 1:40 pm

SESSION 11

Conv. Ctr. Room B1 Tues. 1:40 to 2:10 pm

Invited Paper II

Chair: Ketan K. Mane, Indiana Univ.

1:40 pm: **Information architecture: why design matters (Invited Paper, Presentation Only)**, J. Agutter, Univ. of Utah [6060-24]

Session Break 2:10 to 2:20 pm

SESSION 12

Conv. Ctr. Room B1 Tues. 2:20 to 3:20 pm

Visualization Techniques I

Chair: Matti T. Gröhn, Ctr. for Scientific Computing (Finland)

2:20 pm: **Trees in a treemap: visualizing multiple hierarchies**, M. Burch, S. Diehl, Katholische Univ. Eichstätt (Germany) [6060-25]

2:40 pm: **Focus-based filtering + clustering technique for power-law networks with small world phenomenon**, F. Boutin, J. Thièvre, M. Hascoët, Univ. Montpellier II (France) and CNRS (France) [6060-26]

3:00 pm: **Enhancing scatterplot matrices for data with ordering or spatial attributes**, Q. Cui, M. O. Ward, E. A. Rundensteiner, Worcester Polytechnic Institute [6060-27]

Coffee Break 3:20 to 3:50 pm

SESSION 13

Conv. Ctr. Room B1 Tues. 3:50 to 4:30 pm

Visualization Techniques II

Chair: Edward Suvanaphen, Univ. of Kent (United Kingdom)

3:50 pm: **Content-based text mapping using multidimensional projections for exploration of document collections**, R. Minghim, F. V. Paulovich, A. de Andrade Lopes, Univ. de São Paulo (Brazil) . . . [6060-28]

4:10 pm: **Mapping texts through dimensionality reduction and visualization techniques for interactive exploration of document collections**, A. d. A. de Andrade Lopes, R. Minghim, V. Melo, F. V. Paulovich, Univ. de São Paulo (Brazil) [6060-29]

Session Break 4:30 to 4:40 pm

SESSION 14

Conv. Ctr. Room B1 Tues. 4:40 to 5:20 pm

Bioinformatics

Chair: Robert F. Erbacher, Utah State Univ.

4:40 pm: **Visualizing brain rhythms and synchrony**, K. A. Robbins, D. Veljkovic, E. Plipaviciute, The Univ. of Texas at San Antonio [6060-30]

5:00 pm: **Automatic feature-based surface mapping for brain cortices**, L. Linsen, Ernst Moritz Arndt Univ. Greifswald (Germany) [6060-31]

✓ Posters and Demonstrations-Tuesday

Demonstrations 5:30 to 8:30 pm

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters 5:30 to 7:00 pm

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

✓ **Blogviz: mapping the dynamics of information diffusion in blogspace**, M. S. Lima, Parsons School of Design [6060-32]

✓ **Organizing and visualizing database data using parallel coordinates**, C. G. Presser, Gettysburg College [6060-33]

✓ **Visualizing 3D vector fields with splatted streamlines**, E. Ess, Y. Sun, Purdue Univ. [6060-35]

✓ **SRS browser: a visual interface to the sequence retrieval system**, K. K. Mane, K. Borner, Indiana Univ. [6060-36]

✓ **Tracing parallel vectors**, J. Sukharev, Univ. of California/Santa Cruz [6060-39]

✓ **Output-sensitive volume tracking**, L. Jiang, Rutgers Univ. . . [6060-40]

✓ **Visualization of force fields in protein structure prediction**, S. N. Crivelli, Lawrence Berkeley National Lab. and California Institute for Quantitative Biomedical Research; C. Crawford, O. Kreylos, B. Hamann, Univ. of California/Davis [6060-41]

✓ **Correspondence-based visualization techniques**, M. J. Gerald-Yamasaki, NASA Ames Research Ctr. [6060-42]

Internet Imaging VII

Conference Chairs: **Simone Santini**, Univ. of California/San Diego; **Raimondo Schettini**, DISCo/Univ. degli Studi di Milano-Bicocca (Italy); **Theo Gevers**, Univ. van Amsterdam (Netherlands)

Program Committee: **Jeffrey E. Boyd**, Univ. of Calgary (Canada); **Alberto Del Bimbo**, Univ. degli Studi di Firenze (Italy); **Jennifer Gille**, Raytheon Co.; **Hagit Z. Hel-Or**, Univ. of Haifa (Israel); **Roger David Hersch**, École Polytechnique Fédérale de Lausanne (Switzerland); **Yasuyo G. Ichihara**, Hosen-Gakuen College (Japan); **Reiner Lenz**, Linköpings Univ. (Sweden); **Clement H. C. Leung**, Victoria Univ. of Technology (Australia); **Yong Rui**, Microsoft Research; **Simon Shim**, San José State Univ.; **Alain Trémeau**, Univ. Jean Monnet (France); **Luc J. Van Gool**, Katholieke Univ. Leuven (Belgium)

Tuesday 17 January

<p>Plenary Speaker Tues. 8:30 to 9:15 am</p> <p><i>Marriott Ballroom 1-6</i></p> <p>Image Processing: Interconnections</p> <p>Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign</p> <p><i>See p. 7 for details.</i></p>

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

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Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Subjective trajectory characterization: acquisition, matching, and retrieval**, M. Y. Zhang, L. Olsen, J. E. Boyd, Univ. of Calgary [6061-30]
- ✓ **Archiving of meaningful scenes for personal TV terminals**, S. H. Jin, J. H. Cho, Y. M. Ro, Information and Communications Univ. (South Korea); J. Kim, Electronics and Telecommunications Research Institute (South Korea) [6061-32]
- ✓ **AVIR: a spoken document retrieval system in e-learning environment**, I. Gagliardi, M. Padula, P. Pagliarulo, Consiglio Nazionale delle Ricerche (Italy) [6061-33]
- ✓ **Internet-based remote counseling to support stress management: preventing interruptions to regular exercise in elderly people**, S. Hashimoto, Univ. of Tsukuba (Japan) and National Institute of Information and Communications Technology (Japan); T. Munakata, Univ. of Tsukuba (Japan); N. Hashimoto, Citizen Watch Co., Ltd. (Japan); J. Okunaka, T. Koga, National Institute of Information and Communications Technology (Japan) [6061-34]
- ✓ **Vertex and face permutation order compression for efficient animation support**, E. Chang, Electronics and Telecommunications Research Institute (South Korea); D. Kim, B. Min, S. Lee, Hanyang Univ. (South Korea); N. Hur, S. Lee, Electronics and Telecommunications Research Institute (South Korea); E. S. Jang, Hanyang Univ. (South Korea) [6061-35]

Wednesday 18 January

<p>Plenary Speaker Wed. 8:30 to 9:15 am</p> <p><i>Marriott Ballroom 1-6</i></p> <p>Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging</p> <p>Richard Leahy, Univ. of Southern California</p> <p><i>See p. 7 for details.</i></p>
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SESSION 1

Conv. Ctr. Room B4 **Wed. 9:30 to 10:20 am**

Special Session: Benchmarking I

- 9:30 am: **Requirements for benchmarking personal image retrieval systems (Invited Paper)**, J. Bouguet, C. Dulong, I. V. Kozintsev, Intel Corp. [6061-01]
- 10:00 am: **On usage models of content-based image search, filtering, and annotation**, D. Telleen-Lawton, C. B. Chang, VIMA Technologies, Inc.; E. Y. Chang, Univ. of California/Santa Barbara [6061-02]
- Coffee Break 10:20 to 10:50 am

SESSION 2

Conv. Ctr. Room B4 **Wed. 10:50 to 11:50 am**

Special Session: Benchmarking II

- 10:50 am: **Human factors in automatic image retrieval system design and evaluation**, A. Jaimes, Fuji Xerox Co., Ltd. (Japan) [6061-03]
- 11:10 am: **Lessons from TRECVID: lexicon design for semantic indexing in media databases**, M. R. Naphade, IBM Thomas J. Watson Research Ctr. [6061-04]
- 11:30 am: **Benchmarking without ground truth**, S. Santini, Univ. of California/San Diego [6061-21]
- Lunch/Exhibition Break 11:30 am to 1:00 pm

SESSION 3

Conv. Ctr. Room B4 **Wed. 1:00 to 2:00 pm**

Special Session: Benchmarking III

- 1:00 pm: **Using heterogeneous annotation and visual information for the benchmarking of image retrieval system**, H. Müller, Univ. Hospital of Geneva (Switzerland) [6061-06]
- 1:20 pm: **On benchmarking content-based image retrieval applications**, B. Zhang, Y. Zuo, Tsinghua Univ. (China) [6061-07]
- 1:40 pm: **TRECVID: the utility of a content-based video retrieval evaluation**, A. G. Hauptmann, Carnegie Mellon Univ. [6061-08]

SESSION 4

Conv. Ctr. Room B4 Wed. 2:00 to 3:10 pm

Interfaces and Visualization

- 2:00 pm: **A color selection tool ensuring legibility of textual information on web pages (*Invited Paper*)**, S. Zuffi, Consiglio Nazionale delle Ricerche (Italy); G. B. Beretta, Hewlett-Packard Co.; C. Brambilla, Consultant (Italy) [6061-10]
- 2:30 pm: **A color interface for audio clustering visualization**, S. Zuffi, I. Gagliardi, Consiglio Nazionale delle Ricerche (Italy) [6061-11]
- 2:50 pm: **Interactive internet delivery of scientific visualization vis structured prerendered imagery**, J. Chen, San Francisco State Univ. and Lawrence Berkeley National Lab.; E. W. Bethel, Lawrence Berkeley National Lab.; I. Yoon, San Francisco State Univ. [6061-12]
- Coffee Break 3:10 to 3:40 pm

SESSION 5

Conv. Ctr. Room B4 Wed. 3:40 to 4:20 pm

Ontology and Annotation

- 3:40 pm: **Clustering and semantically filtering web images to create a large-scale image ontology**, S. Zinger, C. Millet, M. Benoit, G. Grefenstette, P. Hède, P. Moëllic, Commissariat a l'Energie Atomique (France) [6061-13]
- 4:00 pm: **Ontology and image semantics in multimodal imaging: submission and retrieval**, Y. Bei, M. Belmamoune, F. J. Verbeek, Leiden Univ. (Netherlands) [6061-14]

Thursday 19 January

SESSION 6

Conv. Ctr. Room B4 Thurs. 9:00 to 10:00 am

Anthropometrics

- 9:00 am: **Combining color models for skin detection**, F. Aldershoff, T. Gevers, H. M. Stokman, Univ. van Amsterdam (Netherlands) . . . [6061-16]
- 9:20 am: **Using context and similarity for face and location identification**, M. Davis, Univ. of California/Berkeley; M. A. Smith, France Telecom R&D (France); J. F. Canny, Univ. of California/Berkeley; F. W. M. Stentiford, Univ. College London (United Kingdom) [6061-17]
- 9:40 am: **Skin segmentation using multiple thresholding**, F. Gasparini, R. Schettini, Univ. degli Studi di Milano-Bicocca (Italy) [6061-18]
- Coffee Break 10:00 to 10:30 am

SESSION 7

Conv. Ctr. Room B4 Thurs. 10:30 am to 12:10 pm

Content Management and Retrieval

- 10:30 am: **Integration of multimedia contents and e-learning resources in a digital library**, M. Pascual, N. Ferran, J. Minguillón Alfonso, Univ. Oberta de Catalunya (Spain) [6061-19]
- 10:50 am: **Selecting the kernel type for a web-based adaptive image retrieval systems (AIRS)**, A. Doloc-Mihu, V. V. Raghavan, Univ. of Louisiana at Lafayette [6061-20]
- 11:10 am: **FaceLab: a tool for performance evaluation of face recognition strategies**, L. Caffisch, Comerson s.r.l. (Italy); A. Colombo, C. Cusano, R. Schettini, F. Tisato, Univ. degli Studi di Milano-Bicocca (Italy) [6061-36]
- 11:30 am: **Medical validation and CBIR of spine x-ray images over the Internet**, S. K. Antani, J. Cheng, J. L. Long, L. R. Long, G. R. Thoma, National Library of Medicine [6061-22]
- 11:50 am: **The integration of cartographic information into a content management system**, M. M. Furnari, C. I. D. Noviello, Consiglio Nazionale delle Ricerche (Italy) [6061-23]
- Lunch Break 12:10 to 1:30 pm

SESSION 8

Conv. Ctr. Room B4 Thurs. 1:30 to 2:10 pm

Video

- 1:30 pm: **Enhanced video display and navigation for networked streaming video and networked video playlists**, S. G. Deshpande, Sharp Labs. of America, Inc. [6061-24]
- 1:50 pm: **3D display technique for moving pictures from web cameras using screen pixel accessing**, T. Hasegawa, T. Namiki, H. Unno, K. Uehira, H. Kasuga, K. Yanaka, Kanagawa Institute of Technology (Japan) [6061-25]

SESSION 9

Conv. Ctr. Room B4 Thurs. 2:10 to 2:50 pm

Vector Displays

- 2:10 pm: **Dynamic conversion between XML-based languages for vector graphics**, A. Di Iorio, F. Vitali, G. Zonta, Univ. degli Studi di Bologna (Italy) [6061-28]
- 2:30 pm: **Bezier curves approximation of triangularized surfaces using SVG**, G. Messina, STMicroelectronics (Italy); E. Ingra, S. Battiato, G. Di Blasi, Univ. di Catania (Italy) [6061-29]

Spectral Imaging: Eighth International Symposium on Multispectral Color Science

Conference Chairs: **Mitchell R. Rosen**, Rochester Institute of Technology; **Francisco H. Imai**, Pixim, Inc.; **Shoji Tominaga**, Osaka Electro-Communication Univ. (Japan)

Program Committee: **Roy S. Berns**, Rochester Institute of Technology; **Jeffrey M. DiCarlo**, Hewlett-Packard Labs.; **Jon Y. Hardeberg**, Gjøvik Univ. College (Norway); **Markku Hauta-Kasari**, Univ. of Joensuu (Finland); **Bernhard Hill**, Univ. Aachen (Germany); **Reiner Lenz**, Linköping Univ. (Sweden); **Yoshitsugu Manabe**, Nara Institute of Science and Technology (Japan); **Yoichi Miyake**, Chiba Univ. (Japan); **Javier Romero**, Univ. de Granada (Spain); **Norimichi Tsumura**, Chiba Univ. (Japan); **Stephen Westland**, Univ. of Derby (United Kingdom)

Monday 16 January

SESSION 1

Conv. Ctr. Room A2 Mon. 9:00 to 10:20 am

Spectral Analysis for Scene Content Identification I

Chair: **Francisco H. Imai**, Rochester Institute of Technology

9:00 am: **Hyperspectral imaging of sulfate evaporite deposits in Western Australia and on Mars (Invited Paper)**, A. J. Brown, Macquarie Univ. (Australia) and Australian Ctr. for Astrobiology (Australia); T. J. Cudahy, Commonwealth Scientific & Industrial Research Organisation (Australia) [6062-01]

9:40 am: **Multispectral imaging determination of pigment concentration profiles in meat**, C. Sáenz, B. Hernández, C. Alberdi, S. Alfonso, M. Berroguí, J. M. Diñeiro, Univ. Pública de Navarra (Spain) [6062-02]

10:00 am: **Visualization of the human face skin moisturizing-ability by spectroscopic imaging using two near-infrared bands**, H. Iwasaki, K. Miyazawa, S. Nakauchi, Toyohashi Univ. of Technology (Japan) . [6062-03]

Coffee Break 10:20 to 10:50 am

SESSION 2

Conv. Ctr. Room A2 Mon. 10:50 am to 12:20 pm

Spectral Analysis for Scene Content Identification II

Chair: **Javier Hernandez-Andres**, Univ. de Granada (Spain)

10:50 am: **Spectral estimation of made-up skin color under various conditions (Invited Paper)**, M. Doi, R. Ohtsuki, S. Tominaga, Osaka Electro-Communication Univ. (Japan) [6062-05]

11:20 am: **Image processing techniques for detection of buried objects in infrared images**, A. Ceron-Correa, Univ. Militar Nueva Granada (Colombia); O. L. Lopera, Royal Military Academy (Belgium) and Univ. de Los Andes (Colombia) [6062-04]

11:40 am: **MODIS versus ASTER water classification**, C. Alecu, S. Oancea, National Meteorological Administration (Romania); E. Bryant, Dartmouth College [6062-06]

12:00 pm: **Improving multivariate curve resolution analysis performance when applied to fluorescence hyperspectral biological imaging (Presentation Only)**, H. D. T. Jones, E. Thomas, D. M. Haaland, J. A. Timlin, M. B. Sinclair, Sandia National Labs. [6062-07]

Lunch Break 12:20 to 1:50 pm

SESSION 3

Conv. Ctr. Room A2 Mon. 1:50 to 2:30 pm

Spectral Estimation Methods

Chair: **Masahiro Yamaguchi**, Tokyo Institute of Technology (Japan)

1:50 pm: **Estimating reflectance parameters from saturated spectral images**, S. Li, Y. Manabe, K. Chihara, Nara Institute of Science and Technology (Japan) [6062-08]

2:10 pm: **Influence of the recovery method in the optimum sensors for spectral imaging of skylight**, M. A. Lopez-Alvarez, J. Hernandez-Andres, J. L. Nieves, J. Romero, Univ. de Granada (Spain) [6062-09]

SESSION 4

Conv. Ctr. Room A2 Mon. 2:30 to 4:50 pm

Spectral Acquisition Systems

Chairs: **Javier Romero**, Univ. de Granada (Spain); **Markku Hauta-Kasari**, Joensuu Yliopisto (Finland)

2:30 pm: **Demosacking methods for multispectral cameras using mosaic focal plane array technology (Invited Paper)**, G. A. Baone, H. Qi, The Univ. of Tennessee [6062-10]

3:00 pm: **Estimation of noise variance of a multispectral image acquisition system**, N. Shimano, Kinki Univ. (Japan) [6062-11]

Coffee Break 3:20 to 3:50 pm

3:50 pm: **Multispectral stand-off imaging with mid-infrared semiconductor lasers**, Y. Wang, Y. Wang, H. Q. Le, Univ. of Houston [6062-12]

4:10 pm: **Designing flat-bed scanning system for spectral and glossiness recording**, T. Takiguchi, S. Abe, T. Makino, N. Tsumura, T. Nakaguchi, Chiba Univ. (Japan); F. Nakaya, H. Ichikawa, Y. Minato, Fuji Xerox Co., Ltd. (Japan); K. Miyata, National Museum of Japanese History (Japan); Y. Miyake, Chiba Univ. (Japan) [6062-13]

4:30 pm: **Color measurements with colorimetric and multispectral imaging systems**, M. de Lasarte, M. Vilaseca, J. Pujol, M. Arjona, Univ. Politècnica de Catalunya (Spain) [6062-15]

Tuesday 17 January

SESSION 7

Plenary Speaker **Tues. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 5

Conv. Ctr. Room A2 **Tues. 9:30 am to 12:00 pm**

Spectral Reproduction

Chair: Shoji Tominaga, Osaka Electro-Communication Univ. (Japan)

9:30 am: **High-fidelity video and still-image communication based on spectral information: natural vision system and its applications** (*Invited Paper*), M. Yamaguchi, Tokyo Institute of Technology (Japan); H. Haneishi, Chiba Univ. (Japan); H. Fukuda, J. Kishimoto, H. Kanazawa, M. Tsuchida, R. Iwama, National Institute of Information and Communications Technology (Japan); N. Ohyama, Tokyo Institute of Technology (Japan) [6062-16]

10:00 am: **Encoding of spectra for multiple observers and multiple illuminants**, T. Boosmann, RWTH Aachen (Germany) [6062-17]

Coffee Break 10:20 to 10:50 am

10:50 am: **Spectral-based color reproduction for print illuminated by image projector** (*Invited Paper*), K. Ueda, S. Yamamoto, N. Tsumura, T. Nakaguchi, Y. Miyake, Chiba Univ. (Japan) [6062-18]

11:20 am: **Spectral-based optimization of screen images for industrial product presentation**, L. Härkönen, J. B. Martinkauppi, H. T. Laamanen, M. Hauta-Kasari, Joensuu Yliopisto (Finland); P. Huhtelin, P. Horttanainen, Tulikivi Oyj (Finland) [6062-19]

11:40 am: **Spectral gamuts and spectral gamut mapping**, M. R. Rosen, Rochester Institute of Technology; M. W. Derhak, Onyx Graphics [6062-20]

Lunch/Exhibition Break 12:00 to 1:30 pm

SESSION 6

Conv. Ctr. Room A2 **Tues. 1:30 to 2:20 pm**

Art Spectral Imaging

Chair: Norimichi Tsumura, Chiba Univ. (Japan)

1:30 pm: **A technique for detecting metameric color areas for investigation of historical materials** (*Invited Paper*), K. Miyata, National Museum of Japanese History (Japan); H. T. Laamanen, T. Jaaskelainen, M. Hauta-Kasari, J. P. Parkkinen, Joensuu Yliopisto (Finland) [6062-21]

2:00 pm: **A scanning device for multispectral imaging of paintings**, C. Bonifazzi, Univ. degli Studi di Ferrara (Italy); P. Carcagni, A. D. Patria, Istituto Nazionale di Ottica Applicata (Italy); S. Ferriani, ENEA (Italy); R. Fontana, M. Greco, M. G. Mastroianni, M. Materazzi, E. M. Pampaloni, A. Romano, Istituto Nazionale di Ottica Applicata (Italy) [6062-22]

Conv. Ctr. Room A2 **Tues. 2:20 to 3:00 pm**

Spectral Video Systems

Chair: Mitchell R. Rosen, Rochester Institute of Technology

2:20 pm: **Spectral video intraframe compression and database**, J. P. Purmonen, M. Hauta-Kasari, J. Tuomela, Joensuu Yliopisto (Finland); M. Yamaguchi, M. Mitsui, Tokyo Institute of Technology (Japan); H. Fukuda, National Institute of Information and Communications Technology (Japan) [6062-23]

2:40 pm: **Real-time, multispectral, color acquisition and display using commodity hardware components**, D. L. Lau, A. M. Tan, Univ. of Kentucky [6062-24]

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

A symposium-wide demonstration session will be open to attendees

5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1.

Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A

poster session, with authors present at their posters, will be held

Tuesday evening, 5:30 to 7:00 pm.

✓ Construction of multichannel camera gamuts, S. Helling, RWTH Aachen (Germany) [6062-25]

✓ Importance of the texture features in a query from spectral image databases, O. Kohonen, M. Hauta-Kasari, Univ. of Joensuu (Finland) [6062-27]

Real-Time Image Processing III

Conference Chairs: **Nasser Kehtarnavaz**, The Univ. of Texas at Dallas; **Phillip A. Laplante**, The Pennsylvania State Univ.

Program Committee: **Mohamed Akil**, École Supérieure d'Ingénieurs en Électronique et Électrotechnique (France); **Matthias F. Carlsohn**, Computer Vision and Image Communication (Germany); **Carlos R. Castro-Pareja**, Univ. of Maryland/Baltimore; **Luciano F. da Fontoura Costa**, Univ. de São Paulo (Brazil); **Philip P. Dang**, STMicroelectronics; **Xavier Desurmont**, Multitel (Belgium); **Edward R. Dougherty**, Texas A&M Univ.; **Sang-Yong Lee**, Texas Instruments Inc.; **Chang-Joon Park**, Electronics and Telecommunications Research Institute (South Korea); **Gregory Pisanich**, NASA Ames Research Ctr.; **Volodymyr I. Ponomaryov**, Instituto Politécnico Nacional (Mexico); **Fatih M. Porikli**, Mitsubishi Electric Research Labs.; **Raghvinder S. Sangwan**, The Pennsylvania State Univ.; **Feng Xiao**, Agilent Technologies

Monday 16 January

SESSION 1

Conv. Ctr. Room B3 Mon. 8:50 to 10:00 am

Medical Applications

Chair: **Nasser Kehtarnavaz**, The Univ. of Texas at Dallas

8:30 am: **Fast computation of free-form deformations in 3D images using FPGAs (Invited Paper)**, C. R. Castro-Pareja, Intel Corp.; R. Shekhar, Univ. of Maryland/Baltimore [6063-01]

9:00 am: **Toward real-time stereoscopic depth reconstruction in laparoscopic surgery**, B. J. McCullagh, F. P. Shevlin, The Univ. of Dublin, Trinity College (Ireland) [6063-02]

9:20 am: **Real-time wavelet denoising with edge enhancement for medical x-ray imaging**, G. Luo, D. Osypiw, Buckinghamshire Chilterns Univ. College (United Kingdom) [6063-03]

Coffee Break 10:00 to 10:30 am

SESSION 2

Conv. Ctr. Room B3 Mon. 10:30 am to 12:00 pm

Video Processing

Chair: **Carlos R. Castro-Pareja**, Intel Corp.

10:30 am: **Real-time high-level video understanding using data warehouse (Invited Paper)**, B. Lienard, X. Desurmont, B. Barrie, J. Delaigle, Multitel A.S.B.L. (Belgium) [6063-05]

11:00 am: **Video surveillance using distance maps**, T. E. Schouten, H. C. Kuppens, Radboud Univ. Nijmegen (Netherlands); E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands) and Katholieke Univ./Nijmegen (Netherlands) [6063-06]

11:20 am: **Vehicle traffic video data real-time processing**, M. Andreae, W. K. Cheng, Massachusetts Institute of Technology [6063-07]

11:40 am: **Vehicle counting system using real-time video processing**, P. Crisostomo-Romero, Pontificia Univ. Católica del Perú (Peru) ... [6063-08]

Lunch Break 12:00 to 1:30 pm

SESSION 3

Conv. Ctr. Room B3 Mon. 1:30 to 3:00 pm

Algorithms

Chair: **Xavier Desurmont**, Multitel A.S.B.L. (Belgium)

1:30 pm: **Real-time auto white balancing using DWT-based multiscale clustering (Invited Paper)**, N. Kehtarnavaz, N. Kim, M. N. Gamadia, The Univ. of Texas at Dallas [6063-09]

2:00 pm: **Real-time antialiasing using adaptive directional filtering**, P. Rokita, Politechnika Warszawska (Poland) [6063-10]

2:20 pm: **A fast eye detector using corners, color, and edges**, L. Chen, C. Grecos, Loughborough Univ. (United Kingdom) [6063-11]

2:40 pm: **Real-time construction of covariance matrices for arbitrary size image windows**, F. M. Porikli, O. Tuzel, Mitsubishi Electric Research Labs. [6063-12]

Coffee Break 3:00 to 3:30 pm

SESSION 4

Conv. Ctr. Room B3 Mon. 3:30 to 5:40 pm

Hardware

Chair: **Mohamed Akil**, École Supérieure d'Ingénieurs en Électronique et Électrotechnique (France)

3:30 pm: **High-performance VLSI architecture for adaptive scaling (Invited Paper)**, P. P. Dang, STMicroelectronics [6063-13]

4:00 pm: **Architecture for hardware driven image inspection based on FPGAs**, J. Fuertler, J. Brodersen, Austrian Research Ctrs. GmbH - Seibersdorf (Austria); P. Roessler, Technische Univ. Wien (Austria); K. J. Mayer, Austrian Research Ctrs. GmbH - Seibersdorf (Austria); G. Cadek, C. Eckel, H. Nachtnebel, Technische Univ. Wien (Austria) [6063-14]

4:20 pm: **Using a field programmable object array (FPOA) to accelerate image processing**, S. Riley, MathStar, Inc. [6063-15]

4:40 pm: **Novel windowing technique realized in FPGA for radar system**, E. Escamilla-Hernández, Instituto Politécnico Nacional (Mexico); V. F. Kravchenko, Instituto Politécnico Nacional (Mexico) and Institute of Radio Engineering and Electronics (Russia); V. I. Ponomaryov, Instituto Politécnico Nacional (Mexico) [6063-16]

5:00 pm: **Real-time hardware for a new 3D display**, M. Akil, B. Kaufmann, École Supérieure d'Ingénieurs en Électronique et Électrotechnique (France) [6063-17]

5:20 pm: **A rapid prototyping methodology to implement and optimize image processing algorithms for FPGAs**, M. Akil, P. Niang, T. Grandpierre, École Supérieure d'Ingénieurs en Électronique et Électrotechnique (France) [6063-18]

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

✓ Posters and Demonstrations-Tuesday

Demonstrations 5:30 to 8:30 pm

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Posters 5:30 to 7:00 pm

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **An efficient illuminance-reflectance nonlinear video stream enhancement model**, L. Tao, V. K. Asari, Old Dominion Univ. [6063-19]
- ✓ **A novel two-pass hexagonal search algorithm for motion estimation**, Y. Wu, The Univ. of Reading (United Kingdom) . . [6063-21]
- ✓ **Real-time image processing based on robust linear combinations of order statistics**, F. J. Gallegos-Funes, J. L. Varela-Benitez, V. I. Ponomaryov, Instituto Politécnico Nacional (Mexico) [6063-22]
- ✓ **A new concept of real-time security camera monitoring with privacy protection by masking moving objects**, K. Yabuta, H. Kitazawa, T. Tanaka, Tokyo Univ. of Agriculture and Technology (Japan) [6063-23]
- ✓ **Online monitoring for wood pieces on a moving conveyor belt**, W. Wang, Chongqing Univ. of Posts and Telecommunications (China) [6063-24]
- ✓ **A hardware-accelerated approach to computing multiple image similarity measures from joint histogram**, C. R. Castro-Pareja, Intel Corp.; R. Shekhar, Univ. of Maryland/Baltimore [6063-25]
- ✓ **Real-time human detection by shape and motion**, H. Ran, Wuhan Univ. of Technology (China) [6063-26]
- ✓ **Uranus: an environment for rapid prototyping of real-time video processing based on FPGA**, M. A. Nuño-Maganda, V. H. Rosales-Hernández, L. N. Castillo-Jimenez, G. Sosa-Ramírez, M. O. Arias-Estrada, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico) [6063-31]
- ✓ **Determination of traffic intensity from camera images using image processing and pattern recognition techniques**, M. Mehrubeoglu, Texas A&M Univ./Corpus Christi; L. McLauchlan, Texas A&M Univ./Kingsville [6063-32]

Monday-Tuesday 16-17 January 2006 • Part of Proceedings of SPIE Vol. 6064
Image Processing: Algorithms and Systems, Neural Networks and Machine Learning

Image Processing: Algorithms and Systems V

Conference Chairs: **Edward R. Dougherty**, Texas A&M Univ.; **Jaakko T. Astola**, Tampere Univ. of Technology (Finland); **Karen O. Egiazarian**, Tampere Univ. of Technology (Finland)

Program Committee: **Til Aach**, RWTH Aachen (Germany); **Sos S. Agaian**, The Univ. of Texas at San Antonio; **Junior Barrera**, Univ. de São Paulo (Brazil); **Reiner Creutzburg**, Fachhochschule Brandenburg (Germany); **Paul D. Gader**, Univ. of Florida; **Atanas P. Gotchev**, Tampere Univ. of Technology (Finland); **John C. Handley**, Xerox Corp.; **Vladimir V. Lukin**, National Aerospace Univ. (Ukraine); **Stephen Marshall**, Univ. of Strathclyde (United Kingdom); **Françoise J. Prêteux**, Institut National des Télécommunications (France); **Giovanni Ramponi**, Univ. Degli Studi di Trieste (Italy); **Jagath K. Samarabandu**, The Univ. of Western Ontario (Canada); **Akira Taguchi**, Musashi Institute of Technology (Japan)

Monday 16 January

SESSION 1

Conv. Ctr. Room C2 Mon. 9:00 am to 12:10 pm

Image Processing Algorithms

- 9:00 am: **Affine invariant surface evolutions for 3D image segmentation**, Y. Rathi, Georgia Institute of Technology; P. Olver, G. Sapiro, Univ. of Minnesota; A. R. Tannenbaum, Georgia Institute of Technology [6064A-01]
- 9:20 am: **Iterative Markovian estimation of mass functions in Dempster Shafer evidence theory: application to multisensor image segmentation**, L. Bentabet, M. Jiang, Bishop's Univ. (Canada) [6064A-02]
- 9:40 am: **Progressive halftoning by Perona-Malik error diffusion and stochastic flipping**, J. J. Shen, Univ. of Minnesota [6064A-03]
- 10:00 am: **Edge-based stochastic active contours for medical imaging**, J. J. Trainsel, A. R. Tannenbaum, Georgia Institute of Technology [6064A-04]
- Coffee Break 10:20 to 10:50 am
- 10:50 am: **Multiple wavelet coherence analysis**, S. C. Olhede, G. Metikas, Imperial College London (United Kingdom) [6064A-05]
- 11:10 am: **New class of interpolation methods based on discretized lie group transforms**, A. Zaratsyan, J. Patera, Univ. de Montréal (Canada); H. Zhu, York Univ. (Canada) [6064A-06]
- 11:30 am: **Optimization procedures for the estimation of phase portrait parameters in orientation fields**, F. J. Ayres, R. M. Rangayyan, Univ. of Calgary (Canada) [6064A-07]
- 11:50 am: **Optimized gradient filters for hexagonal matrices**, T. Shima, S. Saito, Tokyo Institute of Technology (Japan); M. Nakajima, Tokyo Institute of Technology (Japan) and National Institute of Informatics (Japan) [6064A-08]
- Lunch Break 12:10 to 2:00 pm

SESSION 2

Conv. Ctr. Room C2 Mon. 2:00 to 3:00 pm

Efficient Algorithms

- 2:00 pm: **Super-fast Fourier transform**, S. S. Agaian, O. Caglayan, The Univ. of Texas at San Antonio [6064A-09]
- 2:20 pm: **A high-speed rotation method for binary document images based on coordinate operation of run data**, Y. Shima, H. Ohya, Meisei Univ. (Japan) [6064A-11]
- 2:40 pm: **A hardware implementation of the discrete Pascal transform for image processing**, T. J. Goodman, M. F. Aburdene, Bucknell Univ. [6064A-12]
- Coffee Break 3:00 to 3:30 pm

SESSION 3

Conv. Ctr. Room C2 Mon. 3:30 to 4:50 pm

Image Processing Systems

- 3:30 pm: **Using clustering for document reconstruction**, A. Ukovich, A. Zacchigna, G. Ramponi, G. Schoier, Univ. Degli Studi di Trieste (Italy) [6064A-13]
- 3:50 pm: **Automatic detection and tracking of reappearing targets in forward-looking infrared imagery**, A. Bal, M. S. Alam, Univ. of South Alabama [6064A-14]
- 4:10 pm: **Robust human motion detection via fuzzy set based image understanding**, Q. Li, J. You, The Hong Kong Polytechnic Univ. (Hong Kong China) [6064A-16]
- 4:30 pm: **k-max: segmentation based on selection of max-tree deep nodes**, A. G. Silva, S. C. Felipussi, G. L. F. Cassol, Univ. do Estado de Santa Catarina (Brazil); R. de Alencar Lotufo, Univ. Estadual de Campinas (Brazil) [6064A-17]

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 4

Conv. Ctr. Room C2 Tues. 9:40 to 11:50 am

Image Processing Methods

- 9:40 am: **Shape-adaptive DCT for denoising and image reconstruction**, A. Foi, K. Dabov, V. Katkovich, K. O. Egiazarian, Tampere Univ. of Technology (Finland) [6064A-18]
- 10:00 am: **Anisotropic filtering with nonlinear structure tensors**, C. A. Castaño Moraga, J. Ruiz-Alzola, Univ. de Las Palmas de Gran Canaria (Spain) [6064A-19]
- Coffee Break 10:20 to 10:50 am
- 10:50 am: **A modified wavelet transformation based method of linear object extraction**, T. Chen, Univ. of South Carolina [6064A-20]
- 11:10 am: **2D approaches to 3D watermarking: state of the art and perspectives**, M. P. Mitrea, S. A. Duta, F. J. Preteux, Institut National des Télécommunications (France) [6064A-21]
- 11:30 am: **Region-based perceptual grouping: a cooperative approach based on Dempster-Shafer theory**, N. Zlatoff, B. Tellez, A. M. Baskurt, Univ. Claude Bernard Lyon 1 (France) [6064A-22]
- Lunch/Exhibition Break 11:50 am to 1:40 pm

SESSION 5

Conv. Ctr. Room C2 Tues. 1:40 to 3:00 pm

Biomedical Image Processing

- 1:40 pm: **Study of muscular deformation based on surface slope estimation**, M. Carli, M. Goffredo, M. Schmid, A. Neri, Univ. degli Studi di Roma Tre (Italy) [6064A-23]
- 2:00 pm: **An automated diagnosis approach based on histopathological images**, M. C. d'Ornellas, C. C. Danesi, J. A. T. Borges da Costa, Univ. Federal de Santa Maria (Brazil) [6064A-24]
- 2:20 pm: **Variational segmentation of x-ray image with overlapped objects**, G. Yu, Nuctech Co. Ltd. (China); L. Zhang, J. Zhang, Y. Xing, H. Gao, Tsinghua Univ. (China) [6064A-25]
- 2:40 pm: **Image segmentation for automated dental identification**, E. Haj Said, D. E. M. Nassar, H. H. Ammar, West Virginia Univ. . . [6064A-26]
- Coffee Break 3:00 to 3:30 pm

SESSION 6

Conv. Ctr. Room C2 Tues. 3:30 to 5:30 pm

Algorithms and Systems

- 3:30 pm: **Deblending of the UV photometry in GALEX deep surveys using optical priors in the visible wavelengths**, A. Llebaria, Lab. d'Astrophysique de Marseille (France); M. Guillaume, D. Aymeric, Ecole Generaliste d'Ingenieurs de Marseille (France); B. Milliard, S. Arnauts, Lab. d'Astrophysique de Marseille (France) [6064A-27]
- 3:50 pm: **Comparative study of logarithmic enhancement algorithms with performance measure**, E. J. Wharton, Tufts Univ.; S. S. Agaian, The Univ. of Texas at San Antonio; K. A. Panetta, Tufts Univ. [6064A-28]
- 4:10 pm: **MMW video sequence denoising and enhancement in concealed weapons detection applications**, X. Wei, H. Chen, The Univ. of Texas at Arlington; P. K. Varshney, Syracuse Univ. [6064A-29]
- 4:30 pm: **Image denoising with block-matching and 3D filtering**, K. Dabov, A. Foi, V. Katkovnik, K. O. Egiazarian, Tampere Univ. of Technology (Finland) [6064A-30]
- 4:50 pm: **An algorithm for the enhancement of images of large dynamic range**, F. Hassan, J. E. Carletta, Univ. of Akron [6064A-31]
- 5:10 pm: **Nonlinear image enhancement to improve face detection in complex lighting environment**, L. Tao, M. Seow, V. K. Asari, Old Dominion Univ. [6064A-32]

✓ Posters and Demonstrations-Tuesday

Demonstrations. 5:30 to 8:30 pm

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters 5:30 to 7:00 pm

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Noise image enhancement on Hölder function spaces**, M. Lee, National Taiwan Ocean Univ. (Taiwan) [6064A-33]
- ✓ **Ad hoc segmentation pipeline for microarray image analysis**, S. Battiato, G. Di Blasi, G. M. Farinella, G. Gallo, G. C. Guarnera, Univ. di Catania (Italy) [6064A-34]
- ✓ **Color transient improvement via range detection**, G. S. Shin, M. G. Kang, Yonsei Univ. (South Korea) [6064A-35]
- ✓ **For fast classification and segmentation of high-resolution images of multiple and complicated colonies**, W. Wang, Chongqing Univ. of Posts and Telecommunications (China) [6064A-36]
- ✓ **Spatially adaptive multiresolution multispectral image fusion based on Bayesian approach**, J. H. Park, M. G. Kang, Yonsei Univ. (South Korea) [6064A-37]
- ✓ **Segmentation of microspheres in ultrahigh density microsphere-based assays**, A. Mathur, D. M. Kelso, Northwestern Univ. . . [6064A-38]
- ✓ **Discrete Gould transform and its applications**, M. F. Aburdene, H. M. Le, Bucknell Univ. [6064A-39]
- ✓ **The application of image filters combined with the nonlinear regression analysis on optical autofocusing**, M. Lee, W. Hsu, National Kaohsiung Normal Univ. (Taiwan); T. Lin, National Taiwan Univ. (Taiwan) [6064A-40]
- ✓ **Crease enhancement and the segmentation of topographic images**, H. C. Morris, San José State Univ. [6064A-41]
- ✓ **A multiscale approach to contour detection and texture suppression**, G. Papari, Rijksuniv. Groningen (Netherlands); P. Campisi, Univ. degli Studi Roma Tre (Italy); N. Petkov, Rijksuniv. Groningen (Netherlands); A. Neri, Univ. degli Studi Roma Tre (Italy) . . . [6064A-43]
- ✓ **A heuristic approach for the extraction of region and boundary of mammalian cells in bio-electric images**, L. Tao, V. K. Asari, Old Dominion Univ. [6064A-44]
- ✓ **Lip segmentation and tracking for facial palsy**, M. Park, J. Seo, K. S. Park, Seoul National Univ. (South Korea) [6064A-45]
- ✓ **A multithreshold algorithm based on intensity distribution**, D. Chen, M. Sarhadi, Brunel Univ. (United Kingdom) [6064A-46]
- ✓ **An efficient multiresolution GA approach to dental image alignment**, D. E. M. Nassar, M. Ogirala, D. A. Adjeroth, H. H. Ammar, West Virginia Univ. [6064A-47]
- ✓ **Phase unwrapping by means of finite differences**, L. I. Olivos-Pérez, E. de la Rosa Miranda, L. R. Berriel-Valdos, R. Ramos-López, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico) [6064A-48]

Tuesday-Wednesday 17-18 January 2006 • Part of Proceedings of SPIE Vol. 6064
Image Processing: Algorithms and Systems, Neural Networks and Machine Learning

Applications of Neural Networks and Machine Learning in Image Processing X

Conference Chairs: **Nasser M. Nasrabadi**, Army Research Lab.; **Syed A. Rizvi**, CUNY/College of Staten Island

Program Committee: **Pierre Baldi**, California Institute of Technology; **Yoshua Bengio**, Univ. de Montréal (Canada); **Terry M. Caelli**, Curtin Univ. of Technology (Australia); **Rama Chellappa**, Univ. of Maryland/College Park; **Chang Y. Choo**, San José State Univ.; **Sandor Z. Der**, Aerospace Corp.; **Edward R. Dougherty**, Texas A&M Univ.; **Kunihiko Fukushima**, Tokyo Univ. of Technology (Japan); **Erol Gelenbe**, Imperial College London (United Kingdom); **David H. Haussler**, Univ. of California/Santa Cruz; **Nicolaos B. Karayiannis**, Univ. of Houston; **Bart Kosko**, Univ. of Southern California; **Sun-Yuan Kung**, Princeton Univ.; **Richard P. Lippmann**, MIT Lincoln Lab.; **Erkki Oja**, Helsinki Univ. of Technology (Finland); **Sankar K. Pal**, Indian Statistical Institute (India); **Tomaso A. Poggio**, MIT Artificial Intelligence Lab.; **Christoph von der Malsburg**, Univ. of Southern California; **Jacek M. Zurada**, Univ. of Louisville

Tuesday 17 January

<p>Plenary Speaker Tues. 8:30 to 9:15 am</p> <p><i>Marriott Ballroom 1-6</i></p> <p>Image Processing: Interconnections</p> <p>Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign</p> <p><i>See p. 7 for details.</i></p>
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✓ Posters and Demonstrations-Tuesday

Demonstrations 5:30 to 8:30 pm
A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters. 5:30 to 7:00 pm
Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Key-text spotting in documentary videos using Adaboost**, M. Lalonde, L. Gagnon, CRIM (Canada) [6064B-65]
- ✓ **Research on classifying performance of SVMs with basic kernel in HCCR**, L. Sun, YanTai Univ. (China) [6064B-67]
- ✓ **Face recognition based on HMM in compressed domain**, H. Wang, G. Feng, Sun Yat-sen Univ. (China) [6064B-68]
- ✓ **Application of ANN and DT on medium resolution ASTER image to model gully network in Southern Italy**, A. Ghaffari, P. M. Mather, G. Priestnall, M. L. Clarke, The Univ. of Nottingham (United Kingdom) [6064B-69]

Wednesday 18 January

<p>Plenary Speaker Wed. 8:30 to 9:15 am</p> <p><i>Marriott Ballroom 1-6</i></p> <p>Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging</p> <p>Richard Leahy, Univ. of Southern California</p> <p><i>See p. 7 for details.</i></p>

SESSION 7

Conv. Ctr. Room C2 Wed. 9:30 to 10:30 am

Kernel-based Learning for Detection and Shape Analysis
Chair: Heesung Kwon, Army Research Lab.

9:30 am: **Nonlinear shape prior from Kernel space for geometric active contours**, S. Dambreville, Y. Rathi, A. R. Tannenbaum, Georgia Institute of Technology [6064B-49]

9:50 am: **Kernel subspace matched target detectors**, H. Kwon, N. M. Nasrabadi, Army Research Lab. [6064B-50]

10:10 am: **Statistical shape analysis using kernel PCA**, Y. Rathi, S. Dambreville, A. R. Tannenbaum, Georgia Institute of Technology[6064B-51]

Coffee Break 10:30 to 11:00 am

SESSION 8

Conv. Ctr. Room C2 Wed. 11:00 to 11:20 am

Fuzzy Clustering
Chair: Heesung Kwon, Army Research Lab.

11:00 am: **Segmentation and enhancement of digital copies using a new fuzzy clustering method**, M. N. Ahmed, B. E. Cooper, Lexmark International, Inc. [6064B-52]

SESSION 9

Conv. Ctr. Room C2 Wed. 11:20 to 11:40 am

Independent Component Analysis, Adaboost for Recognition

Chair: Syed A. Rizvi, College of Staten Island/CUNY

11:20 am: **2D/3D facial feature extraction**, B. Sankur, L. Akarun, H. Cinar, A. Ali Salah, Bogaziçi Univ. (Turkey) [6064B-54]

Lunch/Exhibition Break 11:40 am to 1:20 pm

SESSION 10

Conv. Ctr. Room C2 Wed. 1:20 to 3:50 pm

Neural Networks Applications for Manifold Learning, Recognition, Color Perception, and Compression

Chair: Syed A. Rizvi, College of Staten Island/CUNY

1:20 pm: **Noniterative neural network learning of an N-dimension curve representing the dynamic history of a time varying pattern**, C. J. Hu, Southern Illinois Univ. [6064B-56]

1:40 pm: **Manifold of color perception: color constancy using a nonlinear line attractor**, V. K. Asari, M. Seow, Old Dominion Univ. [6064B-57]

2:00 pm: **A novel neural net application for image compression**, H. S. Soliman, M. Omari, New Mexico Institute of Mining and Technology [6064B-58]

2:20 pm: **Toward content-based object recognition with image primitives**, G. Wang, J. M. Kinser, George Mason Univ. [6064B-59]

2:40 pm: **Translation invariance in a network of oscillatory units**, A. R. Rao, G. A. Cecchi, C. Peck, J. Kozloski, IBM Corp. [6064B-60]

Coffee Break 3:00 to 3:30 pm

3:30 pm: **Efficient learning and recognition using segmented analytical data of an edge-detected 2D image**, C. J. Hu, Southern Illinois Univ. [6064B-61]

SESSION 11

Conv. Ctr. Room C2 Wed. 3:50 to 4:50 pm

Support Vector Machine and Neural Networks for Face Recognition, Detection, and Classification

Chair: Nasser M. Nasrabadi, Army Research Lab.

3:50 pm: **Support vector machine as digital image watermark detector**, P. H. H. Then, Swinburne Univ. of Technology (Malaysia); Y. C. Wang, Univ. Malaysia Sarawak (Malaysia) [6064B-62]

4:10 pm: **Neural networks approach to high vertical resolution atmospheric temperature profile retrieval from spaceborne high spectral resolution infrared sounder measurements**, D. Jiang, C. Dong, Hunan Meteorological Bureau (China) [6064B-63]

4:30 pm: **Probabilistic multiresolution human classification**, H. Ran, J. Tu, Wuhan Univ. of Technology (China) [6064B-64]

Computational Imaging IV

Conference Chairs: **Charles A. Bouman**, Purdue Univ.; **Eric L. Miller**, Northeastern Univ.; **Ilya Pollak**, Purdue Univ.

Program Committee: **Thomas S. Denney, Jr.**, Auburn Univ.; **Peter C. Doerschuk**, Purdue Univ.; **Maya R. Gupta**, Univ. of Washington; **Peyman Milanfar**, Univ. of California/Santa Cruz; **Joseph A. O'Sullivan**, Washington Univ. in St. Louis; **Zygmunt Pizlo**, Purdue Univ.; **Stanley J. Reeves**, Auburn Univ.; **Yongyi Yang**, Illinois Institute of Technology; **Yibin Zheng**, Univ. of Virginia

Monday 16 January

SESSION 1

Conv. Ctr. Room A4 Mon. 8:30 to 9:00 am

Keynote Presentation I

Chair: **Charles A. Bouman**, Purdue Univ.

Keynote

8:30 am: **Keynote (Invited Paper)**, M. V. de Hoop, Purdue Univ. [6065-01]

SESSION 2

Conv. Ctr. Room A4 Mon. 9:00 to 11:10 am

Hierarchical and Graph-based Image Analysis

Chair: **Peyman Milanfar**, Univ. of California/Santa Cruz

9:00 am: **Modeling hierarchical structure of images with stochastic grammars**, W. Wang, T. Wong, I. Pollak, C. A. Bouman, M. P. Harper, Purdue Univ. [6065-02]

9:20 am: **Multiresolution analysis of digital images using the continuous extension of discrete group transforms**, M. Germain, J. Patera, A. Zaratsyan, Univ. de Montréal (Canada) [6065-03]

9:40 am: **Modeling multiscale differential pixel statistics with applications**, D. Odom, P. Milanfar, Univ. of California/Santa Cruz [6065-04]
Coffee Break 10:00 to 10:30 am

10:30 am: **Graph-based 3D object classification**, S. Baloch, A. H. Krim, North Carolina State Univ. [6065-05]

10:50 am: **Compression via optimal basis selection in large tree-structured dictionaries**, Y. Huang, Purdue Univ. [6065-06]

SESSION 3

Conv. Ctr. Room A4 Mon. 11:10 am to 12:10 pm

Reconstruction from Sparse Data

Chair: **Ilya Pollak**, Purdue Univ.

11:10 am: **Compressed sensing in noisy imaging environments**, J. Haupt, R. Castro, R. D. Nowak, Univ. of Wisconsin/Madison . . . [6065-07]

11:30 am: **Stable signal recovery from incomplete and inaccurate observations**, J. K. Romberg, California Institute of Technology [6065-08]

11:50 am: **A compressed sensing camera: new theory and an implementation using digital micromirrors**, D. Takhar, M. B. Wakin, M. Duarte, D. Baron, K. F. Kelly, R. G. Baraniuk, Rice Univ. [6065-09]

Lunch Break 12:10 to 1:40 pm

SESSION 4

Conv. Ctr. Room A4 Mon. 1:40 to 3:00 pm

Microscopy

Chair: **Peter C. Doerschuk**, Purdue Univ.

1:40 pm: **A fast algorithm for 3D reconstruction from unoriented projections and cryo-electron microscopy of viruses**, J. Lee, Y. Zheng, P. C. Doerschuk, Purdue Univ. [6065-10]

2:00 pm: **Spatially adaptive 3D inverse for optical sectioning**, D. V. Paliy, V. Katkovnik, K. O. Egiazarian, Tampere Univ. of Technology (Finland) [6065-11]

2:20 pm: **On soft clipping of Zernike moments for deblurring and enhancement of optical point spread functions**, N. Becherer, J. Hesser, Univ. Mannheim (Germany) [6065-12]

2:40 pm: **Adaptive sampling for atomic force microscopy with system level motion constraints**, H. Cheng, G. T. C. Chiu, Purdue Univ. [6065-13]

Coffee Break 3:00 to 3:30 pm

SESSION 5

Conv. Ctr. Room A4 Mon. 3:30 to 5:10 pm

Inverse Problems

Chair: **Thomas S. Denney, Jr.**, Auburn Univ.

3:30 pm: **Bayesian image reconstruction from Fourier-domain samples using prior edge information: convergence and parameter sensitivity**, T. S. Denney, Jr., S. J. Reeves, Auburn Univ. [6065-14]

3:50 pm: **Thin digital imaging systems using focal plane coding**, A. D. Portnoy, J. P. Guo, N. P. Pitsianis, D. J. Brady, Duke Univ.; M. A. Fiddy, Univ. of North Carolina/Charlotte; M. R. Feldman, R. D. Te Kolste, Digital Optics Corp. [6065-15]

4:10 pm: **3D reconstructions from spherically averaged Fourier transform magnitude and solution x-ray scattering experiments**, Y. Hwang, P. C. Doerschuk, Purdue Univ. [6065-16]

4:30 pm: **Computed spectroscopy using segmented apertures**, R. T. Hoctor, F. W. Wheeler, GE Global Research; E. B. Barrett, Lockheed Martin Corp. [6065-17]

4:50 pm: **Preconditioned conjugate gradient without linesearch: a comparison with the half-quadratic approach for edge-preserving image restoration**, C. Labat, J. Idier, Institute of Research in Communications and Cybernetics of Nantes (France) [6065-18]

Tuesday 17 January

SESSION 9

Plenary Speaker **Tues. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 6

Conv. Ctr. Room A4 **Tues. 9:30 to 10:00 am**

Keynote Presentation II

Chair: Eric L. Miller, Northeastern Univ.

9:30 am: **Computational methods for image restoration, image segmentation, and texture modeling (Invited Paper)**, G. Chung, T. M. Le, L. H. Lieu, N. Tanushev, L. Vese, Univ. of California/Los Angeles [6065-19]

SESSION 7

Conv. Ctr. Room A4 **Tues. 10:00 am to 12:10 pm**

Image and Video Analysis

Chair: Mireille Boutin, Purdue Univ.

10:00 am: **An adaptive model for restoration of optically distorted video frames**, D. Li, Georgia Institute of Technology; M. J. T. Smith, Purdue Univ.; R. M. Mersereau, Georgia Institute of Technology [6065-20]
 Coffee Break 10:20 to 10:50 am
 10:50 am: **Resource-driven content adaptation**, Y. Lu, D. S. Ebert, E. J. Delp III, Purdue Univ. [6065-21]
 11:10 am: **Algebraic methods for structure from motion**, M. Boutin, J. Zhang, D. G. Aliaga, Purdue Univ. [6065-22]
 11:30 am: **A maximum entropy kernel density estimator with applications to function interpolation and texture segmentation**, N. Balakrishnan, D. Schonfeld, Univ. of Illinois at Chicago [6065-23]
 11:50 am: **Multiple watermarking: a vector space projection approach**, O. Altun, G. Sharma, M. Bocko, Univ. of Rochester [6065-24]
 Lunch/Exhibition Break 12:10 to 1:40 pm

SESSION 8

Conv. Ctr. Room A4 **Tues. 1:40 to 3:00 pm**

Biomedical Imaging

Chair: Miles N. Wernick, Illinois Institute of Technology

1:40 pm: **Spherical harmonics for shape-based inverse problems, as applied to electrical impedance tomography**, S. Babaeizadeh, D. H. Brooks, Northeastern Univ. [6065-25]
 2:00 pm: **3D nonlinear multigrid algorithm for direct reconstruction of chromophore concentrations in diffuse optical tomography**, J. C. Ye, Korea Advanced Institute of Science and Technology (South Korea) [6065-26]
 2:20 pm: **Adaptation of fast marching methods to subcellular modeling**, A. Chikando, J. M. Kinser, George Mason Univ. [6065-27]
 2:40 pm: **Machine learning of human responses to images**, M. N. Wernick, Y. Yang, J. G. Brankov, L. Wei, Illinois Institute of Technology; I. M. El-Naqa, Washington Univ. in St. Louis; N. P. Galatsanos, Univ. of Ioannina (Greece) [6065-28]
 Coffee Break 3:00 to 3:30 pm

Conv. Ctr. Room A4 **Tues. 3:30 to 5:50 pm**

Tomography

Chair: Joseph A. O'Sullivan, Washington Univ. in St. Louis

3:30 pm: **Image reconstruction algorithms for a novel PET system with a half-ring insert**, D. Pal, J. A. O'Sullivan, H. Wu, M. Janecek, Y. C. Tai, Washington Univ. in St. Louis [6065-29]
 3:50 pm: **Improved sampling of parallel projection in cylindrical PET scanners**, B. Farsaii, SUNY/Univ. at Buffalo [6065-30]
 4:10 pm: **A Bayesian approach to tomography of multiply scattered beams**, Z. H. Levine, National Institute of Standards and Technology [6065-31]
 4:30 pm: **Progress in multiple-image radiography**, M. N. Wernick, J. G. Brankov, Y. Yang, G. Khelashvili, Illinois Institute of Technology; D. Chapman, Univ. of Saskatchewan (Canada); I. Mondal, B. Marquet, Illinois Institute of Technology; Z. Zhong, Brookhaven National Lab. ... [6065-32]
 4:50 pm: **A recursive filter for noise reduction in tomographic imaging**, J. Thibault, GE Medical Systems; C. A. Bouman, Purdue Univ.; J. Hsieh, GE Medical Systems; K. D. Sauer, Univ. of Notre Dame [6065-33]
 5:10 pm: **A branch-less distance driven projection and backprojection algorithm**, S. Basu, General Electric Co.; B. De Man, GE Global Research [6065-34]
 5:30 pm: **Cupping artifacts analysis and correction for a FPD-based cone-beam CT**, L. Zhang, H. Gao, Z. Chen, S. Li, Y. Xing, Tsinghua Univ. (China) [6065-35]

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

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Posters **5:30 to 7:00 pm**

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- ✓ **A block-iterative deterministic annealing algorithm for Bayesian tomographic reconstruction**, S. Lee, Paichai Univ. (South Korea) [6065-44]
- ✓ **Deinterlacing in spatial and temporal domain**, I. Kim, C. Lee, Yonsei Univ. (South Korea) [6065-46]
- ✓ **Cosine transform generalized to lie groups SU(2)xSU(2), O(5) and SU(2)xSU(2)xSU(2): application to digital image processing**, M. Germain, J. Patera, Univ. de Montréal (Canada) [6065-47]
- ✓ **A prioritized and adaptive approach to volumetric seeded region growing using texture descriptors**, N. J. Backman, Whitworth College; B. W. Whitney, Northern Kentucky Univ.; J. D. Furst, D. S. Raicu, DePaul Univ. [6065-48]
- ✓ **A fast MAP-based superresolution algorithm for general motion**, M. Tanaka, M. Okutomi, Tokyo Institute of Technology (Japan) ... [6065-49]
- ✓ **Image deblurring by the combined use of a superresolution technique and inverse filtering**, Y. Yamada, K. Nakamae, Osaka Univ. (Japan); H. Fujioka, Fukui Univ. of Technology (Japan) [6065-50]

Wednesday 18 January

Plenary Speaker Wed. 8:30 to 9:15 am

Marriott Ballroom 1-6

Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging

Richard Leahy, Univ. of Southern California

See p. 7 for details.

SESSION 10

Conv. Ctr. Room A4 Wed. 9:30 to 10:30 am

Color

Chair: Stanley J. Reeves, Auburn Univ.

9:30 am: **Estimation of color filter array data from JPEG images for improved demosaicing**, W. Feng, S. J. Reeves, Auburn Univ. . . [6065-36]

9:50 am: **Separation of irradiance and reflectance from observed color images by logarithmical nonlinear diffusion process**, T. Saito, H. Takahashi, T. Komatsu, Kanagawa Univ. (Japan) [6065-37]

10:10 am: **Novel scanner characterization method for color measurement and diagnostics applications**, B. Lee, Thomson Corporate Research; R. Bala, Xerox Corp.; G. Sharma, Univ. of Rochester . [6065-38]

Coffee Break 10:30 to 11:00 am

SESSION 11

Conv. Ctr. Room A4 Wed. 11:00 am to 12:20 pm

Image Modeling and Analysis

Chair: Zygmunt Pizlo, Purdue Univ.

11:00 am: **Elastic surface registration by parameterization optimization in spectral space**, F. G. Vadakkumpadan, Y. Tong, Y. Sun, Purdue Univ. [6065-39]

11:20 am: **Mosaicking of astronomical images with MOPEX**, D. Makovoz, I. Khan, F. J. Masci, California Institute of Technology . [6065-40]

11:40 am: **Image processing using parallel GPU units**, K. A. Bjorke, NVIDIA Corp. [6065-41]

12:00 pm: **Partial shape similarity of contours is needed for object recognition**, Z. Pizlo, Purdue Univ.; L. J. Latecki, Temple Univ. . [6065-42]

Vision Geometry XIV

Conference Chairs: **Longin Jan Latecki**, Temple Univ.; **David M. Mount**, Univ. of Maryland/College Park; **Angela Y. Wu**, American Univ.

Program Committee: **Gady Agam**, Illinois Institute of Technology; **Gilles Bertrand**, Groupe ESIEE (France); **Atsushi Imiya**, Chiba Univ. (Japan); **Jack Koplowitz**, Clarkson Univ.; **Nathan S. Netanyahu**, Bar Ilan Univ. (Israel); **Peter Veelaert**, Hogeschool Gent (Belgium); **Xiaodong Wu**, Univ. of Iowa

Tuesday 17 January

Plenary Speaker **Tues. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 1

Conv. Ctr. Room C4 **Tues. 9:30 am to 12:00 pm**

Shape and Object Recognition I

Chair: Longin Jan Latecki, Temple Univ.

9:30 am: **A deformable model with topology analysis and adaptive clustering for boundary detection**, M. Allili, Bishop's Univ. (Canada); B. Yang, Univ. de Sherbrooke (Canada); L. Bentabet, Bishop's Univ. (Canada) [6066-01]

9:55 am: **Refining road map using active shape model from aerial images**, G. Koutaki, K. Uchimura, Z. Hu, Kumamoto Univ. (Japan) [6066-02]

Coffee Break 10:20 to 10:45 am

10:45 am: **Quantification of line-mura defect level based on multiple characterizing features**, N. K. Park, K. N. Choi, S. I. Yoo, Seoul National Univ. (South Korea) [6066-03]

11:10 am: **Model-based shape classification using shape-transformation-invariant descriptors**, S. C. Lee, Univ. of Oklahoma; Y. Wang, E. T. Lee, Univ. of Oklahoma Health Sciences Ctr. [6066-04]

11:35 am: **Refinement of axial shape description**, A. N. Skourikhine, Los Alamos National Lab. [6066-05]

Lunch/Exhibition Break 12:00 to 1:20 pm

SESSION 2

Conv. Ctr. Room C4 **Tues. 1:20 to 2:00 pm**

Shape and Object Recognition II

Chair: Longin Jan Latecki, Temple Univ.

1:20 pm: **Geometry of human vision (Invited Paper, Presentation Only)**, Z. Pizlo, Purdue Univ. [6066-06]

SESSION 3

Conv. Ctr. Room C4 **Tues. 2:00 to 3:15 pm**

3D Geometry

Chair: Kun Lee, Handong Global Univ. (South Korea)

2:00 pm: **Fitting polygonal regions for matching 3D polyhedra**, L. Mukherjee, V. Singh, J. Xu, R. Berezney, SUNY/Univ. at Buffalo .. [6066-07]

2:25 pm: **Hierarchical two view line segment matching using wavelet transform**, F. Mai, Y. Hung, W. Sze, The Univ. of Hong Kong (Hong Kong China) [6066-09]

2:50 pm: **A vision-based approach to extracting the tilt angle and altitude of a PTZ camera**, I. Chen, S. Wang, National Chiao Tung Univ. (Taiwan) [6066-10]

Coffee Break 3:15 to 3:45 pm

SESSION 4

Conv. Ctr. Room C4 **Tues. 3:45 to 4:35 pm**

Aspects of Vision Geometry

Chair: David M. Mount, Univ. of Maryland/College Park

3:45 pm: **Perspex machine V: compilation of C programs**, M. P. Spanner, J. A. D. W. Anderson, The Univ. of Reading (United Kingdom) [6066-12]

4:10 pm: **Automatic and robust classification of independent motions in video sequences**, X. An, Zhejiang Univ. (China) [6066-13]

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

✓ **A three-dimensional shape measurement method: structure light space-time stereo**, X. Li, Shanghai Univ. (China) [6066-28]

✓ **Multiview image calibration and rectification for and effective 3D display**, K. Bae, 3R Inc. (South Korea); H. Kang, E. Kim, Kwangwoon Univ. (South Korea) [6066-29]

✓ **Perspex machine VI: a graphical user interface to the Perspex machine**, C. J. Kershaw, J. A. D. W. Anderson, The Univ. of Reading (United Kingdom) [6066-30]

✓ **Perspex machine VII: the universal Perspex machine**, J. A. D. W. Anderson, The Univ. of Reading (United Kingdom) [6066-31]

Wednesday 18 January

SESSION 7

<p>Plenary Speaker Wed. 8:30 to 9:15 am</p> <p><i>Marriott Ballroom 1-6</i></p> <p>Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging</p> <p>Richard Leahy, Univ. of Southern California</p> <p><i>See p. 7 for details.</i></p>
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Conv. Ctr. Room C4 **Wed. 3:50 to 5:30 pm**

Surface Reconstruction and Visualization

Chair: Samuel C. Lee, Univ. of Oklahoma

3:50 pm: **Reconstruction of quadratic curves in 3D using two or more perspective views: simulation studies**, S. Kumar, N. Sukavanam, R. Balasubramanian, Indian Institute of Technology Roorkee (India) [6066-24]

4:15 pm: **Visualization of volumetric scattered data by using weighted alpha shapes**, J. Paik, K. Lee, Handong Global Univ. (South Korea); O. Gwun, Chonbuk National Univ. (South Korea) [6066-25]

4:40 pm: **POSS: efficient nonlinear optimization for parameterization methods**, F. G. Vadakkumpadan, Y. Tong, Y. Sun, Purdue Univ. . [6066-26]

5:05 pm: **Piecewise compression of large mesh**, A. Qin, Zhejiang Univ. (China) and Shanxi Univ. (China); J. Shi, Z. Liu, M. Huang, Zhejiang Univ. (China) [6066-27]

SESSION 5

Conv. Ctr. Room C4 **Wed. 9:30 to 11:35 am**

Digital Geometry and Topology

Chair: Peter F. Stiller, Texas A&M Univ.

9:30 am: **Discrete circles: an arithmetical approach with non-constant thickness**, C. Fiorio, D. Jamet, J. Toutant, Univ. Montpellier II (France) [6066-14]

9:55 am: **Estimating the analog perimeter of a pre-digitized shape**, S. C. Lee, Univ. of Oklahoma; Y. Wang, E. T. Lee, Univ. of Oklahoma Health Sciences Ctr. [6066-15]

Coffee Break 10:20 to 10:45 am

10:45 am: **Three-dimensional fast exact Euclidean distance (3D-FEED) maps**, T. E. Schouten, H. C. Kuppens, Radboud Univ. Nijmegen (Netherlands); E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands) [6066-17]

11:10 am: **Estimating the surface area and volume of a general 3D shape**, S. C. Lee, Univ. of Oklahoma; Y. Wang, E. T. Lee, Univ. of Oklahoma Health Sciences Ctr. [6066-18]

Lunch/Exhibition Break 11:35 am to 1:20 pm

SESSION 6

Conv. Ctr. Room C4 **Wed. 1:20 to 3:25 pm**

Image Matching and Registration

Chair: James G. Anderson, The Univ. of Reading (United Kingdom)

1:20 pm: **Dynamic RANSAC**, W. Sze, A. W. Tang, Y. Hung, The Univ. of Hong Kong (Hong Kong China) [6066-19]

1:45 pm: **Singular value decomposition based scale invariant image matching**, W. Sze, A. W. Tang, Y. Hung, The Univ. of Hong Kong (Hong Kong China) [6066-20]

2:10 pm: **Image matching using algebraic topology**, S. Dardar, Univ. de Sherbrooke (Canada); A. Madjid, Bishop's Univ. (Canada); D. Ziou, Univ. de Sherbrooke (Canada) [6066-21]

2:35 pm: **Robustness and statistical analysis of object/image metrics**, P. F. Stiller, Texas A&M Univ. [6066-22]

3:00 pm: **GSIFT: Geometric Scale Invariant Feature Transform for Terrain Data**, Y. Xiao, S. K. Lodha, Univ. of California/Santa Cruz [6066-23]

Coffee Break 3:25 to 3:50 pm

Document Recognition and Retrieval XIII

Conference Chairs: **Kazem Taghva**, Univ. of Nevada/Las Vegas; **Xiaofan Lin**, Hewlett-Packard Labs.

Program Committee: **Tim L. Andersen**, Boise State Univ.; **Apostolos Antonacopoulos**, Univ. of Salford (United Kingdom); **Elisa H. Barney Smith**, Boise State Univ.; **Brian D. Davison**, Lehigh Univ.; **Xiaoqing Ding**, Tsinghua Univ. (China); **David S. Doermann**, Univ. of Maryland/College Park; **Jianying Hu**, IBM Thomas J. Watson Research Ctr.; **Matthew F. Hurst**, Intelliseek, Inc.; **Hisashi Ikeda**, Hitachi, Ltd. (Japan); **Tapas Kanungo**, IBM Almaden Research Ctr.; **Daniel P. Lopresti**, Lehigh Univ.; **Thomas A. Nartker**, Univ. of Nevada/Las Vegas; **Sargur N. Srihari**, SUNY/Univ. at Buffalo; **George R. Thoma**, National Library of Medicine; **Berrin A. Yanikoglu**, Sabanci Univ. (Turkey)

Wednesday 18 January

SESSION 4

Plenary Speaker Wed. 8:30 to 9:15 am
Marriott Ballroom 1-6
Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging
Richard Leahy, Univ. of Southern California
See p. 7 for details.

Conv. Ctr. Room C3 Wed. 3:30 to 5:10 pm

Image Processing

- 3:30 pm: **DOCLIB: a software library for document processing**, S. R. Jaeger, G. Zhu, D. S. Doermann, Univ. of Maryland/College Park [6067-09]
3:50 pm: **Address block features for image-based automated mail orientation**, M. S. Khan, SRI International and Univ. of California; H. B. Aradhye, SRI International [6067-10]
4:10 pm: **A robust stamp detection framework on degraded documents**, G. Zhu, S. R. Jaeger, D. S. Doermann, Univ. of Maryland/College Park [6067-11]
4:30 pm: **Adaptive pre-OCR cleanup of grayscale document images**, I. Zavorin, E. Borovikov, M. I. Turner, CACI International Inc.; L. Hernandez, Army Research Lab. [6067-12]
4:50 pm: **JBIG2 text image compression based on OCR**, J. Shang, C. Liu, X. Ding, Tsinghua Univ. (China) [6067-13]

SESSION 1

Conv. Ctr. Room C3 Wed. 9:30 to 10:30 am

Handwriting Recognition

- 9:30 am: **Combining one- and two-dimensional signal recognition approaches to off-line signature verification**, S. N. Srihari, SUNY/Univ. at Buffalo [6067-01]
9:50 am: **Spotting words in handwritten Arabic documents**, S. N. Srihari, H. Srinivasan, P. Babu, C. Bhole, SUNY/Univ. at Buffalo [6067-02]
10:10 am: **HCCR by contour-based elastic mesh fuzzy feature**, L. Sun, YanTai Univ. (China) [6067-03]
Coffee Break 10:30 to 11:00 am

SESSION 2

Conv. Ctr. Room C3 Wed. 11:00 to 11:40 am

Invited Paper I

- 11:00 am: **Human language technology research at DARPA (Invited Paper, Presentation Only)**, J. Olive, Defense Advanced Research Projects Agency [6067-04]
Lunch/Exhibition Break 11:40 am to 1:40 pm

SESSION 3

Conv. Ctr. Room C3 Wed. 1:40 to 3:00 pm

Optical Character Recognition

- 1:40 pm: **Partitioning of the degradation space for OCR training**, E. H. Barney Smith, T. L. Andersen, Boise State Univ. [6067-05]
2:00 pm: **Match graph generation for symbolic indirect correlation**, D. P. Lopresti, Lehigh Univ.; G. Nagy, A. Joshi, Rensselaer Polytechnic Institute [6067-06]
2:20 pm: **Toward quantifying the amount of style in a dataset**, X. Zhang, S. Andra, Rensselaer Polytechnic Institute [6067-07]
2:40 pm: **Robust feature extraction for character recognition based on binary image**, L. Wang, L. Zhang, Y. Xing, Z. Wang, Nuctech Co. Ltd. (China); H. Gao, Tsinghua Univ. (China) [6067-08]
Coffee Break 3:00 to 3:30 pm

Thursday 19 January

SESSION 5

Conv. Ctr. Room C3 Thurs. 8:40 to 10:20 am

Emerging Applications

- 8:40 am: **Active document versioning: from layout understanding to adjustment**, X. Lin, H. Chao, G. Nelson, E. Durante, Hewlett-Packard Co. [6067-14]
9:00 am: **Graphic design principles for automated document segmentation and understanding**, F. Vega, H. J. Santos-Villalobos, Univ. de Puerto Rico Mayagüez [6067-15]
9:20 am: **A new document authentication method by embedding deformation characters**, X. Wang, X. Ding, H. Liu, C. Liu, Tsinghua Univ. (China) [6067-16]
9:40 am: **CAPTCHA challenge strings: problems and improvements**, J. L. Bentley, C. L. Mallows, Avaya Inc. [6067-17]
10:00 am: **An automatically updateable web publishing solution: taking document sharing and conversion to enterprise level**, F. Rahman, BCL Technologies Inc. [6067-18]
Coffee Break 10:20 to 10:50 am

SESSION 6

Conv. Ctr. Room C3 Thurs. 10:50 to 11:50 am

Document Retrieval

10:50 am: **Automatic redaction of private information using relational information extraction**, K. Taghva, R. Beckley, J. S. Coombs, J. Borsack, R. Pereda, T. A. Nartker, Univ. of Nevada/Las Vegas [6067-19]

11:10 am: **Document clustering: applications in a collaborative digital library**, F. Rahman, BCL Technologies Inc. [6067-20]

11:30 am: **Author name recognition in degraded journal images**, A. de Bodard de la Jacopiere, L. Likforman, École Nationale Supérieure des Télécommunications (France) [6067-21]

Lunch Break 11:50 am to 1:40 pm

SESSION 7

Conv. Ctr. Room C3 Thurs. 1:40 to 2:20 pm

Invited Paper II

1:40 pm: **Complex document information processing: prototype, test collection, and evaluation (Invited Paper)**, G. Agam, Illinois Institute of Technology; S. Argamon, Illinois Institute of Technology; O. Frieder, D. Grossman, D. Lewis, Illinois Institute of Technology [6067-23]

SESSION 8

Conv. Ctr. Room C3 Thurs. 2:20 to 3:40 pm

Learning and Classification

2:20 pm: **Comparative evaluation of different classifiers for robust distorted character recognition**, B. As-Sadhan, Z. Al Bawab, A. El Seed, M. Noamany, Carnegie Mellon Univ. [6067-24]

2:40 pm: **Style consistent nearest neighbor classifier**, S. Andra, X. Zhang, Rensselaer Polytechnic Institute [6067-25]

3:00 pm: **Optimally combining a cascade of classifiers**, K. H. Chellapilla, M. M. Shilman, P. Simard, Microsoft Corp. [6067-26]

3:20 pm: **Versatile document image content extraction**, H. S. Baird, M. A. Moll, Lehigh Univ. [6067-27]

Sensors, Cameras, and Systems for Scientific/Industrial Applications VIII

Conference Chair: **Morley M. Blouke**, Ball Aerospace & Technologies Corp.

Program Committee: **Erik Bodegom**, Portland State Univ. and Technische Univ. Delft (Netherlands); **Robin M. Dawson**, Sarnoff Corp.; **Terrence S. Lomheim**, The Aerospace Corp.; **Gloria G. Putnam**, Eastman Kodak Co.; **Alice L. Reinheimer**, e2v Technologies, Inc.; **Nobukazu Teranishi**, Matsushita Electric Industrial Co., Ltd. (Japan); **Orly Yadid-Pecht**, Univ. of Calgary (Canada)

Tuesday 17 January

Plenary Speaker **Tues. 8:30 to 9:15 am**
Marriott Ballroom 1-6
Image Processing: Interconnections
Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign
See p. 7 for details.

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

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Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

✓ **An improved method for calculating the MTF of an optical system**, A. Walter, S. Lashansky, Israel Air Force (Israel) [6068-30]

Wednesday 18 January

Plenary Speaker **Wed. 8:30 to 9:15 am**
Marriott Ballroom 1-6
Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging
Richard Leahy, Univ. of Southern California
See p. 7 for details.

SESSION 1

Conv. Ctr. Room A6 **Wed. 9:30 to 11:40 am**

CMOS Devices

9:30 am: **In vitro and in vivo on-chip biofluorescence imaging using a CMOS image sensor**, D. C. Ng, M. Matsuo, T. Tokuda, K. Kagawa, M. Nunoshita, J. Ohta, Nara Institute of Science and Technology (Japan) [6068-01]

9:50 am: **An optical and potential dual-image CMOS sensor for bioscientific applications**, T. Tokuda, A. Yamamoto, K. Kagawa, M. Nunoshita, J. Ohta, Nara Institute of Science and Technology (Japan) [6068-02]

Coffee Break 10:10 to 10:40 am

10:40 am: **A CMOS active pixel sensor for retinal stimulation**, M. L. Prydderch, M. J. French, Rutherford Appleton Lab. (United Kingdom); K. Mathieson, C. Adams, D. Gunning, J. Laudanski, J. D. Morrison, A. R. Moodie, J. Sinclair, Univ. of Glasgow (United Kingdom) [6068-03]

11:00 am: **Noise analysis of fault tolerant active pixel sensors with and without defects**, M. L. La Haye, C. G. Jung, M. H. Izadi, G. H. Chapman, K. S. Karim, Simon Fraser Univ. (Canada) [6068-04]

11:20 am: **A model for dark current characterization and simulation**, R. L. Baer, Agilent Technologies [6068-05]

Lunch/Exhibition Break 11:40 am to 1:30 pm

SESSION 2

Conv. Ctr. Room A6 **Wed. 1:30 to 4:20 pm**

CMOS Devices and Applications

1:30 pm: **An image sensor with on-die diffractive optics in 0.18-micron bulk CMOS**, C. J. Thomas, R. I. Hornsey, York Univ. (Canada) .. [6068-06]

1:50 pm: **CMOS long linear array for space application**, G. Lepage, Cypress Semiconductor Corp. (Belgium); D. G. Dantes, Alcatel Alenia Space (France) [6068-08]

2:10 pm: **Experimental single-chip color HDTV image acquisition system with 8-Mpixel CMOS image sensor**, H. Shimamoto, T. Yamashita, R. Funatsu, K. Mitani, Y. Nojiri, NHK Science & Technical Research Labs. (Japan) [6068-09]

2:30 pm: **High-sensitivity 2.5- μ m pixel CMOS image sensor realized using Cu interconnect layers**, K. Tatani, Y. Enomoto, A. Yamamoto, T. Goto, H. Abe, T. Hirayama, Sony Corp. (Japan) .. [6068-11]

2:50 pm: **CMOS image sensor overlaid with organic photoelectric conversion layers and the proposal of stack type solid-state imaging devices**, S. Takada, M. Inuiya, Y. Araki, Fuji Photo Film Co., Ltd. (Japan) [6068-12]

Coffee Break 3:10 to 3:40 pm

3:40 pm: **An ultrawide dynamic-range CMOS image sensor with a linear response**, J. H. Park, M. Mase, S. Kawahito, Shizuoka Univ. (Japan); M. Sasaki, Sendai National College of Technology (Japan); Y. Wakamori, Yamaha Corp. (Japan); Y. Ohta, Hamamatsu Corp. (Japan) [6068-13]

4:00 pm: **A pulse-frequency-modulation vision chip using a capacitive feedback reset with in-pixel 1-bit image processors**, K. Kagawa, S. Yamamoto, T. Furumiya, T. Tokuda, M. Nunoshita, J. Ohta, Nara Institute of Science and Technology (Japan) [6068-14]

Thursday 19 January

SESSION 3

Conv. Ctr. Room A6 Thurs. 9:00 to 11:50 am

Novel Devices and CCDs

9:00 am: **Photon counting imaging: the DigitalAPD**, S. Bellis, R. Wilcock, J. C. Jackson, SensL Technologies Ltd. (Ireland) [6068-15]

9:20 am: **Quantitative and qualitative performance comparison of a biomimetic vision sensor with commercial CCD camera sensors**, R. S. Prabhakara, C. H. G. Wright, S. F. Barrett, W. M. Harman, Univ. of Wyoming [6068-16]

9:40 am: **Quantum efficiency characterization of CCD's part 1: the quantum efficiency machine**, D. E. Groom, C. J. Bebek, M. H. Fabricius, A. Karcher, J. Steckert, Lawrence Berkeley National Lab. [6068-35]

10:00 am: **Quantum efficiency characterization of back-illuminated CCD's part 2: reflectivity measurements**, M. H. Fabricius, Lawrence Berkeley National Lab. [6068-36]

Coffee Break 10:20 to 10:50 am

10:50 am: **28-M CCD imager with RGB compatible binning feature for professional applications**, I. Peters, C. Draijer, F. Polderdijk, L. Meessen, B. G. M. Dillen, W. Klaassens, J. T. Bosiers, DALSA Professional Imaging (Netherlands) [6068-34]

11:10 am: **Large area devices at Semiconductor Technology Associates, Inc.**, K. L. Boggs, R. A. Bredthauer, Semiconductor Technology Associates Inc. [6068-17]

11:30 am: **Development of the orthogonal-transfer array**, B. E. Burke, MIT Lincoln Lab.; J. L. Tonry, Univ. of Hawai'i/West O'ahu; M. J. Cooper, MIT Lincoln Lab.; P. M. Onaka, Univ. of Hawai'i/West O'ahu; D. J. Young, A. H. Loomis, MIT Lincoln Lab. [6068-18]

Lunch Break 11:50 am to 1:30 pm

SESSION 4

Conv. Ctr. Room A6 Thurs. 1:30 to 4:40 pm

Applications

1:30 pm: **Toward 1-mm depth precision with a solid state full-field range imaging system**, A. A. Dorrington, Univ. of Waikato (New Zealand); D. A. Carnegie, Victoria Univ. of Wellington (New Zealand); M. J. Cree, Univ. of Waikato (New Zealand) [6068-22]

1:50 pm: **An ultrafast phase modulator for 3D imaging**, J. Y. Cheng, Northeastern Univ.; Q. Chen, Boston Applied Technologies Inc. . [6068-23]

2:10 pm: **Classification of luminaire color using CCDs with application to airport lighting**, K. R. McMenemy, J. H. Niblock, Queen's Univ. Belfast (United Kingdom) [6068-24]

2:30 pm: **Lateral chromatic aberration correction system for ultrahigh-definition color video camera**, T. Yamashita, H. Shimamoto, R. Funatsu, K. Mitani, Y. Nojiri, NHK Science & Technical Research Labs. (Japan) [6068-25]

2:50 pm: **A new direct detection camera system for electron microscopy**, N. Xuong, L. Jin, A. Milazzo, P. C. Leblanc, F. Duttweiler, J. C. Bouwer, S. Peltier, M. H. Ellisman, Univ. of California/San Diego; S. Li, S. Kleinfelder, Univ. of California/Irvine [6068-26]

Coffee Break 3:10 to 3:40 pm

3:40 pm: **A novel image processing system that autonomously monitors lighting patterns with application to airport lighting**, J. H. Niblock, K. R. McMenemy, G. Irwin, Queen's Univ. Belfast (United Kingdom) [6068-27]

4:00 pm: **Wafer-scale UV embossing of aspheric lenses in phone-camera module**, D. Shin, H. Jeong, S. Kim, S. C. Lee, Y. Jin, J. E. Noh, H. R. Oh, K. Lee, SAMSUNG Electro-Mechanics Co., Ltd. (South Korea) [6068-28]

4:20 pm: **Colony optical image acquisition system**, W. Wang, Chongqing Univ. of Posts and Telecommunications (China) [6068-29]

Digital Photography II

Conference Chairs: **Nitin Sampat**, Rochester Institute of Technology; **Jeffrey M. DiCarlo**, Hewlett-Packard Labs.; **Russel A. Martin**, Foveon USA

Program Committee: **Eiji Atsumi**, Nokia Japan Co., Ltd. (Japan); **Ted J. Cooper**, Sony Electronics Inc.; **Michael A. Kriss**, Sharp Labs. of America; **Jingqiang Li**, Qualcomm, Inc.; **Ricardo J. Motta**, PIXIM, Inc.; **Gloria G. Putnam**, Eastman Kodak Co.; **John R. Reinert Nash**, Lifetouch, Inc.; **Brian G. Rodricks**, Micron Technology, Inc.; **Sabine E. Süssstrunk**, École Polytechnique Fédérale de Lausanne (Switzerland)

Monday 16 January

SESSION 1

Conv. Ctr. Room A6 Mon. 8:30 to 10:20 am

Sensor Design

Chair: **Russel A. Martin**, Foveon, Inc.

8:30 am: **A brief history of 'pixel' (Invited Paper)**, R. F. Lyon, Foveon, Inc. [6069-01]

9:00 am: **31 Mp and 39 Mp full-frame CCD image sensors with improved charge capacity and angle response**, E. J. Meisenzahl, E. K. Banghart, D. N. Nichols, J. P. Shepherd, E. G. Stevens, K. Y. Wong, Eastman Kodak Co. [6069-02]

9:20 am: **Improving low-light CMOS performance with four-transistor four-shared pixel architecture and charge-domain binning**, F. Chu, R. M. Guidash, J. Compton, S. Coppola, W. Hintz, Eastman Kodak Co. [6069-03]

9:40 am: **Optical interaction of space and wavelength in high-resolution digital imagers**, B. G. Rodricks, K. Venkataraman, Micron Technology, Inc.; P. B. Catrysse, B. A. Wandell, Stanford Univ. . . [6069-04]

10:00 am: **Image recovery for a direct color imaging approach using a color filter array**, T. Saito, T. Komatsu, Kanagawa Univ. (Japan) [6069-05]

Coffee Break 10:20 to 10:50 am

SESSION 2

Conv. Ctr. Room A6 Mon. 10:50 am to 12:10 pm

Demosaicing

Chair: **Michael A. Kriss**, Consultant

10:50 am: **Demosaicing: heterogeneity projection hard-decision adaptive interpolation using spectral-spatial correlation**, C. Tsai, K. Song, National Chiao Tung Univ. (Taiwan) [6069-06]

11:10 am: **Iterative asymmetric average interpolation for color demosaicing of single-sensor digital camera data**, Y. Takahashi, H. Kikuchi, S. Muramatsu, Niigata Univ. (Japan); N. Mizutani, Kodak Japan Ltd. (Japan) [6069-07]

11:30 am: **Spatially adaptive superresolution sharpening-demosaicing for a single solid state color image sensor**, T. Saito, T. Komatsu, Kanagawa Univ. (Japan) [6069-08]

11:50 am: **Generic MSFA mosaicing and demosaicing for multispectral cameras**, L. Miao, H. Qi, The Univ. of Tennessee; R. Ramanath, North Carolina State Univ. [6069-09]

Lunch Break 12:10 to 1:40 pm

SESSION 3

Conv. Ctr. Room A6 Mon. 1:40 to 3:00 pm

Auto Exposure, Focus, and White Balance

Chair: **Jeffrey M. DiCarlo**, Hewlett-Packard Labs.

1:40 pm: **Dynamic focus window selection using a statistical color model**, Y. Tian, Univ. of California/Berkeley [6069-10]

2:00 pm: **Combinational AE-AF system with fuzzy climbing search servo**, C. Chen, C. Tseng, C. Hung, I. Yin, S. Wang, National Chiao Tung Univ. (Taiwan) [6069-11]

2:20 pm: **Multidomain pixel analysis for illuminant estimation**, F. Gasparini, R. Schettini, Univ. degli Studi di Milano-Bicocca (Italy); F. Naccari, A. Bruna, STMicroelectronics (Italy) [6069-12]

2:40 pm: **Computational inexpensive two-step auto white balance method**, S. R. Goma, M. Aleksic, ATI Technology (Canada) [6069-13]

Coffee Break 3:00 to 3:30 pm

SESSION 4

Conv. Ctr. Room A6 Mon. 3:30 to 4:50 pm

Image Enhancement

Chair: **Brian G. Rodricks**, Micron Technology, Inc.

3:30 pm: **An effective image enhancement filtering for noisy image sequences**, H. Lee, D. Park, S. Lee, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea) [6069-14]

3:50 pm: **Novel bilateral filter approach: image noise reduction with sharpening**, M. Aleksic, M. Smirnov, S. R. Goma, ATI Technology (Canada) [6069-15]

4:10 pm: **Digital photograph stitching with optimized matching of gradient and curvature**, S. T. Suen, E. Y. Lam, K. K. Wong, The Univ. of Hong Kong (Hong Kong China) [6069-16]

4:30 pm: **Compensation of nonuniform flash illumination in group portrait photography**, J. H. Kim, Pukyong National Univ. (South Korea); B. A. Barsky, Univ. of California/Berkeley [6069-17]

SESSION 5

Conv. Ctr. Room A6 Mon. 4:50 to 5:30 pm

Imaging Systems

Chair: **John R. Reinert Nash**, Lifetouch, Inc.

4:50 pm: **A robotic system for digital photography**, L. W. MacDonald, London College of Communication [6069-18]

5:10 pm: **Source camera identification using footprints from JPEG compression and lens aberration**, K. S. Choi, E. Y. Lam, K. K. Wong, The Univ. of Hong Kong (Hong Kong China) [6069-19]

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 6

Conv. Ctr. Room A6 Tues. 9:30 to 10:20 am

Camera Evaluation I

Chair: Nitin Sampat, Rochester Institute of Technology

9:30 am: **Evaluating digital cameras (*Invited Paper*)**, D. Wueller, Image Engineering (Germany) [6069-20]

10:00 am: **The Imatest program: comparing cameras with different amounts of sharpening**, N. L. Koren, Imatest LLC [6069-21]

Coffee Break 10:20 to 10:50 am

SESSION 7

Conv. Ctr. Room A6 Tues. 10:50 am to 12:10 pm

Camera Evaluation II

Chair: Jingqiang Li, Rochester Institute of Technology

10:50 am: **Resolution for color photography**, P. M. Hubel, Foveon, Inc. [6069-22]

11:10 am: **Resolution and light sensitivity tradeoff with pixel size**, J. E. Farrell, Stanford Univ.; F. Xiao, Agilent Technologies; S. Kavusi, Stanford Univ. [6069-23]

11:30 am: **Characterization of noise in digital photographs for image processing**, S. Lim, Hewlett-Packard Co. [6069-24]

11:50 am: **Proposal for a standard procedure to test mobile phone cameras**, D. Wueller, Image Engineering (Germany) [6069-25]

Demonstration Session

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Machine Vision Applications in Industrial Inspection XIV

Conference Chairs: **Fabrice Meriaudeau**, Univ. de Bourgogne (France); **Kurt S. Niel**, Fachhochschule Wels (Austria)

Program Committee: **Pierrick T. Bourgeat**, BioMedIA Lab. (Australia); **Luciano da Fontoura Costa**, Univ. de São Paulo (Brazil); **Marc M. Ellenrieder**, Daimler Chrysler AG (Germany); **Steven P. Floeder**, 3M Co.; **David Fofi**, Univ. de Bourgogne (France); **Ralph M. Ford**, The Pennsylvania State Univ.; **Edmund Y. Lam**, The Univ. of Hong Kong (Hong Kong China); **Katia Lebart**, Heriot-Watt Univ. (United Kingdom); **Dinesh Nair**, National Instruments; **Paul L. O'Leary**, Montan Univ. Leoben (Austria); **Jeffery R. Price**, Oak Ridge National Lab.; **A. Ravishankar Rao**, IBM Thomas J. Watson Research Ctr.; **Joaquim Salvi**, Univ. de Girona (Spain); **Hamed Sari-Sarraf**, Texas Tech Univ.; **Christoph Stiller**, Univ. Karlsruhe (Germany); **Kenneth W. Tobin, Jr.**, Oak Ridge National Lab.; **Yvon Voisin**, Univ. de Bourgogne (France)

Monday 16 January

SESSION 1

Conv. Ctr. Room C3 Mon. 8:40 to 10:00 am

Industrial Applications I

Chair: **Fabrice Meriaudeau**, Univ. de Bourgogne (France)

8:40 am: **Optical servoing for industrial surface machining**, N. Koller, Hotvision Research GmbH (Austria); R. Ofner, P. L. O'Leary, Montan Univ. Leoben (Austria); E. Fauster, Hotvision Research GmbH (Austria) [6070-01]

9:00 am: **Statistical learning with imbalanced training set in a machine vision application: improve the false alarm rate and sensitivity simultaneously**, J. Q. Li, Agilent Technologies, Inc. [6070-02]

9:20 am: **Boundary detection of projected fringes for surface of inhomogeneous reflectance**, J. Cheng, R. C. Chung, The Chinese Univ. of Hong Kong (Hong Kong China); E. Y. Lam, The Univ. of Hong Kong (Hong Kong China); K. S. M. Fung, F. Wang, W. H. Leung, ASM Assembly Automation Ltd. (Hong Kong China) [6070-03]

9:40 am: **Height inspection of wafer bumps without explicit 3D reconstruction**, M. Dong, R. C. Chung, Y. Zhao, The Chinese Univ. of Hong Kong (Hong Kong China); E. Y. Lam, The Univ. of Hong Kong (Hong Kong China) [6070-04]

Coffee Break 10:00 to 10:30 am

SESSION 2

Conv. Ctr. Room C3 Mon. 10:30 am to 12:10 pm

Multispectral Imaging

Chair: **Kurt S. Niel**, Fachhochschule Wels (Austria)

10:30 am: **Fast recognition method for metallic topographies by the "Three-Color Selective Stereo Gradient Method" (Three-Color SSGM)**, M. Hossfeld, Technische Univ. Hamburg-Harburg (Germany); M. Adameck, Hella KGaA Hueck & Co. (Germany); M. Eich, Technische Univ. Hamburg-Harburg (Germany) [6070-05]

10:50 am: **Robustness of texture parameters for color texture analysis**, A. Marin, A. Roman, Univ. de Bourgogne (France); D. R. Connah, J. Y. Hardeberg, Gjøvik Univ. College (Norway); P. Gouton, Univ. de Bourgogne (France) [6070-06]

11:10 am: **Real-time multispectral imaging application for poultry safety inspection**, B. Park, K. C. Lawrence, W. R. Windham, M. P. Snead, U.S. Dept. of Agriculture [6070-07]

11:30 am: **Flushing analysis by machine vision and fuzzy logic at molten steel for the automation process**, C. Pfob, K. S. Niel, Fachhochschule Wels (Austria); R. Rössler, voestalpine Mechatronics GmbH (Austria) [6070-08]

11:50 am: **Color influence in accuracy of 3D scanner based on structured light**, S. Voisin, The Univ. of Tennessee and Univ. de Bourgogne (France); D. L. Page, The Univ. of Tennessee; S. Fofou, F. Truchetet, Univ. de Bourgogne (France); M. A. Abidi, The Univ. of Tennessee [6070-09]

Lunch Break 12:10 to 1:40 pm

SESSION 3

Conv. Ctr. Room C3 Mon. 1:40 to 2:40 pm

3D Applications I

Chair: **Jeffery R. Price**, Oak Ridge National Lab.

1:40 pm: **Novel view synthesis for projective texture mapping on real 3D objects**, T. Molinier, D. Fofi, P. Gorria, Univ. de Bourgogne (France) [6070-10]

2:00 pm: **3D translucent object reconstruction from artificial vision**, F. Truchetet, Univ. de Bourgogne (France) [6070-11]

2:20 pm: **Real-time 3D wood panel surface measurement using laser triangulation and low-cost hardware**, H. Ramoser, L. Cambrini, H. Rötzer, Advanced Computer Vision (Austria) [6070-12]

SESSION 4

Conv. Ctr. Room C3 Mon. 2:40 to 4:50 pm

Industrial Applications II

Chair: **Kurt S. Niel**, Fachhochschule Wels (Austria)

2:40 pm: **Aerial platform attitude measurement by artificial vision**, F. Truchetet, O. Aubreton, P. Gorria, O. Lalignant, Univ. de Bourgogne (France) [6070-14]

3:00 pm: **A new algorithm for real-time multistage image thresholding**, S. H. Lin, R. Giesen, D. Nair, National Instruments [6070-15]

Coffee Break 3:20 to 3:50 pm

3:50 pm: **Simultaneous photometric correction and defect detection in semiconductor manufacturing**, Y. Shen, E. Y. Lam, The Univ. of Hong Kong (Hong Kong China) [6070-16]

4:10 pm: **Automatic mura detection system for liquid crystal display panels**, L. Fang, H. Chen, I. Yin, S. Wang, C. Wen, C. Kuo, National Chiao Tung Univ. (Taiwan) [6070-17]

4:30 pm: **New developments in image-based characterization of coated particle nuclear fuel**, J. R. Price, D. Aykac, J. D. Hunn, A. K. Kercher, R. N. Morris, Oak Ridge National Lab. [6070-18]

Tuesday 17 January

Plenary Speaker **Tues. 8:30 to 9:15 am**
Marriott Ballroom 1-6
Image Processing: Interconnections
Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign
See p. 7 for details.

SESSION 5

Conv. Ctr. Room C3 **Tues. 9:30 to 11:40 am**

Multiresolution and Mathematical Fitting

Chair: Fabrice Meriaudeau, Univ. de Bourgogne (France)

9:30 am: **Real-time detection of elliptic shapes for automated object recognition and object tracking**, C. Teutsch, D. Berndt, E. Trostmann, M. Weber, Fraunhofer-Institut für Fabrikbetrieb und -automatisierung (Germany) [6070-19]

9:50 am: **Discrete circles measurement for industrial inspection**, F. Mairesse, T. M. Sliwa, S. Binczak, Y. Voisin, Univ. de Bourgogne (France) [6070-20]

Coffee Break 10:10 to 10:40 am

10:40 am: **Twin and scratch detection and removal in micrograph images of Inconel 718**, G. Jakob, A. Rinnhofer, Joanneum Research (Austria); H. Bischof, Technische Univ. Graz (Austria); W. Benesova, Joanneum Research (Austria) [6070-21]

11:00 am: **Tracking fluorescent spots in wide-field microscopy images**, L. A. Muresan, B. Heise, E. P. Klement, Johannes Kepler Univ. Linz (Austria) [6070-22]

11:20 am: **Development of method based on Hough transform or Gabor filtering to discriminate crop and weeds in agronomic image**, J. Bossu, C. Gee, J. Guillemin, Etablissement National d'Enseignement Supérieur Agronomique de Dijon (France); F. Truchetet, Univ. de Bourgogne (France) [6070-23]

SESSION 6

Conv. Ctr. Room C3 **Tues. 11:40 am to 12:20 pm**

3D Applications II

Chairs: Fabrice Meriaudeau, Univ. de Bourgogne (France); Kurt S. Niel, Fachhochschule Wels (Austria)

11:40 am: **A refined range image registration technique applied to multistriple laser 3D scanner**, C. Matabosch, J. Salvi, Univ. de Girona (Spain); D. Fofi, F. Meriaudeau, Univ. de Bourgogne (France) ... [6070-24]

12:00 pm: **Surface orientation recovery of specular microsurface via binary pattern projection**, Z. Song, R. C. Chung, J. Cheng, The Chinese Univ. of Hong Kong (Hong Kong China); E. Y. Lam, The Univ. of Hong Kong (Hong Kong China) [6070-25]

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

✓ **Constructing a simple parametric model of shoulder from medical images**, H. Atmani, F. Mérienne, École Nationale Supérieure d'Arts et Métiers (France); D. Fofi, P. Trouilloud, Univ. de Bourgogne (France) [6070-26]

✓ **A study of automatic monitoring and measuring vehicles by using image analysis**, W. Wang, Chongqing Univ. of Posts and Telecommunications (China) [6070-27]

✓ **An active contour algorithm for detecting the circular features in a PCB x-ray image**, Y. Chen, C. Wu, W. Hu, Yuan Ze Univ. (Taiwan) [6070-28]

✓ **Human vision based detection of nonuniform brightness on LCD panels**, J. H. Kim, Pukyong National Univ.; B. A. Barsky, Univ. of California/Berkeley [6070-30]

✓ **Optimized texture classification by using hierarchical complex networks**, T. Chalumeau, Univ. de Bourgogne (France); L. F. da Fontoura Costa, Univ. de São Paulo (Brazil); F. Meriaudeau, O. Laligant, Univ. de Bourgogne (France) [6070-31]

Multimedia Computing and Networking 2006

Conference Chairs: **Surendar Chandra**, Univ. of Notre Dame; **Carsten Griwodz**, Univ. of Oslo (Norway)

Program Committee: **Tarek F. Abdelzaher**, Univ. of Virginia; **Sarita V. Adve**, Univ. of Illinois at Urbana-Champaign; **Scott A. Brandt**, Univ. of California/Santa Cruz; **David H. Du**, Univ. of Minnesota; **Wu-chi Feng**, Portland State Univ.; **Pascal Frossard**, Ecole Polytechnique Fédérale de Lausanne (Switzerland); **Pål Halvorsen**, Simula Research Lab. (Norway); **Baochun Li**, Univ. of Toronto (Canada); **Ian Marsh**, Swedish Computer Science Institute (Sweden); **Andreas U. Mauthe**, Lancaster Univ. (United Kingdom); **Ketan D. Mayer-Patel**, The Univ. of North Carolina at Chapel Hill; **Klara Nahrstedt**, Univ. of Illinois at Urbana-Champaign; **Wei-Tsang Ooi**, National Univ. of Singapore (Singapore); **Ragunathan Rajkumar**, Carnegie Mellon Univ.; **Karsten Schwan**, Georgia Institute of Technology; **Tajana Simunic-Rosing**, Univ. of California/ San Diego; **Ralf Steinmetz**, Technische Univ. Darmstadt (Germany); **Nalini Venkatasubramanian**, Univ. of California/ Irvine; **Lars Wolf**, Technische Univ. Braunschweig (Germany); **Dongyan Xu**, Purdue Univ.; **Wanghong Yuan**, DoCoMo Communications Labs. USA, Inc.; **Roger Zimmermann**, Univ. of Southern California; **Michael Zink**, Univ. of Massachusetts/Amherst

Wednesday 18 January

Plenary Speaker **Wed. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging

Richard Leahy, Univ. of Southern California

See p. 7 for details.

SESSION 1

Conv. Ctr. Room C1 **Wed. 9:30 am to 12:30 pm**

Application-dependent Transfer

9:30 am: **The effects of frame rate and resolution on users playing first person shooter games**, M. Claypool, Worcester Polytechnic Institute; K. Claypool, F. Damaa, Univ. of Massachusetts/Lowell [6071-01]

10:00 am: **Real-time 3D video compression for tele-immersive environments**, Z. Yang, Y. Cui, Z. Anwar, R. Bocchino, N. Kiyancilar, K. Nahrstedt, R. H. Campbell, Univ. of Illinois at Urbana-Champaign; W. J. Yurcik, National Ctr. for Supercomputing Applications [6071-02]

Coffee Break 10:30 to 11:00 am

11:00 am: **An integrated visual approach for music indexing and dynamic playlist composition**, M. Crampes, S. Ranwez, Ecole des Mines d'Alès (France); F. Velickovski, C. Mooney, Univ. of New South Wales (Australia); N. Mille, Netia, Inc. (France) [6071-03]

11:30 am: **Efficient rate-distortion optimized media streaming for tree-reducible packet dependencies**, M. Röder, Univ. of Konstanz (Germany); J. Cardinal, Univ. Libre de Bruxelles (Belgium); R. Hamzaoui, Univ. of Konstanz (Germany) [6071-04]

12:00 pm: **Popular song and lyrics synchronization and its application to music information retrieval**, K. Chen, S. Gao, Y. Zhu, Q. Sun, Institute for Infocomm Research (Singapore) [6071-05]

Lunch/Exhibition Break 12:30 to 2:00 pm

SESSION 2

Conv. Ctr. Room C1 **Wed. 2:00 to 4:30 pm**

Streaming

2:00 pm: **MMS: a multihome-aware media streaming system**, A. Habib, Siemens Technology to Business Ctr.; J. Chuang, Univ. of California/Berkeley [6071-06]

2:30 pm: **Streamline: a scheduling heuristic for streaming applications on the grid**, B. Agarwalla, N. Ahmed, D. Hilley, U. Ramachandran, Georgia Institute of Technology [6071-07]

Coffee Break 3:00 to 3:30 pm

3:30 pm: **A novel unbalanced multiple description coder for robust video transmission over ad hoc wireless networks**, F. Huang, L. Sun, Y. Zhong, Tsinghua Univ. (China) [6071-08]

4:00 pm: **A transform for network calculus and its application to multimedia networking**, K. Pandit, Technische Univ. Darmstadt (Germany); J. Schmitt, C. Kirchner, Univ. Kaiserslautern (Germany); R. Steinmetz, Technische Univ. Darmstadt (Germany) [6071-09]

Panel Discussion **4:30 to 5:30 pm**

Multimedia Sensors: Technological and Societal Challenges

Chair: Roger Zimmermann, Univ. of Southern California

Thursday 19 January

SESSION 3

Conv. Ctr. Room C1 **Thurs. 8:30 to 10:30 am**

Distribution

8:30 am: **A method to deliver multi-object content in a ubiquitous environment**, T. Mori, M. Katsumoto, National Institute of Information and Communications Technology (Japan) [6071-10]

9:00 am: **Correlation-aware multimedia content distribution in overlay networks**, Y. Zhu, B. Li, Univ. of Toronto (Canada) [6071-11]

9:30 am: **QBIX-G: a transcoding multimedia proxy**, P. Schojer, L. Boeszoermenyi, H. Hellwagner, Univ. Klagenfurt (Austria) [6071-12]

10:00 am: **Preventing DoS attacks in peer-to-peer media streaming systems**, W. G. Conner II, K. Nahrstedt, I. Gupta, Univ. of Illinois at Urbana-Champaign [6071-13]

Coffee Break 10:30 to 11:00 am

SESSION 4

Conv. Ctr. Room C1 **Thurs. 11:00 am to 12:00 pm**

Keynote Presentation

Keynote

11:00 am: **Playstation and multimedia (Invited Paper, Presentation Only)**, K. Hofrichter, Sony Computer Entertainment America ... [6071-14]

Lunch Break 12:00 to 1:30 pm

SESSION 5

Conv. Ctr. Room C1 Thurs. 1:30 to 3:00 pm

Short Papers: Multimedia Systems

1:30 pm: **Investigating a stream synchronization middleware for the NEES MAST system**, J. C. Beyer, S. K. Chirravuri, D. H. Du, Univ. of Minnesota[6071-15]

1:45 pm: **A performance model of effective memory management in HYDRA: a large-scale data stream recording system**, K. Fu, R. Zimmermann, Univ. of Southern California[6071-16]

2:00 pm: **Sender-driven bandwidth differentiation for transmitting multimedia flows over TCP**, J. K. H. Lau, J. Y. B. Lee, The Chinese Univ. of Hong Kong (Hong Kong China)[6071-17]

2:15 pm: **FlexSplit: a workload-aware adaptive load balancing strategy for media clusters**, Q. Zhang, College of William & Mary; L. Cherkasova, Hewlett-Packard Labs.; E. Smirni, College of William & Mary ... [6071-18]

2:30 pm: **Cascades: scalable, flexible, and composable middleware for multimodal sensor networking applications**, J. Huang, W. Feng, N. Bulusu, W. Feng, Portland State Univ.[6071-19]

2:45 pm: **Compression by indexing: an improvement over MPEG-4 body animation parameter compression**, S. Chattopadhyay, S. M. Bhandarkar, K. Li, The Univ. of Georgia[6071-20]

Coffee Break 3:00 to 3:30 pm

SESSION 6

Conv. Ctr. Room C1 Thurs. 3:30 to 5:30 pm

Peer-to-Peer

3:30 pm: **DagStream: locality aware and failure resilient peer-to-peer streaming**, J. Liang, K. Nahrstedt, Univ. of Illinois at Urbana-Champaign[6071-21]

4:00 pm: **Characterizing files in the modern Gnutella network: a measurement study**, S. Zhao, D. Stutzbach, R. Rejaie, Univ. of Oregon[6071-22]

4:30 pm: **Sampling cluster endurance for peer-to-peer based content distribution networks**, V. Darlagiannis, Technische Univ. Darmstadt (Germany); A. U. Mauthe, Lancaster Univ. (United Kingdom); R. Steinmetz, Technische Univ. Darmstadt (Germany)[6071-23]

5:00 pm: **How efficient is BitTorrent?**, G. Wu, T. Chiueh, Stony Brook Univ.[6071-24]

Security, Steganography, and Watermarking of Multimedia Contents VIII

Conference Chairs: **Edward J. Delp III**, Purdue Univ.; **Ping Wah Wong**, Nethra Imaging

Program Committee: **Adnan M. Alattar**, Digimarc Corp.; **Mauro Barni**, Univ. degli Studi di Siena (Italy); **Jeffrey A. Bloom**, Thomson Multimedia Corporate Research; **Gordon W. Braudaway**, IBM Corp.; **Ingemar J. Cox**, Univ. College London (United Kingdom); **Jana Dittmann**, Otto-von-Guericke-Univ. Magdeburg (Germany); **Ahmet M. Eskicioglu**, The City Univ. of New York; **Jessica Fridrich**, Binghamton Univ.; **Teddy Furon**, IRISA (France); **Ton Kalker**, Hewlett-Packard Co.; **Martin Kutter**, AlpVision SA (Switzerland); **Reginald L. Lagendijk**, Technische Univ. Delft (Netherlands); **Benoît B. Macq**, Univ. Catholique de Louvain (Belgium); **Bangalore S. Manjunath**, Univ. of California/Santa Barbara; **Nasir D. Memon**, Polytechnic Univ.; **Pierre Moulin**, Univ. of Illinois at Urbana-Champaign; **Fernando Pérez-González**, Univ. de Vigo (Spain); **Gaurav Sharma**, Univ. of Rochester; **Claus Vielhauer**, Otto-von-Guericke-Univ. Magdeburg (Germany); **Sviatoslav V. Voloshynovskiy**, Univ. de Genève (Switzerland); **Min Wu**, Univ. of Maryland/College Park

Monday 16 January

SESSION 1

Conv. Ctr. Room A5 Mon. 8:30 to 11:20 am

Steganography and Steganalysis I

Chair: **Jessica Fridrich**, Binghamton Univ.

- 8:30 am: **New blind steganalysis and its implications**, M. Goljan, J. Fridrich, T. S. Holotyak, Binghamton Univ. [6072-01]
- 8:50 am: **Statistical modeling and steganalysis of DFT-based image steganography**, Y. Wang, P. Moulin, Univ. of Illinois at Urbana-Champaign [6072-02]
- 9:10 am: **Fourth-order structural steganalysis and analysis of cover assumptions**, A. D. Ker, Univ. of Oxford (United Kingdom) [6072-03]
- 9:30 am: **Application of conditional entropy measures to steganalysis**, J. A. Marsh, T. Knapik, E. Lo, SI International; C. D. Heitzenrater, Air Force Research Lab. [6072-04]
- 9:50 am: **Improving steganalysis by fusion techniques: a case study with image-based steganography**, M. Kharrazi, T. H. Sencar, N. D. Memon, Polytechnic Univ. [6072-05]
- Coffee Break 10:10 to 10:40 am
- 10:40 am: **A two-factor error model for quantitative steganalysis**, R. Böhme, Technische Univ. Dresden (Germany); A. D. Ker, Univ. of Oxford (United Kingdom) [6072-06]
- 11:00 am: **Compression-based steganalysis of LSB embedded images**, C. G. Boncelet, Jr., Univ. of Delaware; L. M. Marvel, A. J. Raglin, Army Research Lab. [6072-07]

SESSION 2

Conv. Ctr. Room A5 Mon. 11:20 am to 12:20 pm

Special Session: Natural Language Watermarking

Chairs: **Mercan Topkara**, Purdue Univ.; **Cuneyt M. Taskiran**, Motorola, Inc.

- 11:20 am: **Natural language processing with linguistic information for digital fingerprinting and watermarking**, O. Uzuner, Massachusetts Institute of Technology [6072-08]
- 11:40 am: **Attacks on linguistic steganography systems using text analysis**, C. M. Taskiran, Motorola, Inc.; M. Topkara, E. J. Delp III, Purdue Univ. [6072-09]
- 12:00 pm: **Natural language watermarking: research challenges and applications**, M. Topkara, Purdue Univ.; G. Riccardi, D. Hakkani-Tür, AT&T Labs. Research; M. J. Atallah, Purdue Univ. [6072-10]
- Lunch Break 12:20 to 1:50 pm

SESSION 3

Conv. Ctr. Room A5 Mon. 1:50 to 3:30 pm

Attacks

Chair: **Fernando Pérez-González**, Univ. de Vigo (Spain)

- 1:50 pm: **Scale estimation in two-band filter attacks on QIM watermarks**, J. Wang, Technische Univ. Delft (Netherlands) and Nanjing Univ. (China); I. D. Shterev, R. L. Lagendijk, Technische Univ. Delft (Netherlands) [6072-11]
- 2:10 pm: **High-rate quantization data hiding robust to arbitrary linear filtering attacks**, F. Pérez-González, C. Mosquera, M. Alvarez-Díaz, Univ. de Vigo (Spain); R. L. Lagendijk, Technische Univ. Delft (Netherlands) [6072-12]
- 2:30 pm: **Countermeasure for collusion attacks against digital watermarking**, M. Steinebach, S. Zmudzinski, Fraunhofer-Institut für Integrierte Publikations- und Informationssysteme (Germany) [6072-13]
- 2:50 pm: **The blind Newton sensitivity attack**, P. Comesaña Alfaro, L. L. Pérez-Freire, F. Pérez-González, Univ. de Vigo (Spain) [6072-14]
- 3:10 pm: **Achieving non-ambiguity of quantization-based watermarking**, X. Kang, Sun Yat-Sen Univ. (China) and New Jersey Institute of Technology; Y. Shi, New Jersey Institute of Technology; J. Huang, Sun Yat-Sen Univ. (China) [6072-15]
- Coffee Break 3:30 to 4:00 pm

SESSION 4

Conv. Ctr. Room A5 Mon. 4:00 to 5:40 pm

Special Session: Biometrics

Chair: **Claus Vielhauer**, Otto-von-Guericke-Univ. Magdeburg (Germany)

- 4:00 pm: **Reference point detection for improved fingerprint matching**, T. Ignatenko, Technische Univ. Eindhoven (Netherlands); T. Kalker, Hewlett-Packard Co. and Technische Univ. Eindhoven (Netherlands); M. van der Veen, Philips Research Labs. (Netherlands); A. M. Bazen, Univ. Twente (Netherlands) [6072-65]
- 4:20 pm: **Analyzing handwriting biometrics in metadata context**, F. Wolf, T. Scheidat, C. Vielhauer, Otto-von-Guericke-Univ. Magdeburg (Germany) [6072-17]
- 4:40 pm: **3D face recognition by projection-based features**, B. Sankur, H. Dutagaci, Bogaziçi Univ. (Turkey); Y. Yemez, Koç Univ. (Turkey) [6072-18]
- 5:00 pm: **Face biometrics with renewable templates**, M. van der Veen, T. Kevenaar, T. H. Akkermans, G. Schrijen, Philips Research Labs. (Netherlands); F. Zuo, Technische Univ. Eindhoven (Netherlands) [6072-19]
- 5:20 pm: **Safety of templates in biometric person authentication using error-correcting code**, T. Ohki, S. Akatsuka, N. Komatsu, Waseda Univ. (Japan); M. Kasahara, Osaka Gakuin Univ. (Japan) [6072-20]

Tuesday 17 January

Plenary Speaker **Tues. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 5

Conv. Ctr. Room A5 **Tues. 9:30 to 10:10 am**

Audio

Chair: Scott A. Craver, Binghamton Univ.

9:30 am: **On the comparison of audio fingerprints for extracting quality parameters of compressed audio**, P. J. Doets, M. Menor Gisbert, R. L. Lagendijk, Technische Univ. Delft (Netherlands) [6072-21]

9:50 am: **Fingerprinting with Wow**, S. A. Craver, Binghamton Univ. [6072-22]

Coffee Break 10:10 to 10:40 am

SESSION 6

Conv. Ctr. Room A5 **Tues. 10:40 am to 12:00 pm**

Steganography and Steganalysis II

Chair: Benoît B. Macq, Univ. Catholique de Louvain (Belgium)

10:40 am: **Limited distortion in LSB steganography**, Y. Kim, Z. Duric, D. Richards, George Mason Univ. [6072-23]

11:00 am: **Multiclass blind steganalysis for JPEG images**, J. Fridrich, T. Pevny, Binghamton Univ. [6072-24]

11:20 am: **MPsteg: hiding a message in the matching pursuit domain**, G. Cancelli, M. Barni, G. Menegaz, Univ. degli Studi di Siena (Italy) [6072-25]

11:40 am: **Stego sensitivity measure and multibit plane based steganography using different color models**, S. S. Agaian, J. P. Perez, B. M. Rodriguez II, The Univ. of Texas at San Antonio [6072-26]

Lunch/Exhibition Break 12:00 to 1:30 pm

SESSION 7

Conv. Ctr. Room A5 **Tues. 1:30 to 4:20 pm**

Embedding I

Chair: Ping Wah Wong, IDzap LLC

1:30 pm: **Zero knowledge ST-DM watermarking**, A. Piva, D. Corazzi, A. De Rosa, Univ. degli Studi di Firenze (Italy); M. Barni, Univ. degli Studi di Siena (Italy) [6072-27]

1:50 pm: **Compression and rotation resistant watermark using a circular chirp structure**, C. E. Fleming, B. G. Mobasser, Villanova Univ. [6072-28]

2:10 pm: **Rotation/scale insensitive spread spectrum image watermarking game**, M. Ossonce, G. Le Guelvouit, C. Delpha, P. Duhamel, Lab. des signaux et systèmes (France) [6072-29]

2:30 pm: **New results on robustness of secure steganography**, M. T. Hogan, F. Balado, N. J. Hurley, G. C. M. Silvestre, National Univ. of Ireland/Dublin (Ireland) [6072-30]

2:50 pm: **Sphere-hardening dither modulation**, F. Balado, N. J. Hurley, G. C. M. Silvestre, National Univ. of Ireland/Dublin (Ireland) [6072-31]

Coffee Break 3:10 to 3:40 pm

3:40 pm: **Secret dither estimation in lattice-quantization data hiding: a set membership approach**, L. L. Pérez-Freire, F. Pérez-González, P. Comesaña Alfaro, Univ. de Vigo (Spain) [6072-32]

4:00 pm: **Performance analysis of nonuniform quantization-based data hiding**, J. E. Vila-Forcén, S. V. Voloshynovskiy, O. J. Koval, T. Pun, Univ. de Genève (Switzerland) [6072-33]

SESSION 8

Conv. Ctr. Room A5 **Tues. 4:20 to 5:40 pm**

Special Session: Forensics

Chair: Nasir D. Memon, Polytechnic Univ.

4:20 pm: **Detecting digital image forgeries using sensor pattern noise**, J. Lukas, J. Fridrich, M. Goljan, Binghamton Univ. [6072-34]

4:40 pm: **Fingerprinting digital elevation maps**, H. Gou, M. Wu, Univ. of Maryland/College Park [6072-35]

5:00 pm: **Information embedding and extraction for electrophotographic printing processes**, A. K. Mikkilineni, P. Chiang, G. T. Chiu, J. P. Allebach, E. J. Delp III, Purdue Univ. [6072-36]

5:20 pm: **An online system for classifying computer graphics images from natural photographs**, T. Ng, S. Chang, Columbia Univ. ... [6072-37]

Demonstration Session

A symposium-wide demonstration session will be open to attendees

5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1.

Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Wednesday 18 January

Plenary Speaker **Wed. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging

Richard Leahy, Univ. of Southern California

See p. 7 for details.

SESSION 9

Conv. Ctr. Room A5 **Wed. 9:30 to 11:20 am**

Theoretical Methods I

Chair: Pierre Moulin, Univ. of Illinois at Urbana-Champaign

9:30 am: **Text data-hiding for digital and printed documents: theoretical and practical considerations**, R. Villan, Sr., S. V. Voloshynovskiy, O. J. Koval, J. E. Vila-Forcén, E. Topak, F. Deguillaume, Y. B. Rytzar, T. Pun, Univ. de Genève (Switzerland) [6072-38]

9:50 am: **E-capacity and security analysis of data-hiding channels with geometrical attacks**, E. Topak, S. V. Voloshynovskiy, O. J. Koval, Univ. de Genève (Switzerland); M. E. Haroutunian, National Academy of Sciences of Armenia (Armenia); J. E. Vila-Forcén, T. Pun, Univ. de Genève (Switzerland) [6072-39]

10:10 am: **Image data hiding based on capacity-approaching dirty-paper coding**, Y. Yang, Y. Sun, V. Stankovic, Z. Xiong, Texas A&M Univ. [6072-40]

Coffee Break 10:30 to 11:00 am

11:00 am: **Wet paper codes with improved embedding efficiency**, J. Fridrich, M. Goljan, D. Soukal, Binghamton Univ. [6072-41]

SESSION 10

Conv. Ctr. Room A5 Wed. 11:20 am to 12:20 pm

Video I

Chair: Adnan M. Alattar, Digimarc Corp.

- 11:20 am: **New modulation-based watermarking technique for video**, A. N. Lemma, M. van der Veen, M. U. Celik, Philips Research Labs. (Netherlands) [6072-42]
- 11:40 am: **Selective encryption for H.264/AVC video coding**, T. Shi, B. King, P. Salama, Indiana Univ./Purdue Univ. at Indianapolis [6072-43]
- 12:00 pm: **Using entropy for image and video authentication watermarks**, S. Thiemert, M. Steinebach, Fraunhofer-Institut für Integrierte Publikations- und Informationssysteme (Germany) [6072-44]
- Lunch/Exhibition Break 12:20 to 1:50 pm

SESSION 11

Conv. Ctr. Room A5 Wed. 1:50 to 3:10 pm

Video II

Chair: Ahmet M. Eskicioglu, The City Univ. of New York

- 1:50 pm: **Temporal synchronization of marked MPEG video frames based on image hash system**, E. Hauer, M. Steinebach, Fraunhofer-Institut für Integrierte Publikations- und Informationssysteme (Germany) [6072-45]
- 2:10 pm: **Towards robust compressed-domain video watermarking for H.264**, M. Noorkami, R. M. Mersereau, Georgia Institute of Technology [6072-46]
- 2:30 pm: **Selective encryption of low-complexity source coding for mobile terminals**, H. Um, E. J. Delp III, Purdue Univ. [6072-47]
- 2:50 pm: **VLC pair tree: a paradigm for MPEG-2 watermarking**, M. P. Marcinak, B. G. Mobasseri, Villanova Univ. [6072-48]
- Coffee Break 3:10 to 3:40 pm

SESSION 12

Conv. Ctr. Room A5 Wed. 3:40 to 5:40 pm

Theoretical Methods II

Chair: Fernando Pérez-González, Univ. de Vigo (Spain)

- 3:40 pm: **Information-theoretic analysis of electronic and printed document authentication**, S. V. Voloshynovskiy, O. J. Koval, R. Villan, Sr., E. Topak, J. E. Vila-Forcén, F. Deguillaume, Y. B. Rytsar, T. Pun, Univ. de Genève (Switzerland) [6072-49]
- 4:00 pm: **Joint data hiding and source coding with partially available side information**, C. Dikici, K. Idrissi, A. M. Baskurt, Institut National des Sciences Appliquées de Lyon (France) [6072-50]
- 4:20 pm: **Asymmetrically informed data-hiding optimization of achievable rate for Laplacian host**, J. E. Vila-Forcén, O. J. Koval, S. V. Voloshynovskiy, E. Topak, T. Pun, Univ. de Genève (Switzerland) [6072-51]
- 4:40 pm: **Some theoretical aspects of watermarking detection**, T. Furon, J. Josse, S. Le Squin, Institut National de Recherche en Informatique et en Automatique (France) [6072-52]
- 5:00 pm: **A framework for the design of good watermark identification codes**, P. Moulin, R. Koetter, Univ. of Illinois at Urbana-Champaign [6072-53]
- 5:20 pm: **On the fundamental tradeoff between watermark detection performance and robustness against sensitivity analysis attacks**, M. M. El Choubassi, P. Moulin, Univ. of Illinois at Urbana-Champaign [6072-16]

Thursday 19 January

SESSION 13

Conv. Ctr. Room A5 Thurs. 8:00 to 10:00 am

Special Session: Benchmarking and Demonstration Session

Chairs: Jana Dittmann, Otto-von-Guericke-Univ. Magdeburg (Germany); Benoît B. Macq, Univ. Catholique de Louvain (Belgium)

- 8:00 am: **Profiles for evaluation: the usage of audio WET**, A. Lang, J. Dittmann, Otto-von-Guericke-Univ. Magdeburg (Germany) [6072-54]
- 8:20 am: **A benchmark assessment of the WAUC watermarking audio algorithm**, D. Megias Jiménez, J. Herrera-Joancomarti, J. Serra i Ruiz, J. Minguillón Alfonso, Univ. Oberta de Catalunya (Spain) [6072-55]
- 8:40 am: **Transparency benchmarking on audio watermarks and steganography**, C. Kraetzer, J. Dittmann, A. Lang, Otto-von-Guericke-Univ. Magdeburg (Germany) [6072-56]
- 9:00 am: **Shape quality measurement for 3D watermarking schemes**, P. Rondao-Alface, B. B. Macq, Univ. Catholique de Louvain (Belgium) [6072-57]
- 9:20 am: **Reliability engineering approach to digital watermark evaluation**, H. C. Kim, E. J. Delp III, O. Guitart, E. J. Delp III, Purdue Univ. [6072-58]
- 9:40 am: **New functionalities in watermark evaluation testbed (WET)**, O. Guitart, H. C. Kim, E. J. Delp III, Purdue Univ. [6072-59]
- Coffee Break 10:00 to 10:30 am

SESSION 14

Conv. Ctr. Room A5 Thurs. 10:30 to 11:50 am

Applications I

Chair: Gordon W. Braudaway, IBM Corp.

- 10:30 am: **Protection and governance of MPEG music player MAF contents using MPEG-21 IPMP tools**, H. Hendry, M. Kim, Information and Communications Univ. (South Korea) [6072-60]
- 10:50 am: **Watermarking of 3D objects based on 2D apparent contours**, J. Bennour, J. Dugelay, Institut Eurécom (France) [6072-61]
- 11:10 am: **Quality assessment of watermarked 3D polygonal models**, W. Funk, J. Prasiswa, Fraunhofer-Institut für Graphische Datenverarbeitung (Germany) [6072-62]
- 11:30 am: **Reducing the processing time of the hierarchical watermark detector when applied to unmarked images**, A. M. Alattar, O. M. Alattar, Digimarc Corp. [6072-63]
- Lunch Break 11:50 am to 1:20 pm

SESSION 15

Conv. Ctr. Room A5 Thurs. 1:20 to 2:20 pm

Applications II

Chair: Min Wu, Univ. of Maryland/College Park

- 1:20 pm: **Exploring QIM-based anti-collusion fingerprinting for multimedia**, A. Swaminathan, S. He, M. Wu, Univ. of Maryland/College Park [6072-64]
- 1:40 pm: **Sheet music fingerprinting based on graphical representation**, G. Kremser, M. Schmucker, Fraunhofer-Institut für Graphische Datenverarbeitung (Germany) [6072-66]
- 2:00 pm: **A web-oriented and interactive buyer-seller watermarking protocol**, F. Frattolillo, S. D'Onofrio, Univ. degli Studi del Sannio (Italy) [6072-67]

SESSION 16

Conv. Ctr. Room A5 Thurs. 2:20 to 5:10 pm

Embedding II

Chair: Mauro Barni, Univ. degli Studi di Siena (Italy)

2:20 pm: **Matrix embedding for large payloads**, J. Fridrich, D. Soukal, Binghamton Univ.[6072-68]

2:40 pm: **Simple reversible watermarking schemes: further results**, D. Coltuc, Univ. Valahia din Targoviste (Romania); J. Chassery, Institut National Polytechnique de Grenoble (France)[6072-69]

Coffee Break 3:00 to 3:30 pm

3:30 pm: **A new watermark detector for spread-spectrum based image watermarking using underdetermined independent component analysis framework**, H. M. Malik, A. A. Khokhar, R. Ansari, Univ. of Illinois at Chicago[6072-70]

3:50 pm: **Optimal detector for an additive watermarking scheme based on human auditory system**, M. Haddad, A. Gilloire, A. Le Guyader, France Télécom (France); P. Duhamel, Lab. des signaux et systèmes (France)[6072-71]

4:10 pm: **A hypothesis testing approach for achieving semi-fragility in multimedia authentication**, C. Fei, Univ. of Toronto (Canada); D. Kundur, Texas A&M Univ.; R. Kwong, Univ. of Toronto (Canada)[6072-72]

4:30 pm: **A DWT-based robust semi-blind image watermarking algorithm using two bands**, E. Elbasi, A. M. Eskicioglu, The City Univ. of New York[6072-73]

4:50 pm: **Evaluating the visual quality of watermarked images**, A. Shnayderman, A. M. Eskicioglu, The City Univ. of New York[6072-74]

Multimedia Content Analysis, Management, and Retrieval 2006

Conference Chairs: **Edward Y. Chang**, Univ. of California/Santa Barbara; **Alan Hanjalic**, Delft Univ. of Technology (Netherlands); **Nicu Sebe**, Univ. van Amsterdam (Netherlands)

Program Committee: **Kiyoharu Aizawa**, The Univ. of Tokyo (Japan); **Aya Aner-Wolf**, GenTech Corp. (Israel); **Noboru Babaguchi**, Osaka Univ. (Japan); **Nozha Boujemaa**, INRIA Rocquencourt (France); **Arbee L. P. Chen**, National Chengchi Univ. (Taiwan); **Tsuhan Chen**, Carnegie Mellon Univ.; **TatSeng Chua**, National Univ. of Singapore (Singapore); **Ajay Divakaran**, Mitsubishi Electric Research Labs.; **Chitra Dorai**, IBM Thomas J. Watson Research Ctr.; **Arun Hampapur**, IBM Thomas J. Watson Research Ctr.; **Alexander G. Hauptmann**, Carnegie Mellon Univ.; **Alejandro Jaimes**, Fuji Xerox Co., Ltd. (Japan); **Mohan S. Kankanhalli**, National Univ. of Singapore (Singapore); **John R. Kender**, Columbia Univ.; **Anil C. Kokaram**, The Univ. of Dublin, Trinity College (Ireland); **Michael S. Lew**, Leiden Institute of Advanced Computer Science (Netherlands); **Chung-Sheng Li**, IBM Corp.; **Rainer W. Lienhart**, Univ. of Augsburg (Germany); **Wei-Ying Ma**, Microsoft Research Asia (China); **Bernard Merialdo**, Institut Eurécom (France); **Kadir A. Peker**, Mitsubishi Electric Research Labs.; **Silvia Pfeiffer**, Commonwealth Scientific & Industrial Research Organisation (Australia); **Alan F. Smeaton**, Dublin City Univ. (Ireland); **John R. Smith**, IBM Thomas J. Watson Research Ctr.; **Hari Sundaram**, Arizona State Univ.; **Ahmet M. Tekalp**, Univ. of Rochester; **Qi Tian**, The Univ. of Texas at San Antonio; **Svetha Venkatesh**, Curtin Univ. of Technology (Australia); **Stephen T. C. Wong**, Harvard Medical School; **Marcel Worring**, Univ. van Amsterdam (Netherlands); **Aidong Zhang**, SUNY/Univ. at Buffalo

Tuesday 17 January

Plenary Speaker **Tues. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

✓ Posters and Demonstrations-Tuesday

Demonstrations **5:30 to 8:30 pm**

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1.

Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **A tree-based paradigm for content-based video retrieval and management**, H. Fang, Univ. of Bradford (United Kingdom); Y. Yin, Chongqing Univ. (China); J. Jiang, Univ. of Bradford (United Kingdom) [6073-31]
- ✓ **Tangible interactive system for document browsing and visualization of multimedia data**, Y. B. Rytsar, S. V. Voloshynovskiy, O. J. Koval, F. Deguillaume, E. Topak, Univ de Genève (Switzerland); S. Startchik, Anteleon Imaging (Switzerland); T. Pun, Univ. de Genève (Switzerland) [6073-32]
- ✓ **Semantic segmentation of video collections using boosted random fields**, B. Janvier, E. Bruno, S. Marchand-Maillet, T. Pun, Univ. de Genève (Switzerland) [6073-33]
- ✓ **Annotating 3D contents with MPEG-7 for reuse purposes**, I. M. Bilasco, J. Gensel, M. Villanova-Oliver, H. Martin, Institut d'Informatique et Mathématiques Appliquées de Grenoble (France) [6073-34]
- ✓ **Multimedia for art retrieval (M4ART)**, E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands); T. Kok, T. E. Schouten, E. Hoenkamp, Radboud Univ. Nijmegen (Netherlands) [6073-35]

- ✓ **Application of image visual characterization and soft feature selection in content-based image retrieval**, K. Jarrah, I. Lee, Ryerson Univ. (Canada); M. J. Kyan, The Univ. of Sydney (Australia); L. Guan, Ryerson Univ. (Canada) [6073-36]
- ✓ **Video shot retrieval using a kernel derived from a continuous HMM**, A. Velivelli, T. S. Huang, Univ. of Illinois at Urbana-Champaign; A. G. Hauptmann, Carnegie Mellon Univ. [6073-37]
- ✓ **Moving camera moving object segmentation in an MPEG-2 compressed video sequence**, J. Wang, Wayne State Univ.; N. Patel, W. Grosky, Univ. of Michigan/Dearborn [6073-38]
- ✓ **Visual object categorization with indefinite kernels in discriminant analysis framework**, S. Kosinov, S. Marchand-Maillet, Univ. de Genève (Switzerland) [6073-39]

Wednesday 18 January

Plenary Speaker **Wed. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging

Richard Leahy, Univ. of Southern California

See p. 7 for details.

SESSION 1

Conv. Ctr. Room B1 **Wed. 9:30 to 10:30 am**

Video Analysis I

Chair: Alan F. Smeaton, Dublin City Univ. (Ireland)

9:30 am: **Blind summarization: content adaptive video summarization using time-series analysis**, A. Divakaran, R. Radhakrishnan, K. A. Peker, Mitsubishi Electric Research Labs. [6073-01]

9:50 am: **Multilevel analysis of sports video sequences**, J. Han, D. Farin, P. H. N. de With, Technische Univ. Eindhoven (Netherlands) ... [6073-02]

10:10 am: **Automated editing of medical training video via content analysis**, A. C. Kokaram, The Univ. of Dublin, Trinity College (Ireland); K. Andrews, Univ. of the West Indies (Trinidad and Tobago); D. Ring, The Univ. of Dublin, Trinity College (Ireland); C. Lee, Royal College of Surgeons in Ireland (Ireland) [6073-03]

Coffee Break 10:30 to 10:50 am

SESSION 2

Conv. Ctr. Room B1 Wed. 10:50 am to 12:10 pm

Audio and Video Retrieval

Chair: Anil C. Kokaram, The Univ. of Dublin, Trinity College (Ireland)

10:50 am: **Statistical model and error analysis of a proposed audio fingerprinting algorithm**, E. P. McCarthy, F. Balado, N. J. Hurley, G. C. M. Silvestre, Univ. College Dublin (Ireland) [6073-04]

11:10 am: **An application of weighted transducers to music information retrieval**, D. Basaldella, N. Orio, Univ. degli Studi di Padova (Italy) [6073-05]

11:30 am: **Video scene retrieval with symbol sequence based on integrated audio and visual features**, K. Morisawa, N. Nitta, N. Babaguchi, Osaka Univ. (Japan) [6073-06]

11:50 am: **Fischlár-DiamondTouch: collaborative video searching on a table**, A. F. Smeaton, H. Lee, C. Foley, S. McGivney, C. Gurrin, Dublin City Univ. (Ireland) [6073-07]

Lunch/Exhibition Break 12:10 to 1:40 pm

SESSION 3

Conv. Ctr. Room B1 Wed. 1:40 to 3:00 pm

Image Retrieval

Chair: Nicu Sebe, Univ. van Amsterdam (Netherlands)

1:40 pm: **Mind the gap: another look at the problem of the semantic gap in image retrieval**, J. S. Hare, P. H. Lewis, Univ. of Southampton (United Kingdom); P. Enser, C. Sandom, Univ. of Brighton (United Kingdom) [6073-08]

2:00 pm: **Evaluation of strategies for multiple sphere queries with local image descriptors**, N. Bouteldja, Conservatoire National des Arts et Metiers/CEDRIC (France); V. Gouet-Brunet, M. Scholl, Conservatoire National des Arts et Métiers/CEDRIC (France) [6073-09]

2:20 pm: **PARIS: a MPEG-7 spatial and temporal referenced personal photograph library**, P. Kuo, M. Ito, T. Aoki, H. Yasuda, The Univ. of Tokyo (Japan) [6073-10]

2:40 pm: **2+2=5: painting by numbers**, C. C. Venters, Univ. of Manchester (United Kingdom); R. J. Hartley, Manchester Metropolitan Univ. (United Kingdom); W. T. Hewitt, Univ. of Manchester (United Kingdom) . . [6073-11]

Coffee Break 3:00 to 3:20 pm

SESSION 4

Conv. Ctr. Room B1 Wed. 3:20 to 4:20 pm

Applications I

Chair: Alan Hanjalic, Technische Univ. Delft (Netherlands)

3:20 pm: **Structuring continuous video recordings of everyday life using time-constrained clustering**, W. Lin, A. G. Hauptmann, Carnegie Mellon Univ. [6073-12]

3:40 pm: **Practical life log video indexing based on content and context**, D. Tancharoen, T. Yamasaki, K. Aizawa, The Univ. of Tokyo (Japan) [6073-13]

4:00 pm: **Multimedia for mobile users: image-enhanced navigation**, S. Gautam, G. Sarkis, E. Tjandranegara, E. Zolkowitz, Y. Lu, E. J. Delp III, Purdue Univ. [6073-14]

Panel Discussion 4:20 to 5:20 pm

Chair: Rainer W. Lienhart, Univ. Augsburg (Germany)

Thursday 19 January

SESSION 5

Conv. Ctr. Room B1 Thurs. 9:00 to 10:00 am

Image Classification

Chair: Michael G. Christel, Carnegie Mellon Univ.

9:00 am: **Semantic classification of business images**, B. Erol, J. J. Hull, Ricoh Innovations, Inc. [6073-15]

9:20 am: **Region labeling using a point-based coherence criterion**, H. Houissa, N. Boujemaa, INRIA Rocquencourt (France) [6073-16]

9:40 am: **BlobContours: adapting Blobworld for supervised color- and texture-based image segmentation**, T. Vogel, D. N. Quyen, J. Dittmann, Otto-von-Guericke-Univ. Magdeburg (Germany) [6073-17]

Coffee Break 10:00 to 10:20 am

SESSION 6

Conv. Ctr. Room B1 Thurs. 10:20 am to 12:20 pm

Special Session: Evaluating Video Summarization, Browsing, and Retrieval Techniques

Chair: Ajay Divakaran, Mitsubishi Electric Research Labs.

10:20 am: **Subjective assessment of consumer video summarization (Invited Paper)**, C. Forlines, K. A. Peker, A. Divakaran, Mitsubishi Electric Research Labs. [6073-18]

10:50 am: **Evaluation of video summarization systems (Invited Paper)**, C. M. Taskiran, Motorola, Inc. [6073-19]

11:20 am: **Subjective evaluation criterion for selecting affective features and modeling highlights (Invited Paper)**, L. Xing, H. Yu, Q. Huang, Graduate School of the Chinese Academy of Sciences (China); Q. Ye, Chinese Academy of Sciences (China); A. Divakaran, Mitsubishi Electric Research Labs. [6073-20]

11:50 am: **Evaluation and user studies with respect to video summarization and browsing (Invited Paper)**, M. G. Christel, Carnegie Mellon Univ. [6073-21]

Lunch Break 12:20 to 2:00 pm

SESSION 7

Conv. Ctr. Room B1 Thurs. 2:00 to 3:00 pm

Feature Extraction

Chair: Edward Y. Chang, Univ. of California/Santa Barbara

2:00 pm: **Semantic feature extraction with multidimensional hidden Markov model**, J. Jiten, B. Merialdo, B. Huet, Eurécom Institute (France) [6073-22]

2:20 pm: **Rotation and translation invariant feature extraction using angular projection in frequency domain**, B. Lee, M. Kim, Information and Communications Univ. (South Korea) [6073-23]

2:40 pm: **Invariant region descriptors for robust shot segmentation**, A. Arasanathan, N. Canagarajah, Univ. of Bristol (United Kingdom) . [6073-24]

Coffee Break 3:00 to 3:20 pm

SESSION 8

Conv. Ctr. Room B1 Thurs. 3:20 to 4:20 pm

Video Analysis II

Chair: Rainer W. Lienhart, Univ. Augsburg (Germany)

3:20 pm: **A video processing method for convenient mobile reading of printed barcodes with camera phones**, C. H. Bäckström, C. Södergård, VTT Information Technology (Finland); S. Udd, UPC Consulting Ltd. (Finland) [6073-25]

3:40 pm: **Flexible surveillance system architecture for prototyping video content analysis algorithms**, R. Wijnhoven, Bosch Security Systems B.V. (Netherlands); E. G. T. Jaspers, P. H. N. de With, LogicaCMG (Netherlands) [6073-26]

4:00 pm: **Motion-based parsing for video from observational psychology**, A. C. Kokaram, E. Doyle, D. Lennon, L. Joyeux, R. Fuller, The Univ. of Dublin, Trinity College (Ireland) [6073-27]

Session Break 4:20 to 4:30 pm

SESSION 9

Conv. Ctr. Room B1 Thurs. 4:30 to 5:10 pm

Applications II

Chair: Berna Erol, Ricoh Innovations, Inc.

4:30 pm: **Occlusion costing for multimedia object layout in a constrained window**, S. Widdowson, Hewlett Packard Labs. . . [6073-28]

4:50 pm: **Using CART to segment road images**, R. L. Davies, Intel Corp.; R. W. Lienhart, Univ. Augsburg (Germany) [6073-30]

Multimedia on Mobile Devices II

Conference Chairs: **Reiner Creutzburg**, Fachhochschule Brandenburg (Germany); **Jarmo H. Takala**, Tampere Univ. of Technology (Finland); **Chang Wen Chen**, Florida Institute of Technology

Program Committee: **David Akopian**, The Univ. of Texas at San Antonio; **Alan Chalmers**, Univ. of Bristol (United Kingdom); **Surendar Chandra**, Univ. of Notre Dame; **Kenneth J. Crisler**, Motorola Labs.; **David S. Doermann**, Univ. of Maryland/College Park; **Uwe Dummann**, Siemens AG (Germany); **Elizabeth Dykstra-Erickson**, Kinoma, Inc.; **Zhihai He**, Univ. of Missouri/Columbia; **Xin Li**, West Virginia Univ.; **Sethuraman Panchanathan**, Arizona State Univ.; **Kari A. Pulli**, Nokia; **Matthias Rauterberg**, Technische Univ. Eindhoven (Netherlands); **Phillip A. Regalia**, Institut National des Télécommunications (France); **Haitao Zheng**, Univ. of California/Santa Barbara

Monday 16 January

SESSION 1

Conv. Ctr. Room B4 Mon. 9:30 to 10:00 am

Invited Paper I

9:30 am: **New APIs for mobile graphics (Invited Paper, Presentation Only)**, K. A. Pulli, Nokia [6074-01]

SESSION 2

Conv. Ctr. Room B4 Mon. 10:00 to 10:20 am

Multimedia Coding I

Chair: **Reiner Creutzburg**, Fachhochschule Brandenburg (Germany)

10:00 am: **A novel fast inter-prediction mode decision for H.264/AVC**, Y. Guo, H. Li, S. Pei, Univ. of Science and Technology of China (China); C. W. Chen, Florida Institute of Technology [6074-02]

Coffee Break 10:20 to 10:50 am

SESSION 3

Conv. Ctr. Room B4 Mon. 10:50 am to 12:10 pm

Multimedia Coding II

Chair: **Chang Wen Chen**, Florida Institute of Technology

10:50 am: **Concealment driven bit rate reduction using the H.264 video coding standard**, S. T. Beesley, A. J. Armstrong, C. Grecos, D. J. Parish, Loughborough Univ. (United Kingdom) [6074-03]

11:10 am: **Image embedded coding with edge preservation based on local variance analysis for mobile applications**, G. Luo, D. Osypiw, Buckinghamshire Chilterns Univ. College (United Kingdom) [6074-04]

11:30 am: **Image coding using adaptive resizing in the block-DCT domain**, J. J. Koivusaari, J. H. Takala, M. Gabbouj, Tampere Univ. of Technology (Finland) [6074-05]

11:50 am: **Spatial scalability of multiple ROIs in scalable video coding**, T. M. Bae, T. C. Thang, D. Y. Kim, Y. M. Ro, Information and Communications Univ. (South Korea); J. Kim, Electronics and Telecommunications Research Institute (South Korea) [6074-06]

Lunch Break 12:10 to 2:00 pm

SESSION 4

Conv. Ctr. Room B4 Mon. 2:00 to 2:30 pm

Invited Paper II

2:00 pm: **Implementing energy efficient embedded multimedia (Invited Paper)**, O. J. Silvén, Univ. of Oulu (Finland) [6074-07]

SESSION 5

Conv. Ctr. Room B4 Mon. 2:30 to 3:10 pm

Mobile Multimedia Retrieval and Classification

Chair: **Stefan Edlich**, Technische Fachhochschule Berlin (Germany)

2:30 pm: **A study of low-complexity tools for semantic classification of mobile images and video**, A. Mariappan, M. Igarta, Purdue Univ.; C. M. Taskiran, B. Gandhi, Motorola, Inc.; E. J. Delp III, Purdue Univ. ... [6074-08]

2:50 pm: **Audio-based queries for video retrieval over Java enabled mobile devices**, I. Ahmad, Nokia Corp. (Finland); F. A. Cheikh, S. Kiranyaz, M. Gabbouj, Tampere Univ. of Technology (Finland) [6074-09]

Coffee Break 3:10 to 3:30 pm

SESSION 6

Conv. Ctr. Room B4 Mon. 3:30 to 5:10 pm

Processors for Multimedia

Chair: **Jarmo H. Takala**, Tampere Univ. of Technology (Finland)

3:30 pm: **Parallel implementation of MPEG-2 video decoder**, A. Sarkar, North Carolina State Univ.; K. Saha, S. Maiti, STMicroelectronics Pvt. Ltd. (India) [6074-11]

3:50 pm: **Software-based geometry operations for 3D computer graphics**, M. Sima, Univ. of Victoria (Canada); D. Iancu, J. C. Glossner, Sandbridge Technologies, Inc.; M. J. Schulte, S. Mamidi, Univ. of Wisconsin/Madison [6074-12]

4:10 pm: **MVSP: multithreaded VLIW stream processor**, S. Sardashti, H. R. Ghasemi, O. Fatemi, Univ. of Tehran (Iran) [6074-13]

4:30 pm: **System-on-chip architecture with media DSP and RISC core for media application**, P. Liu, W. Wang, Q. Yao, Zhejiang Univ. (China) [6074-14]

4:50 pm: **IIA: a novel method to optimize media instruction set of embedded processor**, K. Chen, Q. Yao, W. Wang, P. Liu, Zhejiang Univ. (China) [6074-15]

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 7

Conv. Ctr. Room B4 Tues. 9:30 to 10:00 am

Invited Paper III

9:30 am: **Multimedia services for next-generation mobile networks (Invited Paper)**, S. J. Wee, D. Penkler, Hewlett-Packard Labs. ... [6074-17]

SESSION 8

Conv. Ctr. Room B4 Tues. 10:00 to 10:20 am

Multimedia Applications I

Chair: Reiner Creutzburg, Fachhochschule Brandenburg (Germany)

10:00 am: **Wireless steganography**, S. S. Agaian, D. Akopian, S. D'Souza, The Univ. of Texas at San Antonio [6074-18]

Coffee Break 10:20 to 10:50 am

SESSION 9

Conv. Ctr. Room B4 Tues. 10:50 am to 12:10 pm

Multimedia Applications II

Chair: Zhihai He, Univ. of Missouri/Columbia

10:50 am: **Image processing for navigation on a mobile embedded platform**, H. Loose, C. Lemke, C. Papazov, Brandenburg Univ. of Applied Sciences (Germany) [6074-19]

11:10 am: **Image processing for navigation on a mobile embedded platform**, T. Preuss, L. Gentsch, M. Rambow, Brandenburg Univ. of Applied Sciences (Germany) [6074-20]

11:30 am: **The future is 'ambient'**, A. R. Lugmayr, Tampere Univ. of Technology (Finland) [6074-21]

11:50 am: **Embedded video surveillance system for vehicle over WLAN and CDMA1X**, L. Ming, Wuhan Univ. (China) [6074-22]

Lunch Break 12:10 to 1:40 pm

SESSION 10

Conv. Ctr. Room B4 Tues. 1:40 to 3:00 pm

Multimedia Data Management

Chair: David Akopian, The Univ. of Texas at San Antonio

1:40 pm: **Performance analysis of MPEG-21 technologies on mobile devices**, S. De Zutter, F. De Keukelaere, C. Poppe, R. Van de Walle, Univ. Gent (Belgium) [6074-23]

2:00 pm: **TV-anytime and MPEG-21 DIA based ubiquitous content mobility prototype system for multi-users**, M. Kim, C. Yang, J. Lim, M. Kim, Information and Communications Univ. (South Korea); S. Park, K. Kim, SAMSUNG Electronics Co., Ltd. (South Korea) [6074-24]

2:20 pm: **Multimedia-based construction management and supervision on mobile JTWI devices and the EDF-portal**, S. Edlich, Technische Fachhochschule Berlin (Germany); R. Strauch, edv plan GmbH; L. Visengeriyeva, Fachhochschule Brandenburg; D. Reeck, edv plan GmbH [6074-25]

2:40 pm: **A mobile phone-based context-aware video management application**, J. Lahti, M. Palola, J. Korva, VTT Technical Research Ctr. of Finland (Finland); U. Westermann, P. Pietarila, VTT Elektroniikka (Finland); K. Pentikousis, VTT Technical Research Ctr. of Finland (Finland) . [6074-26]

Coffee Break 3:00 to 3:30 pm

SESSION 11

Conv. Ctr. Room B4 Tues. 3:30 to 5:10 pm

HCI Issues for Mobile Devices

Chair: Jarmo H. Takala, Tampere Univ. of Technology (Finland)

3:30 pm: **MIKE's PET: a participant-based experiment tracking tool for HCI practitioners using mobile devices**, D. Mohamedally, City Univ. London (United Kingdom); S. Edlich, Technische Fachhochschule Berlin (Germany); E. Klaus, Fachhochschule Brandenburg (Germany); P. Zaphiris, H. Petrie, City Univ. London (United Kingdom) [6074-27]

3:50 pm: **Maintenance support: case study for a multimodal mobile interface**, G. Fuchs, D. Reichart, H. Schumann, P. Forbrig, Univ. Rostock (Germany) [6074-28]

4:10 pm: **Breaking the news on mobile TV: user requirements of a popular mobile content**, H. O. Knoche, Univ. College London; A. Sasse, Univ. College London (United Kingdom) [6074-29]

4:30 pm: **Multimodal audio guide for museums and exhibitions**, S. Gebbensleben, J. Dittmann, Otto-von-Guericke Univ. (Germany) [6074-30]

4:50 pm: **Human sound detection on experience movies**, S. Shimura, Y. Hirano, S. Kajita, K. Mase, Nagoya Univ. (Japan) [6074-31]

✓ Posters and Demonstrations-Tuesday

Demonstrations 5:30 to 8:30 pm

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters 5:30 to 7:00 pm

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **A FGS coding method based on LC multiwavelet transform**, W. Liu, South China Normal Univ. (China); Z. Ma, Zhongshan Univ. (China) [6074-34]
- ✓ **A context-aware video display scheme for mobile devices**, K. Seo, C. Kim, Information and Communications Univ. (South Korea) [6074-35]
- ✓ **Verification of WIPI-based T-DMB platform for interactive mobile multimedia services**, B. Bae, W. Kim, J. Yun, C. Ahn, Electronics and Telecommunications Research Institute (South Korea); K. Sohng, Kyungpook National Univ. (South Korea) [6074-36]
- ✓ **New TPEG applications based on digital multimedia broadcasting**, Y. Jeong, S. Cho, G. Kim, C. Ahn, S. Lee, Electronics and Telecommunications Research Institute (South Korea); W. Kim, Chungnam National Univ. (South Korea) [6074-37]
- ✓ **AROMA: augmented reality on mobile devices API (Java)**, S. Edlich, Technische Fachhochschule Berlin (Germany); H. Hörning, R. Hörning, Biting Bit (Germany) [6074-39]
- ✓ **An effective method and its implementation for splicing in terrestrial DMB**, Y. Lee, J. Lee, G. Lee, C. Ahn, S. Lee, Electronics and Telecommunications Research Institute (South Korea); N. Kim, Chungbuk National Univ. (South Korea) [6074-40]
- ✓ **Media digital signal processor core design for multimedia application**, P. Liu, G. Yu, W. Cai, Q. Yao, Zhejiang Univ. (China) [6074-42]

Optical Security and Counterfeit Deterrence Techniques VI

Conference Chair: **Rudolf L. van Renesse**, VanRenesse Consulting (Netherlands)

Program Committee: **Sara E. Church**, Bank of Canada (Canada); **James M. Jonza**, 3M Co.; **Malcolm R. M. Knight**, De La Rue International Ltd. (United Kingdom); **Ian M. Lancaster**, Reconnaissance International (United Kingdom) and International Hologram Manufacturers Association (United Kingdom); **Hiroyuki Matsumoto**, NHK Spring Co., Ltd. (Japan); **Roger W. Phillips**, JDSU-Flex Products Group; **Elisabeth Schulz**, European Central Bank (Germany); **Sybrand Spanenburg**, Joh. Enschedé Security Printing B.V. (Netherlands); **Wayne R. Tompkin**, OVD Kinegram Corp. (Switzerland); **Jan van den Berg**, Sdu Identification (Netherlands)

Tuesday 17 January

Plenary Speaker **Tues. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

✓ **Posters and Demonstrations-Tuesday**

Demonstrations **5:30 to 8:30 pm**

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1.

Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters **5:30 to 7:00 pm**

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Use of metameric filters for future interference security images structures**, B. Baloukas, L. Martinu, Ecole Polytechnique de Montréal (Canada) [6075-42]
- ✓ **Recording the optical identification marks on CDs**, A. A. Kryuchyn, Institute for Information Recording (Ukraine); S. A. Kostyukovich, V. Lashkaryov Institute of Semiconductor Physics (Ukraine); V. V. Petrov, S. M. Shanoylo, Institute for Information Recording (Ukraine) ... [6075-40]
- ✓ **Concealed images in design of security devices and methods of their authentication**, V. I. Girnyk, Optronics, Ltd. (Ukraine); S. O. Kostyukovich, Optronics, Ltd. (Ukraine) and Institute of Semiconductor Physics (Ukraine); E. V. Braginets, Optronics, Ltd. (Ukraine) and National Taras Shevchenko Univ. of Kyiv (Ukraine); A. Soroka, National Taras Shevchenko Univ. of Kyiv (Ukraine) [6075-41]

Wednesday 18 January

Plenary Speaker **Wed. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging

Richard Leahy, Univ. of Southern California

See p. 7 for details.

SESSION 1

Conv. Ctr. Room A7 **Wed. 9:30 to 10:30 am**

Currency I

Chair: Sara E. Church, Bank of Canada (Canada)

9:30 am: **Feed back from the public for better banknote design**, H. A. M. de Heij, De Nederlandsche Bank (Netherlands) [6075-01]

9:50 am: **Robust and reliable banknote authentication and print flaw detection with opto-acoustical sensor fusion methods**, V. Lohweg, Fachhochschule Lippe und Höxter (Germany); J. G. Schaede, KBA-GIORI S.A. (Switzerland); T. Türke, KBA-Bielefeld (Germany) [6075-02]

10:10 am: **The implication of direct laser engraved intaglio plates on bank note security**, H. Deinhammer, Österreichische Banknoten- und Sicherheitsdruck (Austria) [6075-03]

Coffee Break 10:30 to 11:00 am

SESSION 2

Conv. Ctr. Room A7 **Wed. 11:00 am to 12:00 pm**

Currency II

Chair: Elisabeth Schulz, European Central Bank (Germany)

11:00 am: **The circulation simulator method for evaluating bank note and optical feature durability**, W. J. Bartz, Crane & Co., Inc. ... [6075-04]

11:20 am: **Visual and optical evaluation of bank notes in circulation**, S. E. Church, M. P. Lacelle, T. Garanzotis, Bank of Canada (Canada) .. [6075-05]

11:40 am: **The mechanisms of human recognition as a guideline for security feature development**, J. G. Schaede, KBA-GIORI S.A. (Switzerland) [6075-06]

Lunch/Exhibition Break 12:00 to 1:30 pm

SESSION 3

Conv. Ctr. Room A7 **Wed. 1:30 to 3:10 pm**

Security Image Technology I

Chair: Sybrand Spanenburg, Joh. Enschedé Security Printing B.V. (Netherlands)

1:30 pm: **Qualification of security printing features**, S. J. Simske, Hewlett-Packard Labs; J. S. Aronoff, Hewlett-Packard Labs.; J. Arnabat, Hewlett-Packard Co. (Spain) [6075-07]

1:50 pm: **Potentiality of holographic technique in fragile watermarking (Invited Paper)**, G. Schirripa Spagnolo, Univ. degli Studi di Roma Tre (Italy) [6075-08]

2:10 pm: **Secure graphical data storage by full-spectrum image coding**, H. Oltmans, Consultant (Netherlands) [6075-09]

2:30 pm: **Sub-pixel analysis to support graphic security after scanning at low resolution**, R. A. Cordery, Pitney Bowes; S. K. Decker, Digimarc Corp.; B. Haas, Pitney Bowes; H. Gou, Univ. of Maryland/College Park [6075-10]

2:50 pm: **New applications of modulated digital images in document security**, R. Lee, P. W. Leech, L. D. McCarthy, G. F. Swiegers, Commonwealth Scientific & Industrial Research Organisation (Australia) [6075-11]

Coffee Break 3:10 to 3:40 pm

SESSION 4

Conv. Ctr. Room A7 Wed. 3:40 to 5:20 pm

Security Image Technology II

Chair: James M. Jonza, 3M Co.

- 3:40 pm: **Black fluorescent ink and applications**, J. Auslander, R. A. Cordery, Pitney Bowes [6075-37]
- 4:00 pm: **The role of optics in secure credentials**, T. L. Lichtenstein, LaserCard Corp. [6075-13]
- 4:20 pm: **Practical use of lens structures in ID documents**, J. van den Berg, SDU Identification (Netherlands) [6075-14]
- 4:40 pm: **Three-dimensional floating images as overt security features**, D. S. Dunn, T. L. Potts, L. E. Lorimor, J. M. Jonza, R. L. Smithson, S. P. Maki, 3M Co. [6075-15]
- 5:00 pm: **Development of the random-retardation-encoding anti-counterfeiting technology**, W. Huang, C. Tsai, T. Chen, M. Kuan, C. Wen, Industrial Technology Research Institute (Taiwan) [6075-16]

Thursday 19 January

SESSION 5

Conv. Ctr. Room A7 Thurs. 8:10 to 10:10 am

Security Ink Technology

Chair: Roger W. Phillips, JDSU-Flex Products Group

- 8:10 am: **Advanced verification methods for OVI(r) security ink**, P. G. Coombs, Flex Products/JDS Uniphase Corp.; S. F. McCaffery, JDS Uniphase Corp.; T. Markantes, Flex Products/JDS Uniphase Corp. [6075-17]
- 8:30 am: **Overt security features through digital printing**, R. A. Einhorn, M. J. Hampden-Smith, S. Haubrich, J. Shah, R. Bhatia, N. Hardman, R. Kornbrekke, Cabot Corp. [6075-18]
- 8:50 am: **Novel particulate production processes to create unique security materials**, M. J. Hampden-Smith, T. Kodas, S. Haubrich, M. Oljaca, R. A. Einhorn, Cabot Corp. [6075-19]
- 9:10 am: **Combining overt and covert anti-counterfeiting technologies for securities**, T. Uematsu, National Printing Bureau of Japan (Japan) [6075-20]
- 9:30 am: **Bacteriorhodopsin-based multilevel optical security features**, N. A. Hampp, M. Neebe, I. Yang, Philipps-Univ. Marburg (Germany) [6075-21]
- 9:50 am: **Optical security in ink: an industry standard that continues to evolve**, M. Schmid, SICPA SA (Switzerland) [6075-22]
- Coffee Break 10:10 to 10:40 am

SESSION 6

Conv. Ctr. Room A7 Thurs. 10:40 am to 12:00 pm

Optically Variable Devices I

Chair: Wayne R. Tompkin, OVD Kinegram AG (Switzerland)

- 10:40 am: **Current use and efficacy of optical security devices**, I. M. Lancaster, Reconnaissance International Ltd. (United Kingdom) and International Hologram Manufacturing Association (United Kingdom) [6075-23]
- 11:00 am: **The security enhancement of diffractive optically variable image devices**, A. Argoitia, R. W. Phillips, Flex Products/JDSU [6075-24]
- 11:20 am: **The Aztec structure: an improved replicable security device**, J. J. Cowan, Aztec Systems, Inc. [6075-25]
- 11:40 am: **Combination of optically variable diffractive and multilayer interference structures: a new class of security devices**, V. I. Girnyk, Optronics, Ltd. (Ukraine); R. W. Phillips, JDSU-Flex Products Group; E. V. Braginetz, Optronics, Ltd. (Ukraine) and National Kiev Taras Schevchenko Univ. (Ukraine) [6075-26]
- Lunch Break 12:00 to 1:30 pm

SESSION 7

Conv. Ctr. Room A7 Thurs. 1:30 to 2:30 pm

Optically Variable Devices II

Chair: Ian M. Lancaster, Reconnaissance International Ltd. (United Kingdom)

- 1:30 pm: **Novel optically variable color devices**, M. Stalder, F. Seils, Rolic Technologies Ltd. (Switzerland) [6075-27]
- 1:50 pm: **Diffractive Moiré features for optically variable devices**, A. Schilling, W. R. Tompkin, R. Staub, OVD Kinegram AG (Switzerland); R. D. Hersch, S. Chosson, I. Amidror, École Polytechnique Fédérale de Lausanne (Switzerland) [6075-28]
- 2:10 pm: **Combination of e-beam and optical holography on micro- and macro-levels of OVD**, E. V. Braginetz, V. I. Girnyk, Optronics, Ltd. (Ukraine) and National Taras Shevchenko Univ. (Ukraine); B. Holmes, De La Rue International Ltd. (United Kingdom) [6075-29]

SESSION 8

Conv. Ctr. Room A7 Thurs. 2:30 to 4:20 pm

Authentication, Identification, and Biometrics I

Chair: Malcolm R. M. Knight, De La Rue International Ltd. (United Kingdom)

- 2:30 pm: **Choosing the correct forensic marker(s) in currency, document, and product protection**, J. J. Plimmer, Product & Image Security Foundation (United Kingdom) [6075-30]
- 2:50 pm: **Optically variable threads and polarization effects**, F. Kretschmar, Louisenthal GmbH (Germany) [6075-38]
- Coffee Break 3:10 to 3:40 pm
- 3:40 pm: **Life recognition based on color variations in fingerprint images of live and artificial fingers**, K. Tai, M. Kurita, I. Fujieda, Ritsumeikan Univ. (Japan) [6075-32]
- 4:00 pm: **RFID identity theft and countermeasures**, A. Herrigel, Up-Great AG (Switzerland) [6075-33]

SESSION 9

Conv. Ctr. Room A7 Thurs. 4:20 to 5:20 pm

Authentication, Identification, and Biometrics II

Chair: Rudolf L. van Renesse, VanRenesse Consulting (Netherlands)

- 4:20 pm: **On the use of mobile imaging devices for the validation of first and second line security features**, T. F. Rodriguez, M. Weaver III, Digimarc Corp. [6075-34]
- 4:40 pm: **Facets of color laser marking in high secure ID documents**, F. Kappe, M. Schumacher, ORGA Systems enabling services GmbH (Germany); K. Schäfer, M. Hillebrand, M. Hennemeyer-Schwenkner, D. Fischer, Orga Systems GmbH (Germany) [6075-35]
- 5:00 pm: **Protection of data carriers using secure optical codes**, J. A. Peters, A. Schilling, R. Staub, W. R. Tompkin, OVD Kinegram AG (Switzerland) [6075-36]

Standby Oral Presentation

- 5:40 am: **Public education by Central Banks on the Internet**, R. L. van Renesse, VanRenesse Consulting (Netherlands) [6075-39]

Digital Publishing

Conference Chairs: **Jan P. Allebach**, Purdue Univ.; **Hui Chao**, Hewlett-Packard Co.

Program Committee: **Kathrin Berkner**, Ricoh Innovations, Inc.; **Charles A. Bouman**, Purdue Univ.; **David F. Brailsford**, Univ. of Nottingham (United Kingdom); **Richard Furuta**, Texas A&M Univ.; **Steven J. Harrington**, Xerox Corp.; **Yuukou Horita**, Toyama Univ. (Japan); **Charles Jacobs**, Microsoft Corp.; **Dhiraj Kacker**, Caslon & Co.; **John Lumley**, Hewlett-Packard Ltd. (United Kingdom); **Lisa Purvis**, Xerox Corp.; **Fernando Vega**, Univ. de Puerto Rico Mayagüez; **Fabio Vitali**, Univ. degli Studi di Bologna (Italy)

Monday 16 January

SESSION 1

Conv. Ctr. Room A7 Mon. 9:30 am to 12:00 pm

New Publishing Methods

Chair: **Steven J. Harrington**, Xerox Corp.

- 9:30 am: **E-books and the challenge of preservation (Invited Paper)**, F. Romano, Rochester Institute of Technology [6076-01]
10:10 am: **User centered design of the digital book: why looking backward can help us move forward**, J. C. Wallis, Univ. of California/Los Angeles [6076-02]
Coffee Break 10:30 to 11:00 am
11:00 am: **Interactive publications: creation and usage**, G. R. Thoma, G. Ford, M. Chung, K. Vasudevan, S. K. Antani, National Library of Medicine [6076-03]
11:20 am: **Personalized direct marketing using digital publishing**, L. K. Cheeniyil, J. K. Prabhakaran, Hewlett-Packard Co. (India) [6076-05]
11:40 am: **Automated campaign system**, G. L. Vondran, H. Chao, X. Lin, P. Joshi, D. Beyer, C. B. Atkins, P. Obrador, Hewlett-Packard Co. [6076-06]
Lunch Break 12:00 to 1:30 pm

SESSION 2

Conv. Ctr. Room A7 Mon. 1:30 to 3:10 pm

Document Structure and Style

Chair: **John Lumley**, Hewlett-Packard Ltd. (United Kingdom)

- 1:30 pm: **Is the nature of a document changing (Invited Paper)**, J. C. King, S. Towers, Adobe Systems, Inc. [6076-07]
2:10 pm: **Expression of document structure in automatic layout**, S. J. Harrington, Xerox Corp.; R. Price Jones, J. F. Naveda, Rochester Institute of Technology; N. Thakkar, IBM Corp. [6076-08]
2:30 pm: **Evaluating interface aesthetics: measure of symmetry**, H. Balinsky, Hewlett-Packard Ltd. (United Kingdom) [6076-09]
2:50 pm: **Automatic color scheme picker for document templates based on image analysis and dual problem**, P. Obrador, Hewlett-Packard Labs. [6076-10]
Coffee Break 3:10 to 3:40 pm

SESSION 3

Conv. Ctr. Room A7 Mon. 3:40 to 5:20 pm

Artifact Detection

Chair: **Kathrin Berkner**, Ricoh Innovations, Inc.

- 3:40 pm: **Ring artifact measurement for JPEG images**, X. Feng, J. P. Allebach, Purdue Univ. [6076-11]
4:00 pm: **A hybrid intelligence approach to artifact recognition in digital publishing**, F. Vega, H. J. Santos-Villalobos, Univ. de Puerto Rico Mayagüez [6076-12]
4:20 pm: **Nearest-neighbor and bilinear resampling factor estimation to detect blockiness or blurriness of an image**, A. Suwendi, J. P. Allebach, Purdue Univ. [6076-13]
4:40 pm: **Analytical model of skew effect in digital press characterization**, M. Qiao, J. P. Allebach, Purdue Univ. [6076-14]
5:00 pm: **Detection and location of very small print defects in real time for high-speed digital printing**, G. W. Braudaway, IBM Corp. ... [6076-15]

Tuesday 17 January

Plenary Speaker Tues. 8:30 to 9:15 am

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

SESSION 4

Conv. Ctr. Room A7 Tues. 9:30 to 11:20 am

Document and Image Presentation

Chair: **Fabio Vitali**, Univ. degli Studi di Bologna (Italy)

- 9:30 am: **New economy, new strategy: digital technology innovations and applications (Invited Paper)**, N. Raman, Hewlett-Packard Labs. [6076-16]
Coffee Break 10:10 to 10:40 am
10:40 am: **How small should a document thumbnail be?**, K. Berkner, Ricoh Innovations, Inc. [6076-17]
11:00 am: **Image object adaptation in variable data printing**, J. Fan, Hewlett-Packard Labs.; H. Chao, Hewlett-Packard Co. [6076-18]
Lunch/Exhibition Break 11:20 am to 1:20 pm

SESSION 5

Conv. Ctr. Room A7 Tues. 1:20 to 3:00 pm

Document Layout

Chair: **Fernando Vega**, Univ. de Puerto Rico Mayagüez

1:20 pm: **Laying out the future of final-form digital documents (Invited Paper)**, D. F. Brailsford, Univ. of Nottingham (United Kingdom) .. [6076-20]

2:00 pm: **Intelligent content fitting for digital publishing**, X. Lin, Hewlett-Packard Co. [6076-21]

2:20 pm: **A total-fit page-breaking algorithm with user-defined adjustment strategies**, A. Di Iorio, L. Furini, F. Vitali, Univ. degli Studi di Bologna (Italy) [6076-22]

2:40 pm: **Extensible layout in functional documents**, J. Lumley, R. Gimson, O. Rees, Hewlett-Packard Ltd. (United Kingdom) [6076-23]

Coffee Break 3:00 to 3:30 pm

SESSION 6

Conv. Ctr. Room A7 Tues. 3:30 to 5:30 pm

Publishing, Production, and Workflow

Chair: **Dhiraj Kacker**, Caslon & Co., Inc.

3:30 pm: **Production digital printing: making the leap from emerging to everyday (Invited Paper)**, C. Valiquette, Caslon & Co. [6076-24]

4:10 pm: **WARP (workflow for automated and rapid publishing): a framework for end-to-end automated digital publishing workflows**, P. Joshi, Hewlett-Packard Co. [6076-25]

4:30 pm: **A scheduling framework applied to digital publishing workflows**, W. Rivera, W. L'Ozano, Univ. de Puerto Rico Mayagüez [6076-26]

4:50 pm: **Desktop binding: a novel approach to booklet making hardware**, S. W. Trovinger, Hewlett-Packard Co. [6076-27]

5:10 pm: **Color variance in PDF-based production workflows**, M. P. Riordan, Rochester Institute of Technology [6076-28]

Demonstration Session - Tuesday

Visual Communications and Image Processing 2006

Conference Chairs: **John G. Apostolopoulos**, Hewlett-Packard Labs.; **Amir Said**, Hewlett-Packard Labs.

Program Committee: **Kiyoharu Aizawa**, The Univ. of Tokyo (Japan); **Yucel Altunbasak**, Georgia Institute of Technology; **Alan C. Bovik**, The Univ. of Texas at Austin; **Chang Wen Chen**, Florida Institute of Technology; **Charles D. Creusere**, New Mexico State Univ.; **Gerard de Haan**, Philips Research Labs. (Netherlands); **Edward J. Delp III**, Purdue Univ.; **Eric Dubois**, Univ. of Ottawa (Canada); **Frederic Dufaux**, Emitall S.A. (Switzerland); **Touradj Ebrahimi**, Emitall S.A. (Switzerland); **Onur G. Guleryuz**, DoCoMo Communications Labs. USA, Inc.; **Sheila S. Hemami**, Cornell Univ.; **T. Russell Hsing**, Telcordia Technologies, Inc.; **Lina J. Karam**, Arizona State Univ.; **Janusz Konrad**, Boston Univ.; **Alex C. Kot**, Nanyang Technological Univ. (Singapore); **C.-C. Jay Kuo**, Univ. of Southern California; **Reginald L. Lagendijk**, Technische Univ. Delft (Netherlands); **Shipeng Li**, Microsoft Research Asia (China); **Yi Liang**, Qualcomm; **Bangalore S. Manjunath**, Univ. of California/Santa Barbara; **Peyman Milanfar**, Univ. of California/Santa Cruz; **Sanjit K. Mitra**, Univ. of California/Santa Barbara; **Antonio Ortega**, Univ. of Southern California; **Jörn Ostermann**, Univ. Hannover (Germany); **Sethuraman Panchanathan**, Arizona State Univ.; **Thrasyvoulos N. Pappas**, Northwestern Univ.; **William A. Pearlman**, Rensselaer Polytechnic Institute; **Fernando M. B. Pereira**, Instituto Superior Técnico (Portugal); **Béatrice Pesquet-Popescu**, École Nationale Supérieure des Télécommunications (France); **Fatih M. Porikli**, Mitsubishi Electric Research Labs.; **Majid Rabbani**, Eastman Kodak Co.; **Kannan Ramchandran**, Univ. of California/Berkeley; **Kenneth Rose**, Univ. of California/Santa Barbara; **Paul Salama**, Indiana Univ./Purdue Univ. at Indianapolis; **Dan Schonfeld**, Univ. of Illinois at Chicago; **Thomas Sikora**, Technische Univ. Berlin (Germany); **Eckehard G. Steinbach**, Ludwig-Maximilians-Univ. München; **Robert L. Stevenson**, Univ. of Notre Dame; **Thomas Stockhammer**, Technische Univ. München (Germany); **Huifang Sun**, Mitsubishi Electric Research Labs.; **Ming-Ting Sun**, Univ. of Washington; **Andrew G. Tescher**, AGT Associates; **Bhaskaran Vasudev**, Epsilon Palo Alto Lab.; **Anthony Vetro**, Mitsubishi Electric Research Labs.; **John W. Woods**, Rensselaer Polytechnic Institute

Tuesday 17 January

Plenary Speaker **Tues. 8:30 to 9:15 am**

Marriott Ballroom 1-6

Image Processing: Interconnections

Thomas S. Huang, Beckman Institute for Advanced Science and Technology, Univ. of Illinois at Urbana-Champaign

See p. 7 for details.

Sessions 1 and 2 run concurrently.

SESSION 1

SESSION 2

Conv. Ctr. Room B3 **Tues. 1:30 to 5:10 pm**

Special Session: Superresolution

Chair: Onur G. Guleryuz, DoCoMo Communications Labs. USA, Inc.

1:30 pm: **Superresolution of text from nonideal video** (*Invited Paper*), X. Li, West Virginia Univ. [6077-01]

1:55 pm: **Registration of aliased images for super-resolution imaging** (*Invited Paper*), P. Vandewalle, L. M. Sbaiz, S. E. Süssstrunk, École Polytechnique Fédérale de Lausanne (Switzerland); M. Vetterli, École Polytechnique Fédérale de Lausanne (Switzerland) and Univ. of California/Berkeley [6077-02]

2:20 pm: **A practical approach to superresolution** (*Invited Paper*), S. Farsiu, Univ. of California/Santa Cruz; M. Elad, Technion - Israel Institute of Technology (Israel); P. Milanfar, Univ. of California/Santa Cruz ... [6077-03]

2:45 pm: **Jitter camera: a superresolution video camera** (*Invited Paper*), M. Ben-Ezra, Siemens Corporate Research; A. Zomet, S. K. Nayar, Columbia Univ. [6077-04]

Coffee Break 3:10 to 3:40 pm

3:40 pm: **Face recognition with independent component based superresolution** (*Invited Paper*), O. G. Sezer, Sabanci Univ. (Turkey); Y. Altunbasak, Georgia Institute of Technology; A. Ercil, Sabanci Univ. (Turkey) [6077-05]

4:05 pm: **Toward new a compression standard using superresolution techniques** (*Invited Paper*), R. Molina, Univ. de Granada (Spain); A. K. Katsaggelos, Northwestern Univ.; L. Alvarez, J. Mateos, Univ. de Granada (Spain) [6077-25]

4:30 pm: **Robust superresolution based on pixel-level selectivity**, Z. A. Ivanovski, I. Panovski, Ss Cyril and Methodius Univ. (Macedonia); L. J. Karam, Arizona State Univ. [6077-07]

4:50 pm: **Resolution enhancement of low-quality videos using a high-resolution frame**, T. Q. Pham, L. J. van Vliet, Technische Univ. Delft (Netherlands); K. Schutte, TNO-FEL (Netherlands) [6077-08]

Conv. Ctr. Room B2 **Tues. 1:30 to 4:40 pm**

Video Coding

Chair: Robert L. Stevenson, Univ. of Notre Dame

1:30 pm: **Predictive fast motion/disparity search for multiview video coding**, P. Lai, A. Ortega, Univ. of Southern California [6077-09]

1:50 pm: **Complexity scalable motion estimation for H.264/AVC**, C. Kim, Univ. of Southern California; J. Xin, A. Vetro, Mitsubishi Electric Research Labs.; C. C. J. Kuo, Univ. of Southern California [6077-10]

2:10 pm: **Depth map compression for unstructured lumigraph rendering**, U. Fecker, A. Guenegues, I. Scholz, A. Kaup, Friedrich-Alexander-Univ. Erlangen-Nürnberg (Germany) [6077-11]

2:30 pm: **Shape adaptive integer transform for coding arbitrarily shaped objects in H264/AVC**, X. Li, E. A. Edirisinghe, H. E. Bez, Loughborough Univ. (United Kingdom) [6077-12]

2:50 pm: **Optimal bit allocation for hybrid scalable/multiple-description video transmission over wireless channels**, M. Bansal, M. K. Jubran, L. P. Kondi, SUNY/Univ. at Buffalo [6077-13]

Coffee Break 3:10 to 3:40 pm

3:40 pm: **Space-time multiple description video coding**, D. Wang, N. Canagarajah, D. Bull, Univ. of Bristol (United Kingdom) [6077-14]

4:00 pm: **Improving sequential decoding of CABAC encoded data via collective adjustment of the complexity-efficiency trade-off**, S. Ben-Jamaa, M. Kieffer, P. Duhamel, Univ. Paris XI (France) and Ctr. National de la Recherche Scientifique (France) [6077-15]

4:20 pm: **New intra-luma prediction mode in H.264/AVC using collocated weighted chroma pixel value**, I. Cho, J. Lee, W. Lee, D. Jeong, Inha Univ. (South Korea) [6077-16]

✓ **Posters and Demonstrations-Tuesday**

Demonstrations 5:30 to 8:30 pm

A symposium-wide demonstration session will be open to attendees 5:30 to 8:30 pm Tuesday evening in Conv. Ctr. Exhibit Hall 1. Demonstrators will provide interactive, hands-on demonstrations of a wide-range of products related to Electronic Imaging.

Posters 5:30 to 7:00 pm

Posters will be placed on display after 10:00 am in Exhibit Hall 1. A poster session, with authors present at their posters, will be held Tuesday evening, 5:30 to 7:00 pm.

- ✓ **Coupled nonlinear-diffusion color image sharpening based on the chromaticity-brightness model**, T. Saito, R. Nosaka, T. Komatsu, Kanagawa Univ. (Japan) [6077-56]
- ✓ **Parallel implementation of arbitrary-shaped MPEG-4 decoder for multiprocessor systems**, M. Pastrnak, P. H. N. de With, LogicaCMG (Netherlands) and Technische Univ. Eindhoven (Netherlands); S. Stuijk, J. van Meerbergen, Technische Univ. Eindhoven (Netherlands) [6077-57]
- ✓ **A framework for fast mode decision in the H.264 video coding standard**, M. Y. Yang, C. Grecos, Loughborough Univ. (United Kingdom) [6077-58]
- ✓ **Interpolation of still images using the decay and persistence properties of discrete wavelet transform coefficients**, W. Kwak, R. Park, J. Lee, Sogang Univ. (South Korea) [6077-59]
- ✓ **Optimum computational resource allocation and energy minimization for video encoding on portable devices**, Z. He, Univ. of Missouri/Columbia [6077-60]
- ✓ **Optimal video sensing strategy and performance analysis for wireless video sensors**, Z. He, Univ. of Missouri/Columbia . . [6077-61]
- ✓ **Shot boundary detection using scale invariant feature matching**, M. Park, R. Park, S. W. Lee, Sogang Univ. (South Korea) [6077-62]
- ✓ **Extracting focused object from low depth-of-field image sequences**, J. Park, C. Kim, Information and Communications Univ. (South Korea) [6077-63]
- ✓ **Adaptive de-blocking filter for low bit rate applications**, X. Jin, G. Zhu, Huazhong Univ. of Science and Technology (China) [6077-64]
- ✓ **Fast intra-mode decision algorithm of H.264/AVC**, W. Lee, J. Lee, I. Cho, D. Jeong, Inha Univ. (South Korea) [6077-65]
- ✓ **A splitting algorithm for touched particle based on distance map and particle shape information**, W. Wang, Chongqing Univ. of Posts and Telecommunications (China) [6077-66]
- ✓ **Geo-registration of aerial images by feature matching**, Z. Wu, H. Qian, M. Zhu, Zhejiang Univ. (China) [6077-67]
- ✓ **A new segmentation approach using Gaussian color model and temporal information**, M. Karaman, L. Goldmann, T. Sikora, Technische Univ. Berlin (Germany) [6077-68]
- ✓ **Region-based transform-domain video scrambling**, F. Dufaux, T. Ebrahimi, Emitall S.A. (Switzerland) and École Polytechnique Fédérale de Lausanne (Switzerland) [6077-69]
- ✓ **Robust face detection based on components and their topology**, L. Goldmann, U. Mönich, T. Sikora, Technische Univ. Berlin (Germany) [6077-70]
- ✓ **Resolution scalable SPIHT**, D. Choundappan, P. Salama, M. Rizkalla, M. El-Sharkawy, Indiana Univ./Purdue Univ. at Indianapolis . . [6077-72]
- ✓ **Robust global motion estimation in video stabilization for reducing visually induced motion sickness**, I. Tsubaki, Kanagawa Univ. (Japan); T. Morita, NHK Engineering Services (Japan); K. Aizawa, The Univ. of Tokyo (Japan); T. Saito, Kanagawa Univ. (Japan) [6077-73]
- ✓ **Spatially variant morphological image processing: theory and applications**, N. Bouaynaya, D. Schonfeld, Univ. of Illinois at Chicago [6077-74]
- ✓ **Video frame rate up conversion under inconsistent camera**, J. Wang, Wayne State Univ.; N. Patel, W. Grosky, Univ. of Michigan/ Dearborn [6077-75]
- ✓ **Pre-compression rate allocation for JPEG2000 encoders in power constrained devices**, F. Chebil, R. Kurceren, Nokia Americas [6077-76]
- ✓ **Distortion fluctuation control for 3D wavelet-based video coding**, V. Seran, L. P. Kondi, SUNY/Univ. at Buffalo [6077-77]
- ✓ **Reduction of MPEG ringing artifacts using adaptive sigma filter**, H. Pan, Sharp Labs. of America, Inc. [6077-78]
- ✓ **Bit-stream extraction to maximize perceptual quality using quality information table in SVC**, Y. S. Kim, Y. J. Jung, T. C. Thang, Y. M. Ro, Information and Communications Univ. (South Korea) [6077-79]
- ✓ **Active surfaces for video tracking and 3D segmentation based on a new method for multidimensional optimization**, N. Bouaynaya, D. Schonfeld, Univ. of Illinois at Chicago [6077-80]
- ✓ **Robust transmission of packet-based H.264/AVC video with data partitioning over DS-CDMA wireless channels**, A. V. S. Mantravadi, M. Bansal, L. P. Kondi, SUNY/Univ. at Buffalo [6077-81]
- ✓ **A novel VLC-based on second-run-level coding and dynamic truncation**, C. h. Cui, W. y. Liu, X. Jin, Huazhong Univ. of Science and Technology (China) [6077-82]
- ✓ **Efficient coding scheme for super high definition video based on extending H.264 high profile**, S. Naito, A. Matsumura, KDDI R&D Labs. (Japan) [6077-83]
- ✓ **Fish tracking by combining motion-based segmentation and particle filtering**, E. Bichot, L. Mascarilla, P. Courtellemont, Univ. de La Rochelle (France) [6077-85]
- ✓ **Multiresolution color patch extraction**, P. Obrador, Hewlett-Packard Labs. [6077-86]
- ✓ **Disparity estimation using edge model for stereo video compression**, H. J. Kim, Y. Lee, J. B. Ra, K. Cho, Korea Advanced Institute of Science and Technology (South Korea) [6077-87]
- ✓ **Adaptive λ estimation in Lagrangian rate-distortion optimization for video coding**, L. Chen, Mobilygen Corp. . . [6077-88]

Wednesday 18 January

Plenary Speaker **Wed. 8:30 to 9:15 am**
Marriott Ballroom 1-6
Computational Imaging Methods for Functional Brain Mapping and Molecular Imaging
Richard Leahy, Univ. of Southern California
See p. 7 for details.

Sessions 3 and 6 run concurrently.

SESSION 3

SESSION 6

Conv. Ctr. Room B3 **Wed. 9:30 am to 12:05 pm**

Conv. Ctr. Room B2 **Wed. 9:30 am to 12:00 pm**

Special Session: Current Topics in Video Coding

Computer Vision

Chairs: Mary L. Comer, Purdue Univ.; Edward J. Delp III, Purdue Univ.

Chair: Dan Schonfeld, Univ. of Illinois at Chicago

- 9:30 am: **Rate-distortion analysis of SP and SI frames (Invited Paper)**, E. Setton, P. Ramanathan, B. Girod, Stanford Univ. [6077-17]
- 9:55 am: **Wyner-Ziv video coding with universal prediction**, Z. Li, L. Liu, E. J. Delp III, Purdue Univ. [6077-18]
- Coffee Break 10:20 to 10:50 am
- 10:50 am: **Hybrid scalable video coding with multiple description and layered coding (Invited Paper)**, G. Zhang, R. L. Stevenson, Univ. of Notre Dame [6077-19]
- 11:15 am: **Wyner-Ziv video coding: a motion estimation perspective**, Z. Li, L. Liu, E. J. Delp III, Purdue Univ. [6077-20]
- 11:40 am: **A new approach to motion compensation in spatially scalable video coding (Invited Paper)**, M. L. Comer, Purdue University [6077-21]
- Lunch/Exhibition Break 12:00 to 1:35 pm

- 9:30 am: **Parallel multiple target tracking using multiple cooperative trackers**, W. Qu, D. Schonfeld, Univ. of Illinois at Chicago; M. A. Mohamed, Motorola, Inc. [6077-31]
- 9:50 am: **Rao-Blackwellised particle filter with adaptive system noise and its evaluation for tracking in surveillance**, X. Xu, B. Li, Arizona State Univ. [6077-32]
- 10:10 am: **Spatial detection of logos as outliers from the content**, A. Ekin, Philips Research Labs. (Netherlands) [6077-33]
- Coffee Break 10:30 to 11:00 am
- 11:00 am: **Finding corners in images by foveated search**, T. L. Arnow, A. C. Bovik, The Univ. of Texas at Austin [6077-34]
- 11:20 am: **Two-dimensional regularized disparity estimation based on the Gabor transform**, X. Huang, E. Dubois, Univ. of Ottawa (Canada) [6077-35]
- 11:40 am: **Plane-based calibration of cameras with zoom variation**, C. Yu, G. Sharma, Univ. of Rochester [6077-36]
- Lunch/Exhibition Break 12:00 to 2:00 pm

Sessions 4 and 7 run concurrently.

SESSION 4

SESSION 7

Conv. Ctr. Room B3 **Wed. 1:35 to 3:15 pm**

Conv. Ctr. Room B2 **Wed. 2:00 to 3:00 pm**

Special Session: Advances in Image/Video Coding and Delivery

Video Processing

Chair: John G. Apostolopoulos, Hewlett-Packard Labs.

Chair: Remco Muijs, Philips Research Labs. (Netherlands)

- 1:35 pm: **Distributed sender-driven video streaming (Invited Paper)**, J. Chakareski, P. Frossard, École Polytechnique Fédérale de Lausanne (Switzerland) [6077-22]
- 2:00 pm: **Advances in video encoder optimization (Invited Paper, Presentation Only)**, A. Dumitras, Apple Computer, Inc. [6077-23]
- 2:25 pm: **Suprathreshold visual psychophysics and structure-based visual masking (Invited Paper)**, S. S. Hemami, D. M. Chandler, B. Chern, J. A. Moses, Cornell Univ. [6077-24]
- 2:50 pm: **Video compression with flexible playback order based on distributed source coding (Invited Paper)**, N. Cheung, H. Wang, A. Ortega, Univ. of Southern California [6077-89]
- Coffee Break 3:15 to 3:45 pm

- 2:00 pm: **Classification-based hybrid filters for image processing**, H. Hu, Technical Univ. of Eindhoven (Netherlands); G. de Haan, Philips Research Labs. (Netherlands) [6077-37]
- 2:20 pm: **Solving occlusion in film judder elimination**, E. B. Bellers, Philips Semiconductors; J. van Gurp, Philips Semiconductors (Netherlands); J. Janssen, Philips Semiconductors; R. A. C. Braspenning, R. Wittebrood, Philips Research Labs. (Netherlands) [6077-39]
- 2:40 pm: **Similarity-independent and non-iterative algorithm for subpixel motion estimation**, M. Shimizu, S. Chang, M. Okutomi, Tokyo Institute of Technology (Japan) [6077-40]
- Coffee Break 3:00 to 3:30 pm

Sessions 5 and 8 run concurrently.

SESSION 5

Conv. Ctr. Room B3 Wed. 3:45 to 5:25 pm

Distributed Source Coding

Chair: Majid Rabbani, Eastman Kodak Co.

- 3:45 pm: **H.264 redundant slices for systematic lossy error protection of video**, S. D. Rane, B. Girod, Stanford Univ. [6077-26]
- 4:05 pm: **Correlation estimation and performance optimization for distributed image compression**, Z. He, Univ. of Missouri/Columbia [6077-27]
- 4:25 pm: **Correlation structure analysis for distributed video compression over wireless video sensor networks**, Z. He, Univ. of Missouri/Columbia [6077-28]
- 4:45 pm: **Distributed multiview video coding**, X. Guo, Harbin Institute of Technology (China) and Microsoft Research Asia (China); Y. Lu, F. Wu, Microsoft Research Asia (China); W. Gao, Institute of Computing Technology (China); S. Li, Microsoft Research Asia (China) and Beijing Institute of Technology (China) [6077-29]
- 5:05 pm: **Free viewpoint switching in multiview video streaming using Wyner-Ziv video coding**, X. Guo, Harbin Institute of Technology (China); Y. Lu, F. Wu, Microsoft Research Asia (China); W. Gao, Institute of Computing Technology (China); S. Li, Microsoft Research Asia (China) [6077-30]

SESSION 8

Conv. Ctr. Room B2 Wed. 3:30 to 4:30 pm

Image Coding

Chair: William A. Pearlman, Rensselaer Polytechnic Institute

- 3:30 pm: **A wavelet-based two-stage near-lossless coder with L-infinity error scalability**, S. Yea, W. A. Pearlman, Rensselaer Polytechnic Institute [6077-41]
- 3:50 pm: **Region of interest access with three-dimensional SBHP algorithm**, Y. Liu, W. A. Pearlman, Rensselaer Polytechnic Institute [6077-42]
- 4:10 pm: **Optimal JPEG2000 rate control mechanism applicable for super low delay distribution of HDTV programs**, S. Naito, A. Koike, Kokusai Dinshin Denwa KK (Japan) [6077-43]

Thursday 19 January

SESSION 9

Conv. Ctr. Room B3 Thurs. 9:30 to 11:40 am

Media over Networks

Chair: Paul Salama, Indiana Univ./Purdue Univ. at Indianapolis

- 9:30 am: **Error resilience in network driven Wyner-Ziv video coding**, L. Liu, P. Sabria, Purdue Univ.; J. Prades-Nebot, Univ. Politècnica de València (Spain); E. J. Delp III, Purdue Univ. [6077-45]
- 9:50 am: **Receiver buffer requirement for video streaming over TCP**, T. Kim, Freescale Semiconductor, Inc.; M. H. Ammar, Georgia Institute of Technology [6077-46]
- 10:10 am: **Effective overlay multicast tree constructing algorithm over multiple differentiated-service networks**, D. B. Lee, H. Song, Pohang Univ. of Science and Technology (South Korea) [6077-47]
- Coffee Break 10:30 to 11:00 am
- 11:00 am: **A novel source rate control algorithm for video streaming over the Internet**, Z. Peng, Tsinghua Univ. (China); W. Zeng, Univ. of Missouri/Columbia; C. W. Li, Tsinghua Univ. (China) [6077-48]
- 11:20 am: **Motion-embedded residual error for packet loss recovery of video transmission and encryption**, S. Sun, Institute of Information Science (Taiwan); J. Chen, National Central Univ. (Taiwan); C. Lu, Institute of Information Science (Taiwan); P. Chang, K. Fan, National Central Univ. (Taiwan) [6077-49]
- Lunch Break 11:40 am to 1:30 pm

SESSION 10

Conv. Ctr. Room B3 Thurs. 1:30 to 3:10 pm

Scalable Video Coding

Chair: John W. Woods, Rensselaer Polytechnic Institute

- 1:30 pm: **A new structure of 3D dual-tree discrete wavelet transforms and applications to video denoising and coding**, F. Shi, B. Wang, I. W. Selesnick, Y. Wang, Polytechnic Univ. [6077-50]
- 1:50 pm: **On scalable lossless video coding based on subpixel accurate MCTF**, S. Yea, W. A. Pearlman, Rensselaer Polytechnic Institute [6077-51]
- 2:10 pm: **Aliasing reduction via frequency roll-off for scalable image/video coding**, Y. Wu, J. W. Woods, Rensselaer Polytechnic Institute [6077-52]
- 2:30 pm: **Adaptive in-band motion compensated temporal filtering based on motion mismatch detection in the high-pass subbands**, A. Gao, N. Canagarajah, D. Bull, Univ. of Bristol (United Kingdom) . [6077-53]
- 2:50 pm: **Quality-fluctuation-constrained rate allocation for MCTF-based video coding**, Y. Chen, Shanghai Jiao Tong Univ. (China); J. Xu, F. Wu, Microsoft Research Asia (China); H. Xiong, Shanghai Jiao Tong Univ. (China) [6077-54]

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Monday-Wednesday 16-18 January 2006

Part of Proceedings of SPIE Vol. 6055 Stereoscopic Displays and Virtual Reality Systems XIII

6055A-01, Session 1

The use of stereoscopic visualization in chemistry and structural biology

M. Hušák, Institute of Chemical Technology Prague (Czech Republic)

The results of experimental measurements of molecular structures (such as X-ray diffractions techniques or NMR techniques) are often hard to interpret. The obtained 3D data as electron density maps, atoms coordinates and molecular space arrangements are complex objects and they require sophisticated visualization methods. In the presentation will be given an overview of existing chemical software supporting stereoscopic visualization. The main parts of the lecture will discuss our experiences with creating an ergonomically comfortable working environment for everyday stereoscopic visualization use for chemical structure analysis purpose. Implementation of the necessary stereoscopic visualization functionalities in MCE code developed by us (code for interpretation of X-ray diffraction and quantum mechanical calculations) will be discussed as well.

6055A-02, Session 1

Using stereoscopic real-time graphics to shorten training time for complex mechanical tasks

F. Tecchia, M. Carrozzino, F. Rossi, M. Bergamasco, Scuola Superiore Sant'Anna (Italy); M. Vescovi, SIG Simonazzi (Italy)

The present paper presents the hands-on results of the use of a large screen stereoscopic installation to train technicians on maintenance tasks of large machineries for a leading mechanical industry. Such machinery, deployed from the company in remote locations around the world, need complex and lengthy maintenance procedures, to be performed periodically by teams of highly trained technicians. The firm organises continuous training classes to a large number of its technicians, using qualified trainers and continuously updating machinery documentation, resulting in long and expensive periods of time of technicians inactivity. Classes involve training on assembly and disassembly operations of the company complex mechanical products and were traditionally based on the use of video documentation, 2D mechanical drawings and live demonstrations on real equipment. In an attempt to improve this process, the firm equipped one of their training centres with a large stereoscopic projection facility and dedicated software, introducing the use of real-time stereo rendering of CAD models for virtual disassembly/assembly sequences. The firm investigated then potential benefits of the new methodology compared to the traditional one. The present article presents an overview of the technological framework used, and summarises the results of such comparison performed over a period of 6 months.

6055A-03, Session 1

Stereoscopic display of 3D models for design visualization

K. J. Gilson, Parsons Brinckerhoff

Advances in display technology and 3D design visualization applications have made real-time stereoscopic visualization of architectural and engineering projects a reality. Parsons Brinckerhoff (PB) is a transportation consulting firm that has used digital visualization tools from their inception and has helped pioneer the

application of those tools to large scale infrastructure projects. PB is one of the first Architecture/Engineering/Construction (AEC) firms to implement a CAVE- an immersive presentation environment that includes stereoscopic rear-projection capability. The firm also employs a portable stereoscopic front-projection system, and shutter-glass systems for smaller groups.

PB is using commercial real-time 3D applications in combination with traditional 3D modeling programs to visualize and present large AEC projects to planners, clients and decision makers in stereo. These presentations create more immersive and spatially realistic presentations of the proposed designs. This paper will present the basic display tools and applications, and the 3D modeling techniques PB is using to produce interactive stereoscopic content. The paper will discuss several architectural and engineering design visualizations we have produced.

6055A-04, Session 1

Stereoscopic image production: live, CGI, and integration

E. Criado, Enxebre Entertainment (Spain)

Stereoscopic image production is complex, but even more than shooting technical parameters, some of them also considered here, I analyze some other differences between classic or flat production compared to stereoscopic production, that should be taken in care and could make the difference between success and ruin, for a 3-D film. This reading does not try to be an exhaustive analysis, but it could offer a global approach to the problematic of a stereoscopic production, reviewing preproduction, the shooting and postproduction processes, including some details about stereoscopic live and computer graphics imagery integration.

6055A-05, Session 1

Cosmic cookery: making a stereoscopic 3D animated movie

N. S. Holliman, C. Baugh, C. Frenk, A. Jenkins, B. Froner, D. Hassaine, J. Helly, N. Metcalfe, T. Okamoto, Univ. of Durham (United Kingdom)

This paper describes our experience making a short stereoscopic movie visualizing the development of structure in the universe during the 13.7 billion years from the Big Bang to the present day. Aimed at a general audience for the Royal Society's 2005 Summer Science Exhibition, the movie illustrates how the latest cosmological theories based on dark matter and dark energy are capable of producing structures as complex as spiral galaxies and allows the viewer to compare observations from the real universe with theoretical results. 3D is an inherent feature of the cosmology data sets and stereoscopic visualization provides a natural way to present the images, in addition allowing researchers to visualize these complex data sets.

The presentation of the movie used passive polarized projection onto a 2m wide screen and also played back on a Sharp RD3D and subsequently in anaglyph projection at venues without stereoscopic displays. We conclude that the generation of high quality stereoscopic movie content using desktop tools and equipment is feasible. This does require careful quality control and manual intervention, but we believe these overheads are worthwhile when presenting inherently 3D data, as the result is significantly increased impact and better understanding of complex 3D scenes.

6055A-06, Session 2

Evaluation of stereoscopic medical video content on an autostereoscopic display for undergraduate medical education

J. F. R. Ilgner, Univ. Hospital Aachen (Germany); T. Kawai, T. Shibata, T. Yamazoe, Waseda Univ. (Japan); M. Westhofen, Univ. Hospital Aachen (Germany)

Introduction: This study evaluates the usefulness of stereoscopic video in teaching undergraduate medical students.

Material and methods: We chose two clips each of three different microsurgical operations. This material was added by 23 clips of a cochlear implantation, which was specifically edited for a portable computer with an autostereoscopic display (SHARP 3DRD). The footage was edited stereoscopically at the Waseda University by means of our original software for non-linear editing of stereoscopic 3-D movies. 25 4th year medical students who participated in the general ENT course at Aachen University Hospital were asked to estimate depth clues within the six video clips plus cochlear implantation clips. Another 25 4th year students who were shown the material monoscopically on a conventional laptop served as control.

Results: The monoscopic group generally estimated resection depth to much lesser values than in reality. Although this was the case with some participants in the stereoscopic group, too, the estimation of depth features reflected the enhanced depth impression provided by stereoscopy.

Conclusion: Following first implementation of stereoscopic video teaching, medical students who are inexperienced with ENT surgical procedures are able to reproduce depth information and therefore anatomically complex structures to a greater extent following stereoscopic video teaching.

6055A-07, Session 2

Stereoscopic visualization and editing of automatic abdominal aortic aneurysms (AAA) measurements for stent graft planning

L. Zhou, Y. P. Wang, C. Goh, R. Kockro, L. Serra, Volume Interactions Pte. Ltd. (Singapore)

For stent graft selection in the treatment of abdominal aortic aneurysms (AAA) anatomic considerations are important. They determine GO/NO-GO of the treatment and help customize the stent. Current systems for AAA stent insertion planning based on pre-operative CT and MR of the patient do not provide an intuitive interface to view the resulting measurements against the pre-operative CT/MR. Subsequent modifications of the measurements are frequent when automatic algorithms are inaccurate. However, 3D editing is difficult to achieve because of the limitations of monoscopic displays and 2D interface. In this paper, we present a system for automatic AAA measurement and interactive 3D editing. The strength of this approach is that the resulting measurements can be reviewed and edited interactively in the 3D context of the volumetric rendering of the aorta, so that relationships of the measurements and the aorta are clearly perceived. This understanding is facilitated by the stereoscopic rendering that makes it possible to see the transparent vessel and its corresponding measurements all in one image.

6055A-08, Session 2

A hybrid virtual environment for training of radiotherapy treatment of cancer.

R. Phillips, The Univ. of Hull (United Kingdom)

There is often insufficient access to patients and linear accelerator treatment rooms to train radiotherapy students. An alternative approach is to train using a hybrid Immersive Visualization Environment (IVE) that simulates an actual radiotherapy treatment machine controlled with the actual machine handheld control pendant. A study of training using this IVE is presented for "skin apposition" treatment, where the patient couch and radiotherapy equipment are positioned so that the X-ray beam strikes the skin perpendicularly.

The IVE developed comprises a virtual treatment room with a linear accelerator, modelled from laser scan data, stereoscopically projected onto a 16 x 8 foot work-wall. A genuine linear accelerator control handheld "pendant" provided the user interface to the virtual linear accelerator thus creating a hybrid IVE. A virtual patient, based on the visible human female dataset, complete with rectangular markings for a range of different treatment sites, provided a range of treatment scenarios. Quantitative metrics on how well the patient was positioned were also produced by the IVE.

A study of 42 students was conducted to evaluate learning. 93% of students perceived an improvement in their understanding of this treatment using the IVE and 69% found the control system to be "easy to master".

6055A-09, Session 2

Blur spot limitations in distal endoscope sensors

A. Yaron, Visionsense Inc.; M. Shechterman, N. Horesh, U. Ronen, Visionsense Ltd. (Israel)

With current development of sensors, displays and bandwidth, image quality of video systems is typically limited by optics. Further reduction of pixel size in distal endoscope CCD or CMOS cameras will not provide a better image quality. The limiting factor is the blur spot (diffraction limit) phenomena. Stereo sensors that multiplex the horizontal field are indifferent to this optical effect and thus can provide additional depth resolution without sacrificing 2D resolution. Additional advantages of such sensors are reduced aliasing and improved tolerance to noise.

6055A-10, Session 3

Visual comfort with mobile stereoscopic gaming

J. P. Häkkinen, Nokia Research Ctr. (Finland) and Univ. of Helsinki (Finland); M. Liinasuo, Nokia Research Ctr. (Finland); J. Takatalo, G. S. Nyman, Univ. of Helsinki (Finland)

Stereoscopic displays are known to cause eye strain because of the convergence-accommodation conflict caused by the stereoscopic content. We tested the level of eye strain with a stereoscopic mobile phone game with small disparities. The users played a simple puzzle game with Sharp SH505i mobile phone which has a parallax barrier autostereoscopic display. There were 5 experiments with different disparity in each: 1) Far depth 5.4 arc min, 2) Far depth 2.7 arc min, 3) Zero disparity, 4) Near depth 2.7 arc min and 5) Near depth 5.4 arc min. In every experiment there were 30 users, so the total number of participants was 150. We measured subjective sickness symptoms with the Simulator Sickness Questionnaire and visual functioning by testing the heterophoria and the near point of accommodation. The results showed that most of the users got

some eye strain symptoms both in the disparity conditions and in the zero disparity condition. The mean eye strain levels did not significantly differ in the zero disparity and other experimental conditions. The results indicate that using small disparities in the mobile stereoscopic displays enables a comfortable user experience.

6055A-11, Session 3

Effect of disparity and motion on visual comfort of stereoscopic images

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It is well known that some viewers experience visual discomfort when looking at stereoscopic displays. One of the factors that can give rise to visual discomfort is the presence of large horizontal disparities. The relationship between excessive horizontal disparity and visual comfort has been well documented for the case in which disparity magnitude does not change across space and time, e.g. for objects in still images. Much less is known about the case in which disparity magnitude varies over time, e.g., objects moving in depth at some velocity. In this study, we investigated the relationship between binocular disparity, object motion and visual comfort using computer-generated stereoscopic video sequences. Specifically, viewers were asked to rate the visual comfort of stereoscopic sequences that had objects moving periodically back and forth in depth. These sequences varied with respect to the number, size, position in depth, and velocity of movement of the objects included in the scene. The results indicated that with motion in depth, ratings of visual comfort depend on the velocity of the stereoscopic objects rather than on disparity per se. The results also suggest that rapid switches between crossed and uncrossed disparities might negatively affect visual comfort.

6055A-12, Session 3

Analysis of an autostereoscopic display: the perceptual range of the three-dimensional visual fields and saliency of static depth cues

P. R. Havig, Air Force Research Lab.; J. P. McIntire, Consortium Research Fellows Program; R. McGruder, U.S. Air Force Academy

Autostereoscopic displays offer users the unique ability to view 3-dimensional (3D) imagery without special eyewear or headgear. However, the users' head must be within limited "eye boxes" or "viewing zones." Further, little research has evaluated these viewing zones from a human-in-the-loop, subjective perspective. In the first study, twelve participants evaluated the quality and amount of perceived 3D images. We manipulated distance from observer, viewing angle, and stimuli to characterize the perceptual viewing zones. The data was correlated with objective measures to investigate the amount of concurrence between the objective and subjective measures. In a second study we investigated the benefit of generating stimuli that take advantage of monocular depth cues. The purpose of this study was to determine if one could develop optimal stimuli that would give rise to the greatest 3D effect with off-axis viewing angles. Twelve participants evaluated the quality of depth perception of various stimuli each made up of one monocular depth cue (i.e., linear perspective, occlusion, haze, size, texture, and horizon). Viewing zone analysis is discussed in terms of optimal viewing distances and viewing angles. Stimuli properties are discussed in terms of image complexity and depth cues present.

6055A-13, Session 3

Effects of gender, application, experience, and constraints on interaction performance using autostereoscopic displays

Z. Y. Alpaslan, S. Yeh, A. A. Rizzo III, A. A. Sawchuk, Univ. of Southern California

We describe a set of experiments that compare 2D CRT, shutter glasses and autostereo displays; measure user preference for different tasks in different displays; measure the effect of previous user experience in the interaction performance for new tasks; and measure the effect of constraining user's hand motion and hand eye coordination.

In this set of tests, we used interactive object selection and manipulation tasks using standard scalable configurations of 3D block objects. We also used a 3D depth matching test in which subjects are instructed to align two objects located next to each other on the display to the same depth plane.

New subjects tested with hands out of field of view constraint performed more efficiently with glasses than with autostereoscopic displays, meaning they were able to match the objects with less movement. This constraint affected females more negatively than males. From the results of the depth test, we note that previous subjects on average performed better than the new subjects. Previous subjects had more correct results than the new subjects, and they finished the test faster than the new subjects. The depth test showed that glasses are preferred to autostereo displays in a task that involves only stereoscopic depth.

6055A-14, Session 3

Examination of asthenopia recovery using stereoscopic 3D display with dynamic optical correction

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The common cause of asthenopia is viewing objects from a short distance, such as in VDT (Visual Display Terminal) work. In general, recovery from asthenopia, especially accommodative asthenopia, is aided by looking into the distance. The authors have developed a stereoscopic 3-D display with dynamic optical correction. The display can reduce the discrepancy between accommodation and convergence while viewing stereoscopic 3-D images. Since the display presents images as if they were actually in the distance, the authors considered that viewing images on the display might reduce asthenopia. The authors previously performed the visual acuity test before and after presenting stereoscopic 3-D images in order to verify the hypothesis. The result showed that there was a tendency to recover asthenopia. In this study, the authors developed a feedback function of the presenting stereoscopic 3-D images on the developed display for the purpose of making viewer's distant vision more effective. Using the function, the refraction under viewing is fed back for the image presentation, and the viewer can gradually take distant vision. From the result of the experiment, it was suggested that asthenopia recovery using stereoscopic 3-D images was effective in comparison with 2-D images.

6055A-15, Session 4

High-resolution insets in projector-based stereoscopic displays: principles and techniques

G. Godin, P. Massicotte, L. Borgeat, National Research Council Canada (Canada)

We propose a dual-resolution foveated stereoscopic display built from commodity projectors and computers. The technique is aimed at increasing the access to fine details of 3D models on a wall-type interactive display: it projects a high-resolution inset (or fovea, by analogy to biological vision) that is registered in image space with the large display. A specific issue that must be addressed is the conflict in depth perception between the apparent depth of the natural boundary of the projected inset images (visible due to changes in color, brightness, and resolution) and that of the underlying scene being displayed. We solve this problem by dynamically adjusting the position of the boundaries so that they lie on identical scene points or points visible in only one image. The system can accommodate approximately aligned projectors, through image warping applied as part of the rendering pipeline. The method for image boundary adjustment is discussed along with implementation details. Finally, we show applications of the technique that we are exploring as part of our research in collaborative visualization of large 3D models of environments and sites, built using laser range sensing and/or photogrammetry.

6055A-16, Session 4

Stereo projection using interference filters

H. Jorke, M. Fritz, Infitec GmbH (Germany)

Conventional stereo display techniques by projection separate images for the left and right eye by (i) wavelength multiplexing (this is known also as the classic anaglyph approach, using for instance red-green filters), by (ii) polarization (linear or circular polarization) or by (iii) time multiplexing (shutter glasses technique). Stereo projection using interference filters is an advanced wavelength multiplexing approach, that specifically takes into account the nature of the human eye, which is characterized by three types of receptors, which are associated to the primary colours blue, green and red. Correspondingly, the two filters used for the left and for the right eye have three narrow transmission bands, respectively. The three transmission bands B1, G1 and R1 of the filter type A for the left eye image and the three transmission bands B2, G2 and R2 of the filter type B for the right eye image are placed such in the visible spectral range (400 to 700 nm) that (1) conjugated transmission bands (B1-B2, G1-G2, R1-R2) are within the sensitivity range of the respective receptor and (2) conjugated transmission bands do not overlap.

Advantages of stereo projection using the interference filter technique (Infitec) are:

- full colour capacity
- superior channel separation
- passiveness of glasses
- compatibility with any white screen for mobile and portable presentations
- compatibility with standard cinema screens
- compatibility also with low gain screens (rear and front projection) for superior image homogeneity, especially in tiled display systems.
- compatibility with any digital projection technology (LCD, DLP and D-ILA).

6055A-18, Session 4

3D in digital cinema

W. J. Husak, Dolby Labs.

The transition from celluloid based cinema to Digital Cinema offers opportunities to the film maker and the cinema operator to provide 3D content to theatrical audiences. In the past, 3D content required anaglyphic glasses or multiple projectors for stereoscopic presentation. Digital Cinema projectors offer the capability to present both monoscopic and stereoscopic content with a minimal amount of infrastructure upgrade.

3D films have been released periodically throughout the history of filmmaking. The releases have ranged from classic horror movies to IMAX documentaries. 3D movies have been considered a niche market with audience acceptance waxing and waning throughout the years. Much of the difficulties have arisen due to limitations in technology and infrastructure.

Early film based 3D presentation was using anaglyph. The resulting image was difficult to watch for the length of a standard movie. A recently released film used a method of a mixing of anaglyph and monoscope between scenes. Another method of theatrical 3D is display of two simultaneous orthogonally polarized images using two separate projectors. The dual projectors are expensive and require complementary left and right film reel sets.

Digital Cinema projectors have the capability of changing polarization on every other frame allowing the use of a single projector. This capability coupled with appropriately polarized glasses allows full color stereoscopic images with significantly less artifacts than traditional anaglyph presentation. In addition, modern image processing allows conversion of films originally shot in 2D to be converted into 3D. This will allow movies that were never intended for stereoscopic display to be re-released in 3D.

Even with digital technologies, there are several issues that need to be overcome in order for 3D cinema to be successfully deployed. Among these issues are viewer fatigue, narrow viewing angles, limited head tilt, and light output. There are also practical issues such as acquisition, distribution, and collection of glasses. This paper will review the opportunities, technologies, and issues related to 3D distribution and presentation using a Digital Cinema infrastructure.

6055A-55, Session 4

Development of the real-time stereoscopic error corrector and convergence controller

S. Nam, C. Park, Korean Broadcasting System (South Korea); Y. S. Yu, K. Lee, TVLogic Co. Ltd. (South Korea)

The geometric differences between left and right images are known as a main factor of eye fatigue in the stereoscopic system, so the discrepancy should be eliminated for good stereoscopic images. We developed a real-time stereoscopic error corrector which can adjust the vertical errors, the disparity, and the size (field of view) errors of HD moving pictures in VCR tape. The main idea of this system is to extract the common areas in both images by cropping the left and right images independently. For this system, we developed real-time HD scaling hardware and stereoscopic error correcting software. We tested the system with the video streams taken by our HD stereoscopic camera. As a result, we confirmed that the developed system could reduce the efforts and time for correcting the stereoscopic errors compared to the other methods.

In this paper, we introduced the mechanism and function of the real-time stereoscopic error corrector developed by KBS, and compared it with non-real-time NLE-based compensation system. Also we evaluated the possibility of using the same hardware as a real-time convergence controller of parallel-axis stereoscopic camera. It doesn't need the parallax control motors which are used to slide the lenses apart from the cameras in moving parallel axis type. We also described the results of it in this paper.

6055A-19, Session 5

Platelet-based coding of depth maps for the transmission of multiview images

Y. Morvan, D. Farin, P. H. N. de With, Technische Univ. Eindhoven (Netherlands)

Emerging 3-D displays show simultaneously several views of the scene. A direct transmission of some of these views is impractical since various displays support a different number of views and the decoder has to interpolate the intermediate views. The interpolation of views can be simplified by only transmitting the texture data for the central view and corresponding depth map. Additionally to the coding of the texture data, this technique requires the efficient coding of depth maps. Since the depth map represents the scene geometry, sharp edges, corresponding to object boundaries, should be preserved.

We propose an algorithm that models depth maps using piecewise linear functions (platelets). To adapt to varying scene detail, we employ a quadtree decomposition that divides the image into rectangular sub-images of variable size, each sub-image being approximated by one platelet. In order to preserve sharp object boundaries, the support area of each platelet is adapted to the object boundary. The subdivision of the quadtree and the selection of the platelet type are optimized in a unified rate-distortion framework.

Experimental results show that the described method can improve the compression of depth maps by 2 dB when compared to a JPEG-2000 encoder.

6055A-20, Session 5

Efficient view synthesis from uncalibrated stereo

R. A. C. Braspenning, M. Op de Beeck, Philips Research Labs. (Netherlands)

3D Displays that are capable of presenting an illusion of a real 3-dimensional scene to the viewer have been a topic of research for a long time. Common approaches include displays that require the viewer to wear glasses in order to separate the left and right image from the mixed light output of the display. Well-known are the red-cyan or polarized glasses used for viewing 3D movies in amusement parks.

However, wearing such, non-customized, glasses can cause discomfort, especially for longer viewing periods, as would be the case for 3D TV applications. Therefore, so-called auto-stereoscopic displays that do not require the viewer to wear glasses, have been researched. The two main techniques use, either barriers [1], or lenses (lenticular sheets) [2] to create 2 or more views. In this paper, we will focus on the multiview 3D TV application. Using more than 2 views enables a considerable freedom of movement by the viewer and the viewing by multiple viewers simultaneously. Both are very important requirements for the 3D TV application.

However, besides the 3D displays, also 3D content needs to be available. Especially the multiview 3D displays still need algorithms to convert existing video material into multiview material delivering a 3D experience. The available video content can be roughly divided into two categories, regular 2D video content and stereo video material, although some multiview content is appearing now. The conversion from 2D material to multiview usually comprises estimating a depth map per pixel first [3] and subsequently rendering new views using the original image and the depth map [4]. In this paper we will only focus on stereo material and use both left and right images to generate new views, without calculating an explicit depth map.

6055A-21, Session 5

A fast image multiplexing method robust to viewer's position and lens misalignment in lenticular 3D displays

Y. Lee, J. B. Ra, Korea Advanced Institute of Science and Technology (South Korea)

Among various autostereoscopic display systems, the lenticular display is one of the most popular systems due to its easy manufacturability. For N-view lenticular display, N view images are to be regularly sub-sampled and interleaved to produce a 3D image. In our previous work, we have pointed out the two problems that cause 3D image distortion. Namely, the system provides the best quality only at a fixed optimal viewing distance and the lenticular sheet may not be precisely aligned on the LCD pixel array. Then, we have proposed the compensation algorithm to solve these problems. However, the proposed algorithm requires a considerable computational burden. In this paper, we propose a new fast multiplexing algorithm using a mapping table. The mapping table consists of two terms related with a viewer's position and the alignment error, respectively. Since the latter term is fixed for a given display system, we can reduce the computational complexity by repeatedly reusing it. In contrary to the previous algorithm, the proposed algorithm can make real time compensation possible without degrading image quality.

6055A-22, Session 6

Real-time rendering for multiview displays

R. M. Berretty, F. J. Peters, Philips Research Labs. (Netherlands); G. Volleberg, Philips Applied Technologies (Netherlands)

In video systems, the introduction of 3D video might be the next revolution after the introduction of color. Nowadays multiview autostereoscopic displays are in development. The various views produced on the display differ with respect to their associated camera positions.

A video format that is highly suited for rendering from different camera positions is the usual 2D format enriched with a depth related channel, i.e., for each pixel in the video not only its color is given, but also, e.g., its distance to a camera. This format, also called the 2.5D video format, has several advantages. It is device independent — it can be used for any multiview system without specifying the number of views at recording time— and it allows for efficient coding.

In this paper, we demonstrate that high image quality can be achieved when using the image plus depth format for 3D video systems. We present an efficient high quality real time rendering algorithm that uses forward mapping to reduce aliasing artefacts. It deals properly with occlusions. Image quality is achieved by advanced filtering techniques, taking into account the optical characteristics of the display.

6055A-23, Session 6

Anisotropic scene geometry resampling with occlusion filling for 3DTV applications

J. Kim, T. Sikora, Technische Univ. Berlin (Germany)

Image-based rendering and video-based rendering technologies have recently attracted attention as key technologies to provide a dynamic photorealistic environment with depth perception. Coarse samples of the scene geometry cause aliasing problems in uncovered areas with hidden information. To fill the uncovered area, the hidden information should be additionally analyzed to refine the samples for a better rendering quality. In this paper, we investigate a resampling method based on diffusion tensor theory to raise the density of samples. A scene can be divided into several

homogeneous regions by edges of depth or disparity. However, inaccurate depth or disparity should be localized by edges of texture regions. Resampling condition is defined within causality of edges throughout the evolution in coarse-to-fine scheme using Gaussian scale-space. The variations in texture and scene geometry are incorporated to find real edges of discontinuity. Anisotropic sampling is proceeded using different weighting to suppress the amount of diffusion for orthogonal direction of the real edges, while isotropic sampling is proceeded in the scale-space. Our method propagates the samples over the occlusion before the real edge but avoids local minima of diffusion on large texture gradients inside the edge. Simulation results show improvements in coding efficiency and rendering quality.

6055A-24, Session 6

Distributed rendering for multiview parallax displays

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3D display technology holds great promise for the future of television, virtual reality, entertainment, and visualization. Multiview parallax displays deliver stereoscopic views without glasses to arbitrary positions within the viewing zone. These systems must include a high-performance and scalable 3D rendering subsystem in order to generate multiple views at real-time frame rates. This paper describes a distributed rendering system for large-scale multiview parallax displays built with a network of PCs, commodity graphics accelerators, multiple projectors, and multiview screens. The main challenge is to render various perspective views of the scene and assign rendering tasks effectively. In this paper we investigate two different approaches: Optical multiplexing for lenticular screens and software multiplexing for parallax barrier displays. We describe the construction of large-scale multi-projector 3D display systems using lenticular and parallax-barrier technology. We have developed different distributed rendering algorithms using the Chromium stream-processing framework and evaluate the trade-offs and performance bottlenecks. Our results show that Chromium is well suited for interactive rendering on multiview parallax displays.

6055A-25, Session 7

On the number of viewing zones required for head-tracked autostereoscopic display

N. A. Dodgson, Univ. of Cambridge (United Kingdom)

A head-tracked display could be made from a two-view autostereoscopic display where head tracking allows the display to swap the two views when the eyes move from viewing zone to viewing zone. Variations in human interpupillary distance mean that this basic two-view version will not work well for the significant minority of the population who have eye separation significantly different from the average. Woodgate et al. proposed, in 1997, that a three-view system would work well. Analysis of an ideal version of their proposal shows that it does work well for the vast majority of the population. However, most multi-view, multi-lobe autostereoscopic displays have drawbacks which mean that, in practice, such a system would be unacceptable because of the inter-view dark zones generated by the inter-pixel dark zones on the underlying display technology. Variations of such displays have been developed which remove the inter-view dark zones by allowing adjacent views to overlap with one another: the views appear to smoothly blend from one to the next at the expense of a little blurring. Such displays need at least five viewing zones to accommodate the majority of the adult population with head-tracking and at least six viewing zones to accommodate everyone.

6055A-26, Session 7

Multiview LCD wall system

I. Relke, Opticality GmbH (Germany)

The principle construction of the unique autostereoscopic 3D LCD wall is considered. This glasses-free 3D LCD wall provides presentation of high-quality stereo images for many users simultaneously. The technical characteristics of the 3D LCD wall are compared with the corresponding parameters of the multiview 3D projection wall. The general equation for the evaluation of the multiview stereo image in this 3D LCD wall will be presented and all of its parameters are analysed. We introduce here the fundamental matrices, in which will be contained the information about the contribution of the different views in every subpixel. The properties of these matrices as well as their use for the evaluation of the stereo-image are considered. The problem of the adjustment of the stereoscopic image on the 3D LCD wall is also discussed and different types of adjustment are considered. For some of them the corresponding equations are given. The presented approach may be applied also to the case of the multiview autostereoscopic 3D plasma wall.

6055A-27, Session 7

Flatbed-type autostereoscopic display system and its image format for encoding

T. Saishu, S. Numazaki, K. Taira, R. Fukushima, A. Morishita, Y. Hirayama, Toshiba Corp. (Japan)

We have developed a flatbed-type autostereoscopic display system showing continuous motion parallax as an extended form of a one-dimensional integral imaging (1D-II) display system. 1D-II display architecture is suitable for both flatbed and upright configurations because it has a large margin for viewing distance and angle to allow for differences in viewing distances between the near-side and far-side edges of the display area. We have also designed an image format specification for encoding 1D-II data. In this parallax image array format, two (or more) viewpoint images whose viewpoint numbers are separated by a constant number are paired, and all of the paired images are combined to obtain an image the same size as the elemental image array. The boundaries inside the paired image correspond to the edges of the 3-D viewing area, while the boundaries between the paired images match the boundaries of DCT blocks and macro blocks. Therefore, 3-D image quality is hardly degraded by lossy codec. The conversion from this format to the elemental image array is simple and does not depend on changes in the viewing distance and associated changes in camera number. Decoding and converting speeds are sufficiently high due to utilization of middleware based on DirectX.

6055A-28, Session 7

Autostereoscopic 3D display

A. Schwerdtner, SeeReal Technologies GmbH (Germany)

Autostereoscopic 3D Display

Autostereoscopic Displays (ASD) tend to become enhanced 2D displays rather than being 3D specific displays. Accordingly, they have to meet strong requirements such as high image quality, large viewing angle, high resolution, etc. These requirements pose enormous challenges on the development of ASDs as their optical design often differs strongly from that of 2D displays. Therefore, most often ASD fulfil only a few features while sacrificing others. High resolution is often retained only with the single user tracking mode and complex opto-mechanical design. Multi user mode displays are easier to manufacture and more cost effective but exhibit lower resolution. The viewing angle is generally limited to 30 through 40 degrees. ASD which are capable of displaying 2D and 3D content most often are limited to switch only between both modes but do not offer simultaneous 2D and 3D displaying.

There are several components contained in ASDs not present in usual displays.

Most critical are optical components. Generally beam splitters are needed to focus the left and right stereoscopic images onto the left and right eyes of the observers. SeeReal Technologies focus the images to spots called Sweet Spots (SSP). Any cross-talk between SSPs has to be avoided unless the 3D impression is compromised. This puts hard requirements on optical design and manufacturing. The flat parallel channel optics pose extreme challenges on accurateness. Lateral deviations of the positions of the individual lenses must not exceed 5 microns. The requirements of evenness and thickness are subject to similar conditions. Other issues are waviness and accurateness of the individual lenses. But most importantly, after assembling the optical parts of the ASD the total deviations have to be within a very narrow range depending on the size and resolution of the display.

Another issue is backlighting. Due to the optical design, severe attenuations of light intensity may occur. High intensity backlights are needed.

SeeReal Technologies achieves high resolution of their ASDs employing tracking. The entire line of tracking from picking-up by the cameras up to the Sweet Spots must not exceed 40 ms.

Additional limitations occur when considering ASD as marketable products. Price is an important issue which is strongly affected by features listed above, such as mechanical tracking. The optical components as well as the overall tolerances of the ASD have to be kept reproducibly. The demonstration of a prototype is not sufficient. All components have to be made available.

Furthermore, ASDs need to support widespread available software, especially for graphics design such as software based on OpenGL or DirectX.

SeeReal Technologies has developed an ASD which it believes to meet most requirements potential customers need. Based on tracking it features native high resolution, switch between 2D and 3D or simultaneous display of 2D and 3D, multi user, and wide angle. As it employs field sequential software almost all 3D applications run on it.

Additionally, it has developed the technology for key components such as the high accurate and reproducible beam splitter optics, and tracking.

6055A-29, Session 7

The HoloVizio system

T. Balogh, Holografika Kft. (Hungary)

We present the HoloVizio system design and give an overview about Holografika's approach to the 3D displaying. The HoloVizio technology uses a specially arranged array of optical modules and a holographic screen. Each point of the holographic screen emits light beams of different color and intensity to the various directions. The light beams generated in the optical modules hit the screen points in various angles and the holographic screen makes the necessary optical transformation to compose these beams into a perfectly continuous 3D view. With proper software control, light beams leaving the pixels propagate in multiple directions, as if they were emitted from the points of 3D objects at fixed spatial locations. We show that the direction selective light emission is a general requirement for every 3D systems and provide quantitative data on the FOV, on the angular resolution, determining field of depth of the displays, affecting the total number of light beams necessary for high-end 3D displaying. We present the results with the 10 Mpixel desktop display and the 50Mpixel large-scale system. We cover the real-time control issues at high pixel-count systems with the HoloVizio software environment and describe concrete 3D applications developed in the frame of European projects.

6055A-30, Session 8

Development of autostereoscopic display system for remote manipulation

T. Honda, Y. Kuboshima, K. Iwane, T. Shiina, Chiba Univ. (Japan)

When a 3D display system is used for remote operation, the special glasses for looking at the 3D-image disturb the manipulation. So auto-stereoscopic display is preferable for remote manipulation work. However, the eye position area of the auto-stereoscopic display which shows the 3D-image is generally narrow. We constructed a 3D display system which solved these problems.

In the system, 1. stereoscopic images displayed on the special LCD are projected on a large concave mirror by a projection lens. 2. The aperture is set between the projection lens and the concave mirror. 3. The real image of the aperture is made at a certain position in vacant space by the concave mirror, and the image position is the viewing zone. By putting both eyes at the position and looking at the concave mirror plane, the viewer can see the stereoscopic image without glasses.

To expand the area which can observe the 3D-image, we proposed and constructed the system of the eye-position tracking of the viewing zone by detecting the eye-position of the viewer. A viewer can not only move horizontally and vertically by rotating the concave mirror, but also move to front and back by moving the viewing zone limiting aperture.

6055A-31, Session 8

Ray-space acquisition and reconstruction within cylindrical objective space

T. Yendo, T. Fujii, M. Tanimoto, Nagoya Univ. (Japan)

A ray-based cylindrical display is proposed that allows multiple viewers to see 3D images from a 360-degree horizontal arc without wearing 3-D glasses. This technique uses a cylindrical parallax barrier and a one-dimensional light source array constructed from such semiconductor light sources as LEDs aligned in a vertical line. The light source array rotates along the inside of the cylindrical parallax barrier, and the intensity of each light is synchronously modulated with the rotation. Since this technique is based on the parallax panoramagram, the density of rays is limited by the diffraction at the parallax barrier. In order to solve this problem, revolving parallax barrier is employed. Two prototype displays have been developed and showed high presence 3D image. Especially the newer one is capable of displaying color images whose diameter is 200mm, it is suitable for displaying real object like a human head. We successfully reconstructed a real object within cylindrical space from ray-space data acquired by a video camera rotating around the object. In this paper, we describe details of the system and discuss about ray control method to reconstruct an object from acquired ray-space data.

6055A-32, Session 8

72-directional display having VGA resolution for high-appearance image generation

Y. Takaki, T. Dairiki, Tokyo Univ. of Agriculture and Technology (Japan)

The high-density directional display, which was originally developed in order to realize a natural three-dimensional display, is not only a three-dimensional display but also a high-appearance display. The appearances of objects, such as glare and transparency, are the results of the reflection and the refraction of rays. The faithful reproduction of such appearances of objects is impossible using conventional two-dimensional displays because rays diffuse on the display screen. The high-density directional display precisely

controls the horizontal ray directions so that it can reproduce the appearances of objects. The fidelity of the reproduction of object appearances depends on the ray angle sampling pitch. The angle sampling pitch is determined by considering the human eye imaging system. In the present study the high-appearance display which has the resolution of 640Å~400 and emits rays in 72 different horizontal directions with the angle pitch of 0.38° was constructed. Two 72-directional displays were combined, each of which consisted of a high-resolution LCD panel (3,840Å~2,400) and a slanted lenticular sheet. Two images produced by two displays were superimposed by a half mirror. A slit array was placed at the focal plane of the lenticular sheet for each display to reduce the horizontal image crosstalk in the combined image.

6055A-33, Session 8

Combining volumetric edge display and multiview display for expression of natural 3D images

R. Yasui, I. Matsuda, H. Kakeya, Univ. of Tsukuba (Japan)

In the present paper the authors present a novel stereoscopic display method combining volumetric edge display technology and multiview display technology to realize presentation of natural 3D images where the viewers do not suffer from contradiction between binocular convergence and focal accommodation of the eyes. Most of the conventional 3D electronic displays, including multiview displays, use only binocular parallax to make the viewers perceive depth, which causes contradiction between convergence and accommodation of our eyes. This contradiction often causes eyestrain and sickness of the viewer, which are often thought to be the main reason why 3D electronic displays have not been used widely so far. Though several expensive solutions, such as electronic holograms or super-multiview technology, have been invented, these technologies have to process huge amount of data even to show very low resolution images. Therefore it is hard to attain high resolution 3D images with these technologies in the near future. As for cheaper solutions which require less data processing, volumetric display technology is available. 3D images given by volumetric displays do not include contradiction between binocular convergence and focal accommodation. Volumetric displays, however, cannot express occlusion or gloss of the objects. Also volumetric displays require complete volumetric model of the 3D space to be presented, which is hard to capture on the real-time basis in the real world. Thus the conventional volumetric display technology is not a realistic solution for 3D television. To overcome these defects of volumetric displays, the authors propose a method to draw edge areas and flat areas separately. We adopt volumetric display method only for edge drawing, while we adopt stereoscopic approach for flat areas of the image. Since focal accommodation of our eyes is affected only by the edge part of the image, natural focal accommodation can be induced if the edges of the 3D image are drawn on the proper depth. As for the hardware of the volumetric display we can use layered monochrome TFT panels, for we only need to express edges here. Since the conventional stereo-matching technique can give us robust depth values of the pixels which constitute noticeable edges, it is not hard to extract and draw only the edge part of the 3D image on the volumetric display. Also occlusion and gloss of the objects can be roughly expressed with the proposed method since we use stereoscopic approach for the flat area. When we use multiview technology to realize stereoscopy in this system, we can attain a system where many users can view natural 3D objects at the consistent position and posture at the same time. A simple optometric experiment using a refractometer suggests that the proposed method can give us 3-D images without contradiction between binocular convergence and focal accommodation.

6055A-34, Session 8

Adaptive parallax control for multiview stereo panoramas

C. Wang, A. A. Sawchuk, Univ. of Southern California

Several types of 3D autostereoscopic (AS) visual displays have been developed recently. We are exploring a personal panoramic virtual environment system using stereo panorama capture and AS displays to improve the sense of immersion. The stereo panorama pairs are created by stitching strips that are sampled from images captured with swing panorama structure. We apply Peleg's disparity adjustment algorithm for the generated stereo panorama to achieve large disparity (horizontal parallax) of far away scenes and smaller disparity of closer scenes for stereo perception. Unfortunately, vertical parallax in the stereo panorama still occurs, causing display artifacts and problems in image fusion.

To solve these problems, we first present a general image capture model, specify geometrical parameters, and describe the panorama generating process. We then describe an efficient stitching algorithm that matches image regions. The algorithm also corrects for dynamic exposure variation and removes moving objects without manual selection of ground-truth images. We present expressions for the horizontal and vertical parallax, evaluate different parallax measuring techniques, and develop an adaptive vertical and horizontal parallax control algorithm for rendering in different viewing directions. We show several examples subjective tests of stereo panoramas rendered on AS and other stereo displays, and discuss the relative quality of each.

6055A-46, Poster Session

Real-time stereographic display of volumetric datasets in radiology

X. H. Wang, G. S. Maitz, J. K. Leader, W. F. Good, Univ. of Pittsburgh

A workstation for testing the efficacy of stereographic displays for applications in radiology has been developed, and is currently being tested on lung CT exams acquired for lung cancer screening. The system exploits pre-staged rendering to achieve real-time dynamic display of slabs, where slab thickness, axial position, compositing method, brightness and contrast are interactively controlled by viewers. Stereo viewing is by means of shutter-glasses synchronized to a 144 Hz monitor. The system enables viewers to toggle between alternative renderings such as one using distance-weighted ray casting by maximum-intensity-projection, which is optimal for detection of small features in many cases, and ray casting by distance-weighted averaging, for characterizing features once detected. A reporting mechanism is provided which allows viewers to use a stereo cursor to measure and mark the 3D locations of specific features of interest, after which, a pop-up dialog box appears, into which findings can be entered. The system's impact on performance is being tested on chest CT exams for lung cancer screening. Radiologists' subjective assessments have been solicited for other kinds of 3D exams (e.g., breast MRI), their responses have been positive. Objective estimates of changes in performance and efficiency, however, must await the conclusion of our study.

6055A-47, Poster Session

Ergonomic evaluation system for stereoscopic video production

T. Kawai, S. Kishi, T. Yamazoe, T. Shibata, Waseda Univ. (Japan); T. Inoue, Kanagawa Institute of Technology (Japan); Y. Sakaguchi, K. Okabe, Y. Kuno, Let's Corp. (Japan); T. Kawamoto, Chukyo TV Broadcasting Corp. (Japan)

This paper describes the development of ergonomic evaluation system for producing stereoscopic images. The purpose of the system is to quantify the depth sensation of stereoscopic videos, and evaluate from the view point of safety and amenity. The authors applied the image processing to compute optical flow between right and left videos. The parameters for safety and amenity were examined by referring previous reports and carrying two subjective evaluation experiments. This paper reports the results of the improvement and discusses the validity of the system in terms of stereoscopic video production.

6055A-48, Poster Session

Wide-viewing-angle three-dimensional display system using HOE lens array

H. Takahashi, H. Fujinami, Osaka City Univ. (Japan); K. Yamada, Hiroshima Institute of Technology (Japan)

Integral imaging systems has the problem of the limitation of viewing angle. This paper describes a wide-viewing-angle 3D display system using holographic optical element (HOE) lens array. This display system has a flat HOE lens array. But, the axis of each elemental HOE lens is eccentric. Since every axes of lens is convergent, a flat HOE lens array works as a curved lens array. So, although both a lens array and a screen are flat, this display system has a wide viewing angle. On the other hand, generally, in the integral imaging system each elemental lens has its corresponding area on the display panel. To prevent the image flipping, the elemental image that exceeds the corresponding area is discarded. Therefore, the number of the elemental images is limited and the viewing angle is limited. At the elemental image side, since the axis of each HOE lens is normal, the elemental image does not exceed the corresponding area and the barriers to eliminate the flipped images are not required. Since both a lens array and a screen are flat, the configuration of this display system is simple.

6055A-49, Poster Session

Depth maps created from blur information using images with focus at near and at far

S. Cho, Electronics and Telecommunications Research Institute (South Korea); J. W. Tam, F. Speranza, R. Renaud, Communications Research Ctr. Canada (Canada); N. Hur, S. Lee, Electronics and Telecommunications Research Institute (South Korea)

We demonstrate the use of two original images, near-and far-focused images, with one in which the camera focus is at near and the other at far, respectively, for the generation of depth maps that are useful for DIBR. The method involves the following steps:

- i) Edges are detected for two original images that are near- and far-focused images, respectively, based on the gradient which is estimated in the luminance function using steerable Gaussian first derivative basis filters. The gradient represents the intensity for each edge using local scale control.
- ii) Blur is estimated based on the gradient and luminance differential between two regions that are divided by one edge-pixel in order to get an estimate of the blur value which is not unduly influenced by local contrast.
- iii) Edge-depth map is estimated based on the relation between the blur information of the edges in both near- and far-focused images.
- iv) Fill-depth map is generated by filling the regions based on the Edge-depth map.
- v) We generate another viewpoint image to complete a stereoscopic pair by using the depth map and one of the original images. Finally, we evaluate the quality of our depth map and the stereoscopic images.

6055A-50, Poster Session

Depth map-based disparity estimation technique using multiview and depth camera

G. Um, Electronics and Telecommunications Research Institute (South Korea); S. Kim, K. Kim, Gwangju Institute of Science and Technology (South Korea); N. Hur, Electronics and Telecommunications Research Institute (South Korea); K. Lee, Gwangju Institute of Science and Technology (South Korea)

In this paper, we propose a depth map-based disparity estimation technique for the trinocular camera system. Depth map is captured using a depth camera with active sensors, and it is used as an initial estimate of setting adaptive search ranges for solving correspondence problems between image pairs. Existing stereo matching techniques usually produce inaccurate disparities or geometric distortions because of occlusion and mismatching. In case that many objects are widely arranged in 3D space and a baseline between two cameras is long, the search range should be largely set to find all correspondences. But largely fixed search range increases the computation time and the mismatching rate. In our system, we obtained three-view standard definition (SD) images and additional depth map for the center-view image. Since the depth map has relatively reliable accuracy and linearity, the depth map is converted into disparities to be used as reference values for stereo matching using calibrated camera parameters. We perform the stereo matching based on the converted disparity values to increase the matching accuracy and to reduce the computational time. Obtained disparity maps can be used for 3D scene reconstruction and stereoscopic view synthesis using depth image-based rendering (DIBR).

6055A-51, Poster Session

A uniform metric for anaglyph calculation

Z. Zhang, D. F. McAllister, North Carolina State Univ.

We evaluate a new method for computing color anaglyphs based on uniform approximation in CIE color space. The method depends on the spectral distribution properties of the primaries of the monitor and the transmission functions of the filters in the viewing glasses. We will compare the result of this method with several other methods that have been proposed for computing anaglyphs. To compute the color at a given pixel in the anaglyph image requires solving a linear program. We exploit computational properties of the simplex algorithm to reduce computation time by 75 to 80 percent. After computing the color at one pixel, a depth-first search is performed around it to collect all the pixels with color close enough to it. We use criteria for measuring closeness of colors such that the colors of all the collected pixels can be computed using a simple matrix-vector multiplication. We also parallelize the algorithm and implement it on a cluster environment. Many interesting results are described, including the effects of different data dividing schemes.

6055A-53, Poster Session

Multiview autostereoscopic display with double-sided reflecting scanning micromirrors

A. Nakai, K. Hoshino, K. Matsumoto, I. Shimoyama, The Univ. of Tokyo (Japan)

We report on the multiview autostereoscopic display with double-sided reflecting scanning micromirrors. There is a trade-off between the resolution and the number of the view angles in existing multiview stereoscopic displays. In order to solve this problem, we propose the way of projecting time-series pixel data into the discrete

directions by using scanning micromirrors. As the number of the view angles depends on the number of pixel data projected in one cycle of the scan, the resolution and the number of the view angles can be independently increased. Double-sided reflecting micromirrors actuated by both external magnetic force and Lorentz force were designed and fabricated based on the MEMS (Micro Electro Mechanical Systems) technology. Fabricated micromirrors are $450\ \mu\text{m} \times 520\ \mu\text{m}$ in size, and characteristics of a micromirror, for example the range of the movement and the resonance frequency, were measured. Then the fabricated micromirrors were integrated with a microlens array, pinhole arrays and an LED matrix to construct a prototype of the multiview autostereoscopic display, and the relationship between the view angle and the light intensity was measured. The validity of our proposed method was proved from the light intensity distribution of this prototype.

6055A-54, Poster Session

Depth-enhanced floating display system based on integral imaging

J. Kim, Seoul National Univ. (South Korea); S. Min, Information and Communications Univ. (South Korea); Y. Kim, S. Cho, H. Choi, B. Lee, Seoul National Univ. (South Korea)

Though the floating display system based on integral imaging can provide moving picture with great feel of depth to the observer, it has limited expressible depth range because the expressible depth range of integral imaging is limited. In this paper, the expressible depth range of the floating display system based on integral imaging is analyzed based on the analysis on the expressible depth range of the integral imaging. Also, a depth-enhanced floating display system based on integral imaging is proposed. In the proposed depth-enhanced floating display system, the lens array of the integral imaging is placed at the focal plane of the floating lens. Additionally, the seams on the lens array become less distinct since they are also placed at the focal plane of the floating lens. However, the size of the object changes when the object is out of the overall central depth plane. Thus, the size of objects in elemental image should be rescaled to display correct three-dimensional image. The analysis on the rescaling and the experimental results will be given at the presentation.

6055A-56, Poster Session

Three-dimensional sprites for lenticular-type three-dimensional display

T. Dairiki, Y. Takaki, Tokyo Univ. of Agriculture and Technology (Japan)

The present study proposed the three-dimensional sprite technique that enables to rapidly update three-dimensional images of lenticular type three-dimensional displays. In the present study, the three-dimensional sprite was developed for the 72-directional display which consists of a WQXGA ($3,840\text{Å} \sim 2,400$) LCD panel and a slanted lenticular sheet. It projects a large number of directional images in different horizontal 72 directions with nearly parallel rays. Using a slanted lenticular sheet, the images interpolation is required in the image interlacing process. The time required for updating the three-dimensional image is about 0.5 second when using a PC (Pentium4 2.4GHz) The three-dimensional sprites were implemented by software. The developed software has the ability to display 40, 12, and 4 sprites at the video rate (30 Hz) for the sprite sizes of $8\text{Å} \sim 8$, $16\text{Å} \sim 16$, and $32\text{Å} \sim 32$, respectively. The three-dimensional sprite technique developed in the present study has following features: (a) three data types (two-dimensional type, three-dimensional type, and 360° type), (b) three image size ($8\text{Å} \sim 8$, $16\text{Å} \sim 16$, and $32\text{Å} \sim 32$), (c) scaling of sprites depending on z-coordinate, and (d) occlusion of sprites depending on z-coordinate.

6055A-57, Poster Session

Optical design considerations for a beam combiner in a StereoMirror (TM) 3D display

A. Hochbaum, VAV Consulting; J. L. Fergason, Fergason Patent Properties

We present a first order optical model for the StereoMirror(tm) 3D display system consisting of two LCD monitors butted top to top. Each monitor is a source to one image of a stereo pair thus retaining the full native resolution and providing high brightness. A beam-combiner intersecting the angle between the monitors fuses the two images. We present an optical analysis and data regarding the effect of the beam-combiner.

The beam-combiner's transmission and reflectivity as well as the local angle of incidence affect the features of the perceived 3D image. We calculate the distribution of angles of incidence at the beam-combiner for various observer positions and points on the monitor and the average AOI for which it should be optimized.

We present experimental data of commercial combiners and model results to calculate the optimal combiner parameters that maximize brightness and light efficiency and minimize cross-talk.

The polarization directions of 15"-17" monitors are at $\pm 45^\circ$ to the plane of incidence leading to an AOI dependent cross-talk effect. We analyze the phenomenon and discuss the magnitude of this effect and means to reduce it to an acceptable level.

6055A-58, Poster Session

Horizontal parallax distortion in toe-in camera systems with fisheye lens

H. Kang, D. Kim, N. Hur, Electronics and Telecommunications Research Institute (South Korea)

In this paper, we propose a novel method that can correct a horizontal parallax distortion (HPD) that happens in toe-in camera configuration with fisheye lenses. In a toe-in camera system, the disparity of the object that is located at convergence point on the convergence plane is 0 where the convergence plane means the specific plane that is located at the distance at which optical axes of two cameras intersect. However, disparities of the other objects that are located the left or right side in the centre on the convergence plane are not zero, and increase according to the distance between objects and convergence point on the horizontal axis. Accordingly, the distribution of disparities is a tangent-like function of the distance from the convergence point to the left or right side on the convergence plane. In order to correct the HPD, we propose a model of a toe-in camera configuration, and calculate the distribution of the HPD.

In this paper, we have presented a HPD correction method for a toe-in camera system with fisheye lenses. In experiment, we used CCD cameras whose focal lengths are 2.5mm and 12mm, known as a fisheye lens, corrected a barrel distortion and HPD from CCD camera, and fixed color inconsistency.

6055A-59, Poster Session

Implementation of 3DTV broadcasting system for realistic broadcasting services

B. Bae, S. Cho, K. Yun, H. Kang, N. Hur, C. Ahn, Electronics and Telecommunications Research Institute (South Korea)

This paper presents a noble 3DTV broadcasting system that is fully compatible with the existing DTV system including MPEG-2 standard, which is a basic one based on various digital broadcasting systems such as ATSC, DVB, OpenCable and so on. The presented system shows the configuration of a flexible, 2D-compatible, and commercially feasible end-to-end 3DTV broadcasting system. To

achieve 2D compatibility, left-view images are encoded by using the MPEG-2 standard and 3D additional information for right-view images is encoded by using the AVC, which is an advanced coding method. Both encoded streams are transmitted in a single program with the proposed map tables. The proposed 3DTV system was verified by two kinds of DTV receivers, which are a commercial and conventional DTV receiver and the developed receiver for receiving 3D information. As results of experiments, we confirmed that the 3D pictures or the 2D pictures can be played on the 3DTV STB according to users' selection and the 2D pictures are only displayed on the commercial DTV receiver without any problems. In the future, the proposed system is expected to be a next-generational one for the advanced digital broadcasting services.

6055A-61, Poster Session

Performance analysis of a compact electro-optical 3D adapter with a wide capturing angle

S. Kim, J. Lee, E. Kim, Kwangwoon Univ. (South Korea)

In this paper, a new 3D adapter system with a lens unit interposed between a photographing lens and an adapter housing for alternately passing right and left moving images of an object there through, wherein the lens unit has an entrance pupil point formed outside the lens unit, the lens unit has a magnification of 1:1, and the lens unit comprises a plurality of symmetrically arranged lenses for reversing the moving images, whereby it is possible to capture moving images with wide picture angles without increasing the size of the adapter housing, and to prevent occurrence of any distortion in the resulting moving images comprised of the integrated right and left images of the object.

Some experimental results confirm the superiority of the newly developed 3D adapter system and its usefulness in the practical applications.

6055A-62, Poster Session

New method of zoom-convergence interlocked control in the moving parallel-axes style stereoscopic camera

J. Lee, S. Nam, J. Lee, C. Park, S. Chung, Korean Broadcasting System (South Korea)

We have devised a new and efficient method of zoom-convergence interlocked control in the moving-parallel axes style stereoscopic camera system.

As a stereoscopic camera system for broadcasting, the zoom function is indispensable. But, without some special method or apparatus, the zoom operation in the stereoscopic camera system will result in unpredictable change of the disparity in the stereoscopic image.

To solve such problems, we devised this new method. First, instead of making the Look-Up-Table by measuring the zoom value and the convergence at each step, we utilized the lens data sheet, which can be obtained from the lens manufacturer, so that we can secure the accuracy and the handiness without any measuring.

And, we set up a simple and smart algorithm of our own, which is based on the basic geometry of the stereoscopic camera system. By utilizing the relationship among the inter-camera distance, the object distance and the focal length, namely the distance from lens to image sensor, it can calculate the convergence and keep the convergence or disparity constant at a certain point in spite of zooming operation.

From such functions, we can make the stereoscopic contents with smooth zooming and adequate disparity with ease.

6055A-35, Session 9

Integral videography of high-density light field with spherical layout camera array

T. Koike, M. Oikawa, N. Kimura, F. Beniyama, T. Moriya, M. Yamasaki, Hitachi, Ltd. (Japan)

We propose a spherical layout for a camera array system when shooting images for use in integral videography (IV). IV is an autostereoscopic video image technique based on integral photography (IP) and is one of the preferred autostereoscopic techniques for displaying images. There are many studies on autostereoscopic displays based on this technique indicating its potential advantages. Other camera arrays have been studied, but their purpose addressed other issues, such as acquiring high-resolution images, capturing a light field, creating contents for non-IV-based autostereoscopic displays and so on. Moreover, IV displays images with high stereoscopic resolution when objects are displayed close to the display. As a consequence, we have to capture high-resolution images in close vicinity to the display. We constructed the spherical layout for the camera array system using 30 cameras arranged in a 6 x 5 array. Each camera had an angular difference of 6 degrees, and we set the cameras to the direction of the sphere center. These cameras can synchronously capture movies. The resolution of the cameras was 640 x 480. With this system, we determined the effectiveness of the proposed layout of cameras and compared image qualities and computational speeds of some algorithms.

6055A-36, Session 9

Imaging properties of microlens arrays for integral imaging system

J. Arai, M. Okui, Y. Nojiri, F. Okano, NHK Science & Technical Research Labs. (Japan)

Integral imaging (II) system, based on Integral photography proposed by Lippmann, enables three-dimensional (3-D) images corresponding to a viewpoint to be observed under natural light in real time. However, there has been the problem of pseudoscopic images, which must be avoided when creating a real-time system. We propose an elemental optics using a combination of convex lenses in order to avoid pseudoscopic images. Firstly, we describe the structure of an element. For an orthoscopic image, the element of either the capturing or display system must have lateral magnification opposite to the magnification of the usual convex lens. We show that this structure can provide an elemental image for an orthoscopic image. Secondly, overlap between neighboring elemental images must be prevented. We also show that, with our proposed structure, there is no overlap between neighboring elemental images. Finally, we have fabricated a lens array of the proposed elements and have constructed an experimental setup for II system. The results of experiments confirmed that an orthoscopic image is produced in real time. The discussions and experimental results described here show the feasibility of generating high-resolution 3-D images in real time using the proposed lens arrays.

6055A-37, Session 9

Comparative study on 3D-2D convertible integral imaging systems

B. Lee, H. Choi, J. Kim, Y. Kim, Seoul National Univ. (South Korea)

With the development of the display technology, the three-dimensional(3D) display attracts much attention as a next generation display technique. In this paper, we compare two types of 3D/2D convertible display methods which we had proposed, and discuss the merits and demerits of each one. One method uses a polymer-dispersed liquid crystal(PDLC) and a point light source array. With the adjustment of the PDLC, we can form or eliminate a point light

source array behind of the spatial light modulator and can switch between the 3D and 2D display modes. The other method uses layered panels. By changing the role of two display panels, the 3D and 2D images can be displayed by the principles of the integral imaging and liquid crystal display(LCD) respectively. Both systems require no mechanical movement and can provide a full color 3D image with continuous viewpoints and no special glasses. The one using a PDLC is advantageous for the depth of displayed 3D image while the other one is advantageous for the resolution. We also discuss the generation of the elemental images and some improved methods for both two types of 3D/2D convertible displays. A method to prevent the occlusion problem will also be proposed.

6055A-39, Session 10

Application of 3DHiVision: a system with a new 3D HD renderer

P. Sun, Sun Advanced Engineering, Inc. (Japan); S. Nagata, InterVision (Japan)

This paper discusses about some strategies that will help to solve the problems that prevent 3D Stereo from being popular. A 3DHiV (3DHiVision) System Solution Modern projection systems and stereo LCD panels have made it possible to enable a 3D stereo video experience for many more people in a broader range of applications. The key limitations to more mainstream applications of 3D video have been the availability of 3D contents and the cost and complexity of 3D video production, content management and playback systems. Even with the modern PC based video production tools, projection systems and increased interest in 3D applications, the 3D video industry remains small and stagnant. The inescapable fact is that the production and playback of high quality 3D video is still expensive. The system has accepted the challenge of overcoming these difficulties and has created a complete end-to-end 3D Video system based on an embedded PC platform, which significantly reduces the cost and complexity of creating museum quality 3D video. Amateur or professional film makers will be able to easily create, distribute and playback 3D video contents.

6055A-40, Poster Session

3D animation in three dimensions: the rocky road to the obvious

H. Murray, IMAX Corp. (Canada)

That animation created using CG modeling and animation tools is inherently three-dimensional is well known. In the middle to late nineties IMAX Corporation began actively exploring CG animated features as a possible source of economically viable content for its rapidly growing network of stereoscopic IMAX(r) 3D theatres. The journey from there to the spectacular success of the IMAX(r) 3D version of The Polar Express is an interesting mix of technical, creative and production challenges. For example 3D animations often have 2D elements and include many sequences that have framing, composition and lens choices that a stereographer would have avoided had 3D been part of the recipe at the outset. And of course the decision to ask for a second set of deliverables from an already stressed production takes nerve. The talk will cover several of these issues and explain why the unique viewing experience enabled by the wide-angle geometry of IMAX(r) 3D theatres makes it worth all the pain.

6055A-41, Session 12

A method of real-time construction of full parallax light field

K. Tanaka, S. Aoki, Sony Corp. (Japan)

We designed and implemented a dynamic light field acquisition and reproduction system, which serves as a 3D live video system for multiple viewers. The acquisition unit consists of circularly arranged NTSC cameras surrounding an object. The display consists of circularly arranged projectors and a rotating screen. The projectors are constantly projecting images captured by the corresponding cameras onto the screen. The screen rotates around an in-plane vertical axis so that it faces each of the projectors in sequence. Since the surfaces of the screens are covered by light-collimating plastic films with their louver patterns being vertical, which have a role to make the screen retro-reflective horizontally, a viewer can observe only an image projected by a projector located in the same direction as the viewer. Thus the viewer can see a dynamic image of an object according to his or her head position. We evaluated the system by projecting both objects and human figures, and confirmed that the system can reproduce live video sequences with horizontal parallax. Application areas of this system include product design review, sales promotion, art exhibition, fashion show, and sports training with form checking.

6055A-43, Session 12

Simulation of 3D image depth perception in a 3D display using two stereoscopic displays at different depths

K. Uehira, Kanagawa Institute of Technology (Japan)

We studied a new 3-D display that uses two stereoscopic displays instead of two 2-D displays in a depth-fused 3D display. We found that two 3-D images with the same shape displayed at different depths by the two stereoscopic displays were fused into one 3-D image when they were viewed as overlapping. Moreover, we found that the perceived depth of the fused 3-D image depends on both the luminance ratio of the two 3-D images and their original perceived depth. This paper presents the simulation results for the perceived depth of the fused 3-D image on the new 3-D display. We applied a model in which the human visual system uses a low-pass filter to perceive the fused image, the same as on a conventional DFD display. The simulation results revealed that the perceived depth of the fused image changed depending on both the luminance ratio of the two 3-D images and their original perceived depth, as in the subjective test results, and the low-pass filter model accurately presented the perception of a 3-D image on our 3-D display.

6055A-44, Session 12

Innovative stereoscopic display using variable polarized angle

J. E. Gaudreau, PolarScreens, Inc. (Canada) and MacNaughton, Inc.; M. Bechamp, PolarScreens, Inc. (Canada); B. MacNaughton, V. S. Power, MacNaughton, Inc.

PolarScreens has developed an innovative stereoscopic display (US patent # 5,629,798) that has the unique advantage of displaying the two images without any multiplexing. PolarScreens uses 2 LCD panels stacked on one another where the second LCD adds extra information to the photon using a polar coordinate transformation algorithm. The first LCD controls total pixel intensity and the second controls left-eye/right-eye distribution ratio. Notably, this is the only technology where one photon contains information for both eyes!

Based on this theory, PolarScreens has developed the technologies required to make it practicable and built a 19in, 1280x1024 stereoscopic desktop monitor with very low crosstalk, high

brightness and a wide angle of vision using passive polarized glasses.

The biggest problem in stereoscopic monitors is crosstalk. It is a measure of the interference between the left and right pictures. Existing stereoscopic monitors produce around 10% crosstalk. This monitor brings this down to 2%. That's a 500% improvement. Moreover, at the push of a button, the display can switch between different modes of operation:

- Stereoscopic (user wear passive 3D glasses)
- Normal 2D display
- Contrast Enhanced 2D (just by adding a film on the display surface)
- Private (where only the person wearing special glasses can see the image).

This technology, as shown with the first product manufactured by NuVision, has a great potential in the professional as well as entertainment markets.

6055A-45, Session 12

A novel walk-through 3D display

S. DiVerdi, A. Olwal, I. K. Rakkolainen, T. Höllerer, Univ. of California/Santa Barbara

We present a novel walk-through 3D display based on the patented FogScreen, an "immaterial" indoor 2D projection screen, which enables high-quality projected images in free space. We extend the basic 2D FogScreen setup in three major ways: First, we implemented various techniques for tracking a viewer's head, enabling correct perspective 3D projection for one viewer, second, we added support for stereoscopic imagery, and third, we present the front and back views of the graphics content on the two sides of the FogScreen, so that the viewer can cross the screen to see the content from the back.

The 3D objects in free space look natural when viewed on-axis. While the image quality is not perfect from off-axis viewing angles, our system produces a believable 3D impression, implementing the first human-scale reach- and walk-through pseudo-volumetric display. Our informal user evaluation of the system suggests that the display leads to an enhanced viewing experience. It creates a strong visual effect of 3D objects floating in air, even in the case when the image is not stereoscopic. This is a first step in the direction of a truly volumetric walk-through display.

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6055B-63, Session 13

Texturing of continuous LoD meshes with the hierarchical texture atlas

H. Birkholz, Univ. Rostock (Germany)

For the rendering of detailed virtual environments, trade-offs have to be made between image quality and rendering time. An immersive experience of virtual reality always demands high frame-rates with the best reachable image quality. Continuous Level of Detail (cLoD) triangle-meshes provide an continuous spectrum of detail for a triangle mesh that can be used to create view-dependent approximations of the environment in real-time. This enables the rendering with a constant number of triangles and thus with constant frame-rates. Normally the construction of such cLoD mesh representations leads to the loss of all texture information of the original mesh. To overcome this problem, a parameter domain can be created, in order to map the surface properties (colour, texture, normal) to it. This parameter domain can be used to map the surface properties back to arbitrary approximations of the original mesh. The parameter domain is often a simplified version of the mesh to be parameterised. This limits the reachable simplification to the domain mesh which has to map the surface of the original mesh with the least possible stretch. In this paper, a hierarchical domain mesh is presented, that scales between very coarse domain meshes and good property-mapping.

6055B-64, Session 13

Optimal approximation of head-related transfer function's zero-pole model based on genetic algorithm

J. Zhang, Southeast Univ. (China)

In the research of spatial hearing and virtual auditory space, it is important to effectively model the head-related transfer functions (HRTFs). Based on the analysis of HRTFs' spectrum and some perspectives of psychoacoustics, this paper applied multiple demes' parallel and real-valued coding genetic algorithm (GA) to the approximation of HRTFs' zero-pole model. Using the logarithmic magnitude's error criterion for human auditory sense, the results show that the performance of GA is averagely 39% better than that of traditional Prony method, and 46% than that of Yule-Walker algorithm.

6055B-65, Session 13

Multiprojector image distortion correction scheme for curved screens on the example of the Cybersphere

B. V. Shulgin, J. Ye, V. H. Raja, Univ. of Warwick (United Kingdom)

A problem appearing in the virtual reality (VR) is the image distortion and blending for curved screens. Because of the different distance from the part of a curved screen to projectors the different parts of the projected image have different magnification that leads to distortion. There are ways to solve this problem via a special circuit implementation within the image projectors or via special image correction PC based boxes. The projected image should be pre-distorted initially in order to get an undistorted image on the curved screen. These existing solutions are limited in number of projectors or screen configurations. We propose an original image correction algorithm which can work on screen surfaces of arbitrary geometry. It was tested on the Cybersphere, the VR technology developed by the University of Warwick. The method allows blending images from

multiple projectors confining the corrected image within given boundaries. We propose software implementation of the algorithm which allows using it for any programs not limited by OpenGL technology. We also propose using it for distributed image rendering and projection such as Chromium based sets. We apply the method for variable curvature screen, a novel patented VR set developing at the Warwick Manufacturing Group, University of Warwick.

6055B-66, Session 13

3D workflow for HDR image capture of projection systems and objects for CAVE virtual environments authoring with wireless touch-sensitive devices

M. J. Prusten, Optical Design Labs.; M. K. McIntyre, Total Eclipse Studios; M. Landis, The Univ. of Arizona

We present a 3D workflow pipeline for the high dynamic range (HDR) image capture of projected scenes or objects, for authoring in CAVE virtual environments. The methods of high dynamic range digital photography of environments vs. objects are reviewed. The image collection of a scene or object requires a digital photographic procedure and post software libraries to reconstruct the high dynamic photographs for the specific virtual reality applications. Once the high dynamic range images have been acquired our workflow pipeline, CAVEPIPE, can be incorporated. Samples will be reviewed of both types of virtual authoring being, the actual CAVE environment and a sculpture. Our virtual reality environment, from FakeSpace, consists of four 8x10 ft screens on three sides and a floor, which are the rear projection screens and the boundaries of the 3D space. The projected images are edge-blended multiple projector tiles with 1600x1200 resolution at 96 Hz refresh. The software library tools being used at the AZ-LIVE (Arizona Laboratories for Immersion Visualization Environments) are a series of software tools incorporated into a pipeline called CAVEPIPE. This pipeline includes: OpenGL performer, CAVELib, NUKE and the major 3D animation packages, Lightwave, Maya, Softimage, and Houdini. OpenGL Performer is a high performance 3D rendering toolkit for developing real-time, multi-processed, interactive graphics. The CAVELib routines in the virtual reality applications provide the building blocks for the multiple display devices, the viewer-centered perspective camera projections, stereoscopic viewing, and the 3D tracked input devices. With the captured data rendered, we composite the various image layers into image sequences. Both object and scene images can be composited into a photorealistic scene. The NUKE compositor is a new tool that supports object importing, projection mapping, and 3D camera import from all industry standard trackers. This allows for high-resolution objects and scenes to be composited together in natural illumination environments and presented in our CAVE virtual reality environment. This workflow for authoring 3D content has been demonstrated in: atomic modeling, architectural modeling, and on HDR captured data of virtual projection environments and HDR images of objects. The 3D object and scene importers are being expanded to handle data formats from Houdini, Softimage XSI, Maya animation packages and the NUKE compositor. The 3D scene acquisition are being updated acquire data not just from a fisheye lens, but also from a wide-angle lens to eliminate the aberrations at the edge of field. The use of touch panel display systems and wireless devices are also being customized and added to the CAVE interface. This will allow the user to have more useful graphical user interfaces (GUI) while exploring and developing virtual reality content in the CAVE.

6055B-67, Session 14

Examination of corner vane estrangement evaluation method for a circular tunnel

H. Yokoyama, O. Fujishima, Hitachi, Ltd. (Japan)

For the next several years, tunnel construction several with highway construction are planned around a Japanese city.

Furthermore, several ventilation facilities constructions are planned by these constructions. There are circle or rectangle tunnel, and rectangle duct in these tunnel ventilation facilities.

And a rectification board called a corner vane is installed to reduce a pressure loss on these corner parts.

For design of conventional corner vane, 2D CAD has been generally used. However, the design in curved surface part in ceiling part of shield tunnel became difficult. Because, the ceiling part is complicated curved surface shape.

Furthermore, When a difference (a building error) of form of actual form was identified as a design value, Estrangement occurs between a ceiling part and corner vane ends. Therefore, in a design or installing, correspondence method had to be examined.

In this problem, when laser scanner that can acquire wide 3D data in real time was used for 3D measurement of ceiling side of circle tunnel, an actual form will be grasped. Furthermore, an actual form can reappear on 3D CAD by taking measurement result.

This point was paid attention by the authors; laser scanner was made to grapple together with 3D CAD, The estrangement of a corner vane for a circular tunnel-related evaluation method and effectiveness were examined.

Authors will be content about this topic.

6055B-68, Session 14

Virtual technical support for field engineers in the water and ventilation hygiene industry

I. A. Nicholas, Cardiff Univ. (United Kingdom); D. Kim, Aqua Marc Ltd. (United Kingdom)

This paper presents an industrial application of VR, which has been integrated as a core component of a virtual technical support system. The problems that often impede conventional technical support and the way in which a virtual technical support system can overcome them are discussed. Field engineers are able to use the system to access improved information and knowledge through their laptop computers while on-the-job. Thereby, taking advantage of scarce investment resources. When used in synergy, the application of VR, multimedia, coordinated multiple views and knowledge-based technologies can be shown to significantly reduce technical support costs. Initial results are presented showing the effectiveness and benefits of such a system for field engineer support in the water and ventilation hygiene industry.

6055B-69, Session 14

Virtual reality in construction industry: a requirement compatibility analysis approach

J. Ye, B. V. Shulgin, V. H. Raja, Univ. of Warwick (United Kingdom)

Virtual Reality (VR) is regarded as a high-end user-computer interface that involves real-time simulation and interactions through multiple sensorial channels. It is assumed that VR will reshape the interaction interfaces between user and computer technology by offering new approaches for the communication of information, the

visualisation of processes and the creative expression of ideas. The VR application in construction has a relatively long history but its successful stories are not heard quite often.

In this paper, the authors have explored how much further the construction industry could be supported by new three dimensional (3D) VR technologies in different construction processes. The design information in the construction industry has been discussed first followed by a detail construction process analysis. A questionnaire survey has been conducted and the results of the survey are presented and discussed. As an investigation into the application of 3D VR technologies in the context of the construction processes, the benefits and challenges of current and potential applications of 3D VR in the construction industry have been identified. This study also reveals the strengths and weaknesses of 3D VR technology applications in the construction processes. Suggestions and future works are also provided in this paper.

6055B-70, Session 14

Adding tactile realism to a virtual reality laparoscopic surgical simulator with a cost-effective human interface device

I. W. Mack, Queen's Univ. Belfast (United Kingdom); S. Potts, The Royal Group of Hospitals (United Kingdom); K. R. McMenemy, R. S. Ferguson, Queen's Univ. Belfast (United Kingdom)

The laparoscopic technique for performing abdominal surgery requires a very high degree of skill in the medical practitioner. Much interest has been focused on using computer graphics to provide simulators for training surgeons. Unfortunately, these tend to be complex and have a very high cost, which limits availability and restricts the length of time over which an individual can practice their skills. There is no reason why the cost should be high as computer game technology delivers excellent graphics that easily fulfil any requirement of a surgical simulator. If it was down to the graphics alone every surgeon could have a training and practising tool on their laptop. It is the appropriate human interface hardware, the equivalent of the 'joystick', which is missing. This paper presents a design for a very low cost device to address this vital issue. The design encompasses: the mechanical construction, the electronic interfaces and the software protocols to mimic a laparoscopic surgical set-up. Thus the surgeon has the capability of practising two-handed procedures with the possibility of force feedback. The force feedback and collision detection algorithms allow surgeons to practice realistic operating theatre procedures with a good degree of authenticity.

6055B-71, Session 15

Inverse perspective

M. Dolinsky, Indiana Univ.

This paper will discuss the potentiality towards a methodology for creating perceptual shifts in virtual reality (VR) environments. A perceptual shift is a cognitive recognition of having experienced something extra-marginal, on the boundaries of normal awareness, outside of conditioned attenuation. Perceptual shifts are further defined, demonstrated in a historical tradition, analyzed through various categories of sensory illusions and explained via biological perceptual mechanisms and the sciences, including neuroscience and cognitive science. This paper explores perspective, illusion and projections to situate an artistic process in terms of perceptual shifts. Most VR environments rely on a single perceptual shift while there remains enormous potential for perceptual shifts in VR. Examples of paintings and VR environments that develop this idea will be presented.

6055B-72, Session 15

Virtual reality and the unfolding of higher dimensions

J. C. Aguilera, Univ. of Illinois at Chicago

As augmented reality evolves, the need for spaces that are responsive to structures independent from three dimensional spatial constraints, become apparent. The visual medium of computer graphics may also challenge these self imposed constraints. If one can get used to how projections affect objects in three dimensions, it may also be possible to compose a situation in which to get used to the variations that occur while moving through higher dimensions. The presented application is an enveloping landscape of concave and convex forms which are determined by the orientation and displacement of the user in relation to a grid made of hypercubes. The interface accepts input from tridimensional and four dimensional transformations, and smoothly displays such interactions in real-time. The motion of the user becomes the graphic element whereas the higher dimensional grid references to his/her position relative to it. The user learns how motion inputs affect the grid, recognizing a correlation between the input and the transformations. Mapping information to complex grids in virtual reality is valuable for engineers, artists and users in general because navigation can be internalized like a dance pattern, and further engage us to maneuver space in order to know and experience.

6055B-73, Session 15

Framing the magic

D. Tsoupikova, Univ. of Illinois at Chicago

This paper will explore how the aesthetics of the virtual world affects, transforms, and enhances an immersive emotional experience of the user. What we see and what we do upon entering the virtual environment influences our feelings, mental state, physiological changes and sensibility. To create a unique virtual experience the important component to design is the beauty of the virtual world based on the aesthetics of the graphical objects such as textures, models, animation, and special effects. When the user is immersed into the visual art world, what they see inspires imagination, remembrance and positive feelings. Through aesthetics the immersive effect is much stronger and more compelling. In order to control a user emotions the virtual reality environment must be customized for an individual experience. But quality of the graphics, poetics and the aesthetics of the virtual world can be made to evoke certain sensible changes in the user's state of mind such as engaging interactivity, fun, thought provocation, and challenging storyline. These changes and effects on the user can be adopted from the art and science by researching the fields of color theory, art education, art therapy, visual music, design, architecture and art history.

Many artists these days work on the aesthetics of virtual reality, based upon their experiences in traditional arts such as painting, sculpture, design, education and music to create higher quality stereo graphics of virtual worlds. This paper will use examples of virtual art projects such as World Skin by Maurice Benayoun, Beat Box by Margaret Dolinsky, PAAPAB by Dave E. Pape, and Josephine Anstey, Yiggdrasil by Bino and Cool, Uzume by Petra Gemeinboeck, Osmose by Char Davies and others to compare the immersive power of aesthetics into their emotional effect and how stereo technology could benefit the creativity. Arthur Clarke, the renowned science fiction writer once said that sufficiently complex technology was indistinguishable from magic. The ratio between virtual reality aesthetics and human perceptions is the key for the development of the impressive immersive experience.

6055B-74, Session 15

Virtual reality, immersion, and the unforgettable experience

J. F. Morie, Univ. of Southern California

Thirty years ago, working in the nascent field of virtual reality meant combining simple polygons, adding some textures and figuring out a method for navigating that space. Today, we think not only about the space, but also time and story, the amount of agency provided, the expected degrees of immersion and the quality of presence. There are new flavors of virtual reality, too, from the private, meditative ones to massively multiplayer online versions. There are virtual worlds, virtual environments, virtual stories, interactive plays and collaborative performances. This expansion of VR territory requires a more sophisticated approach to understanding exactly what VR is, and ultimately, what it still might be. At the core of virtual reality is the desire to make a technological work that provides a participant with an unforgettable experience. Diverse disciplines, such as art, cognitive science, psychology, phenomenology, embodiment, performance, and play all contribute to the design of such experiences. The distinction between spatial and social immersion is especially important for categorizing modern virtual realities and this paper will explore how these two approaches contribute uniquely to the design of the ultimate "unforgettable experience".

6055B-75, Session 16

Teleoperation interface for mobile robot with perspective-transformed virtual 3D screen on PC display

T. Kimura, H. Kakeya, Univ. of Tsukuba (Japan)

The authors propose an inexpensive human interface for teleoperation of mobile robots by giving a perspective-transformed image of a virtual 3D screen on a standard PC display. Conventional teleoperation systems of mobile robots have used multiple screens for multiple cameras or a curved screen for a wide view camera, both of which are expensive solutions intended only for professional use. We adopt a single standard PC display as the display system for the operator to make the system affordable to all PC users. To make the angular location perceivable with a 2D display, the authors propose a method to show on the flat screen a perspective-transformed image of a virtual 180-degree cylindrical screen. In this system the image shown on the 2D screen preserves angular information of the remote place, which can help the operator grasp the angular location of the objects in the image. The result of the experiments indicates that the perspective-transformed images of the cylindrical screen can give the operator a better understanding of the remote world, which enables easier and more instinctive teleoperation.

6055B-76, Session 16

An orientation sensing interface for portable situation awareness displays

J. Bleecker, Univ. of Southern California

No abstract available

6055B-77, Session 16

An interactive camera placement and visibility simulator for image-based VR applications

A. State, G. Welch, A. Ilie, The Univ. of North Carolina at Chapel Hill

Many VR-based or surveillance-oriented applications use multi-camera setups in view of 3D reconstruction or observation of target scenes and environments. Choosing the number of cameras as well as their locations, orientations, fields of view and other parameters for such setups is a difficult task. This paper describes an interactive software simulator that assists in the development of such scenarios.

The simulator allows interactive placement and manipulation of multiple cameras within a pre-modeled 3D environment. It shows the user the exact scene coverage for each camera, by projecting user-specified 2D patterns from each camera onto the scene, taking into account occluded areas. The user can navigate through the modeled scene, investigate lacking or overlapping coverage and interactively adjust camera parameters. The 2D patterns can be structured to indicate local imaging resolution at each point in the scene. Specialized patterns and projection techniques can be used to describe the dynamic coverage areas of pan-tilt-zoom cameras. We describe the simulator and its interface and show an example multi-camera setup for remote 3D medical consultation including some preliminary results.

interface (API) using OSC, a logical server layer implemented in Python, and an audio engine using SuperCollider. We discuss spatialization implementation and other features. Finally, we document the Synthecology project which premiered at WIRED Nextfest 2005 and was the first virtual environment to use Another Sound Server. We also discuss various techniques that enhance presence in networked virtual environments, as well as possible and planned extensions of Another Sound Server.

6055B-78, Session 16

Overview of virtual camera mechanisms for collaborative virtual environments: an application to the VRIMOR project

E. E. Alvarez, A. A. De Antonio, Univ. Politécnica de Madrid (Spain)

This article presents a research on the control of automated cameras in dynamic 3D virtual environments, which analyses the different branches that are currently being developed and improved in relation to the placement and movement of the virtual cameras. The aim of this research is to choose a method to design a management system for automatic cameras to be applied in the project VRIMOR. This project allows operators of nuclear power plants to design interventions with the aid of virtual mannequins with humanoid form. The designed intervention will be used for the learning of the operators in collaborative virtual environments. It is at this stage when the automated management of virtual cameras becomes relevant.

6055B-79, Session 16

Synthecology: 'sound' use of audio in teleimmersion

G. A. Baum, SUNY/Univ. at Buffalo; M. Gotsis, Univ. of Southern California; B. Chang, R. Drinkwater, D. St. Clair, Art Institute of Chicago

We examine historical audio applications used to provide real-time immersive sound for CAVE environments and discuss their relative strengths and weaknesses. We examine and explain issues of providing spatialized sound immersion in real-time virtual environments, some problems with currently used sound servers, and a set of requirements for an 'ideal' sound server. We present the initial configuration of a new cross-platform sound server solution using open source software and the Open Sound Control (OSC) specification for the creation of real-time spatialized audio with CAVE applications, specifically ygdrazil environments. The application, Another Sound Server, establishes an application

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6056-01, Session 1

A novel design of grating projecting system for 3D reconstruction of wafer bumps

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A challenge in the semiconductor industry is the 3D inspection of solder bumps grown on wafers for direct die-to-die bonding. In an earlier work we proposed a mechanism for reconstructing wafer bump surface in 3D, which is based upon projecting a binary grating to the surface from an inclined angle. For the purpose of 3D reconstruction with high speed and accuracy, the requirements for the projection lens system are as the followings: (1) having a tilted angle, usually about 60 degree, between the projection plane and the optical axis; (2) having high bandwidth to let high-spatial-frequency harmonics contained in the binary grating pass through the lens and be projected onto the inspected surface properly; (3) having high Modulation Transfer Function (MTF); (4) having large Field of View (FOV); and (5) having large Depth of Field (DOF) that corresponds to the depth range or height of the inspected surface. The above requirements lead to many difficulties in the design of the projection lens system. We designed a system consisting of a grating and several pieces of spherical lens, that addresses the requirements. To reduce the lens aberrations, the grating is laid out with a tilting angle specifically to make the grating, the lens, and the image plane intersect at the same line. Such a system can project a high spatial-frequency binary grating onto the inspected surface properly. Simulation results, including performance analysis and tolerance analysis, are shown to demonstrate the feasibility of the design.

6056-02, Session 1

Measurement of discontinuities on 3D objects using digital moiré

J. Liao, L. Cai, The Hong Kong Univ. of Science and Technology (Hong Kong China)

In this paper, a two-dimensional, binary fringe pattern is designed as structured light for 3D measurement. A feature, i.e., a white cross, is placed in the center of the fringe grating. The cross serves as axes of a reference frame. White square grids are alternated by black stripes vertically or horizontally elsewhere. Relative position of a given point on the fringe with respect to the center can be identified. When the fringe pattern is projected onto the surface of the object, its image is distorted. Therefore, image processing and pattern recognition algorithms are designed to calculate which row and column the particular point belongs to in the original fringe-frame. The pair of emitting and receiving angles for each point in the fringe and CCD frames, respectively, is acquired. And coordinate of each 3D point can be calculated. Compared with traditional digital moiré methods, this method achieves an absolute measurement of 3D surface because the information contained in the pattern is globally structured. Therefore, discontinuity measurement can be solved more easily. And resolution of the proposed method is larger than that of current methods of coding patterns under the same line width limitation due to principle of pattern design.

6056-03, Session 1

High-speed and high-sensitive demodulation pixel for 3D imaging

B. Büttgen, T. Oggier, Ctr. Suisse d'Electronique et de Microtechnique SA (Switzerland); P. Seitz, Swissnex; F. Lustenberger, Ctr. Suisse d'Electronique et de Microtechnique SA (Switzerland)

Optical time-of-flight (TOF) distance measurements can be performed using so-called smart lock-in pixels. By sampling the optical signal 2, 4 or n times in each pixel synchronously with the modulation frequency, the phase delay between the emitted and reflected signal is extracted and allows determining the object distance. The high integration-level of such lock-in pixels enables the real-time acquisition of the three-dimensional environment without using any moving mechanical components. A novel design of the 2-tap lock-in pixel in a 0.6 μ m semiconductor technology is presented. The pixel was implemented on a sensor with QCIF resolution. Although a small pixel size of 40x40 μ m² has been realized, high optical sensitivity is still achieved due to an optical fill factor of larger than 20% and high quantum efficiency. The optimized buried channel allows high-speed operation of the device resulting in a near-optimum demodulation performance and precise distance measurements which are almost exclusively limited by photon shot noise. In-pixel background-light suppression allows the sensor to be operated in an outdoor environment with full sun-light incidence. The highly complex pixel functionality of the sensor was successfully demonstrated on the new SwissRanger SR3000 3D-TOF camera design.

6056-04, Session 1

A QVGA-size CMOS time-of-flight range image sensor with background light charge draining structure

T. Ushinaga, I. Abdul Halin, T. Sawada, S. Kawahito, Shizuoka Univ. (Japan); M. Homma, Sharp Corp. (Japan); Y. Maeda, Suzuki Motor Corp. (Japan)

Range image sensors can be used in a variety of applications such as in automobile, medicine, robot vision systems, security and so on. Time-of-Flight (TOF) range imaging is a 3D image capture method where the roundtrip time of flight of light pulses from a sensor to a target is sensed. Range is then determined by multiplying half of the TOF with the speed of light constant, c. Recently TOF sensors are implemented using CCD, CCD-CMOS hybrid, and CMOS technologies. However the reported maximum spatial resolution is only 160 \AA ~ 124.

This paper presents a new type of CMOS TOF range image sensor using single layer polysilicon gates on thick field oxide. A structure for background light induced charge reduction is also included in the pixel. The sensor with a spatial resolution of 336 \AA ~ 252 (QVGA) pixels of 15 \AA ~ 15 μ m(c)² size was fabricated in a 0.35 μ m standard CMOS process. For preventing photoelectrons to be captured at Si-SiO₂ interface, an additional process step for buried channel structure is used. The light source used is an array of near-infrared LEDs. Using a small duty cycle (1-10%) light pulse and the charge draining structure drastically reduces the effect of background illumination, because reducing the duty cycle can increase tolerable maximum optical power in the LED.

The sensor achieves a minimum range resolution of 2.8cm at a framerate of 30fps, while the resolution is improved to 4.2mm at 3fps, corresponding to 10 frames averaging.

6056-05, Session 2

Overview of 3D surface digitization technologies in Europe

N. D'Apuzzo, Homometrica Consulting (Switzerland)

The solutions for 3D surface measurement offered by major European companies can be divided into different groups depending on various characteristics, such as, technology (e.g. laser scanning, white light projection), system construction (e.g. fix, on CNC/robot/arm) or measurement type (e.g. surface scanning, profile scanning). Crossing between the categories is possible, however, the majority of commercial products can be divided into the following six groups: (a) laser profiler mounted on robot/CNC/arm, (b) white light projection system mounted on robot and/or object on rotating platform, (c) laser point measurement system where both sensor and object move, (d) hand held profiler or point measurement systems, (e) portable laser scanning or white light projection surface measurement systems, (f) dedicated systems.

This paper presents an overview of the different 3D surface digitization technologies commercially available in the European market. It describes them with their advantages and disadvantages. Various examples of their use are shown for different application fields. A special interest is given to applications regarding the 3D surface measurement of the human body.

6056-06, Session 2

Automatic 3D real world surface texture mapping using perspective projection methods

C. Shih, MingDao Univ. (Taiwan)

Traditional digital reconstruction methods require large amount of human interactions that will impede the speed and accuracy of full detail full color model reconstruction.

This research proposes to explore the techniques to build an automatic procedure that can correlate a 3D mesh of a CAD model with a set of photos taken from the corresponding real world object. Correct pixel mapping from 2D space to 3D coordinate is the key to the success of such system.

Moreover due to large amount of human intervention during picture correlation step, texture wrapping deviation is inevitable and left unexplored. A research on the factors affecting the precision of perspective photo mapping and texturing seems to lighten up a way leading to automatic and accurate full color mesh model display.

The research plan to use the following steps in achieving the goal. (1) build an initial 3D image coordinate system by correlating a few pictures taken on the object. These pictures will cover a few limited number of carefully selected control points located on the real object. (2) derive a composite transformation matrix that combines the image coordinate system with the local mesh coordinate system. (3) use a visibility checking and Z buffer algorithm to do view planning and generate a few photo angles that will allow complete coverage of all the meshes. (4) for every photo taken, a perspective photo mapping procedure is taken to map corresponding pixel to the 3D mesh.

The results of this research can directly reduce human interaction and increase the productivity of digital recovery effort. Not only does it increase the value of digital reconstruction industry, but also prove the effectiveness of iterative least square fit theory on texture mapping.

6056-07, Session 2

Virtual confocal macroscopy

P. M. Hanna, U.S. Air Force; B. D. Rigling, Wright State Univ.

There is a need for persistent-surveillance assets to capture high-resolution, three-dimensional data for use in assisted target recognizing systems. Passive electro-optic imaging systems are presently limited by their ability to provide only 2-D measurements. We describe a methodology and system that uses existing technology to obtain 3-D information from disparate 2-D observations. This data can then be used to locate and classify objects under obscurations and noise.

We propose a novel methodology for 3-D object reconstruction through use of established con-focal microscopy techniques. A moving airborne sensing platform captures a sequence of geo-referenced, electro-optic images. Con-focal processing of this data can synthesize a large virtual lens with an extremely sharp (small) depth of focus, thus yielding a highly discriminating 3-D data collection capability based on 2-D imagery. This allows existing assets to be used to obtain high-quality 3-D data (due to the fine z-resolution).

This paper presents a stochastic algorithm for reconstruction of a 3-D target from a sequence of affine projections. We iteratively gather 2-D images over a known path, detect target edges, and aggregate the edges in 3-D space. In the final step, an expectation is computed resulting in an estimate of the target structure.

6056-08, Session 2

A robust algorithm for estimation of depth map for 3D shape recovery

A. Malik, T. Choi, Gwangju Institute of Science and Technology (South Korea)

Three-dimensional shape recovery from one or multiple observations is a challenging problem of computer vision. In this paper, we present a new focus measure for calculation of depth map. That depth map can further be used in techniques and algorithms leading to recovery of three dimensional structure of object which is required in many high level vision applications. The focus measure presented has shown robustness in presence of noise as compared to the earlier focus measures. This new focus measure is based on an optical transfer function using Discrete Cosine Transform and its results are compared with the earlier focus measures including Sum of Modified Laplacian (SML) and Tenenbaum focus measures. With this new focus measure, the results without any noise are almost similar in nature to the earlier focus measures however drastic improvement is observed with respect to others in the presence of noise. The proposed focus measure is applied on a test image, on a sequence of 97 simulated cone images and on a sequence of 97 real cone images. The images were added with the Gaussian noise which arises due to factors such as electronic circuit noise and sensor noise due to poor illumination and/or high temperature.

6056-09, Session 3

Formation of stereoscopic image pairs from a sequence of frames

M. A. Wessels, Dimensional Imaging, LLC

Under certain conditions of relative motion between an object and an observer, stereoscopic image pairs may be constructed from a sequence of monoscopic frames depicting the object at specific points in time. Pure transverse relative motion will produce slightly displaced views from frame to frame in the sequence.

These displacements are the source of the stereoscopic separation necessary for stereoscopic depiction.

In general, the displacements occur around a stereoscopic axis that may lie at any orientation in the frame. The algorithm determines this axis, and then rotates the image pair to set the axis to lie in the vertical direction. Actual motion may include rotations of the object itself, which are superimposed upon the gross transverse motion. Non-contributing rotations are identified and removed.

The starting point of this process is a displacement map which shows by how much specific points in a frame have shifted with respect to their counterparts in the corresponding reference frame. Pairs which exhibit good stereoscopic separation will yield displacement maps characterized by a strong gradient over the field. Analysis of the orientation of this gradient yields the stereoscopic axis.

6056-10, Session 3

3D model generation using unconstrained motion of a hand-held video camera

C. Baker, C. H. Debrunner, M. Whitehorn, PercepTek, Inc.

We have developed a shape and structure capture system which constructs accurate, realistic 3D models from video imagery taken with a single freely moving handheld camera, without the need for an expensive custom inertial measurement system. Using an inexpensive off the shelf hand-held video camera, we demonstrate the feasibility of fast and accurate generation of these 3D models at a very low cost.

In our approach the operator films a scene while observing some very simple camera motion constraints. Our system identifies and tracks high interest image features and computes the relative pose of the camera using a RANSAC-based approach to solve for the camera pose and 3D structure which best describes the feature motion.

Once we have the pose for many frames in the video sequence we perform correlation-based stereo to obtain dense point clouds. These point clouds are integrated into a 3D model, using an octree structure for efficient representation. The integration technique enables filtering based on voxel occupancy counts which eliminates many stereo outliers and results in an accurate, 3D model which may be inspected from novel viewpoints.

This paper describes our approach in detail and shows reconstructed results of both indoor and outdoor scenes.

6056-11, Session 3

3D from arbitrary 2D video

I. A. Ideses, L. P. Yaroslavsky, Tel-Aviv Univ. (Israel)

In this paper we present a method to synthesize 3D video from arbitrary 2D video. The 2D video is analyzed by computing frame-by-frame motion maps. For this computation several methods were tested, among them are optical flow, MPEG motion vectors extraction and correlation based target location. Using the computed motion maps, the video undergoes analysis and the frames are segmented to provide object-wise depth ordering.

The frames are then used to synthesize stereo pairs. This is performed by resampling of the image on a grid that is governed by the depth-map. In order to improve the quality of the synthetic video and in order to enable 2D viewing where 3D visualization is not possible, several techniques for image enhancement are used. In our test case, anaglyph projection was selected as the 3D visualization method, since this method is mostly suited to standard displays. The drawback of this method is ghosting artifacts. In our implementation we minimize these unwanted artifacts by modifying the computed depth-maps using non-linear transformations. Defocusing was also used to counter such artifacts.

Our results show that non-linear operations on the depth-maps enable synthesis of high quality 3D videos.

6056-12, Session 3

Nonintrusive viewpoint tracking for 3D for perception in smart video conference

X. Desurmont, I. Ponte, J. Meessen, J. Delaigle, Multitel A.S.B.L. (Belgium)

Globalisation of people's interaction in the industrial world and the ecological cost of transport make video-conference an interesting solution for collaborative work. However, the lack of immersive perception makes video-conference not appealing. TIFANIS tele-immersion system was conceived to let users interact as if they were physically together.

In this paper, we focus on an important feature of the immersive system: the automatic tracking of the user's point of view in order to render correctly in his display the scene from the other site.

Viewpoint information has to be computed in a very short time and the detection system should be no intrusive, otherwise it would become cumbersome for the user.

The viewpoint detection system consists of several modules. First, an analysis module identifies and follows regions of interest (ROI) where faces are detected. We will show the cooperative approach between spatial detection and temporal tracking. Secondly, an eye detector finds the position of the eyes within faces. Then, the 3D positions of the eyes are deduced using stereoscopic images from a binocular camera. Finally, the 3D scene is rendered in real-time according to the new point of view.

The performances of the system are evaluated in terms of accuracy of face and eyes 3D positions in various sequences.

6056-13, Session 3

Internal shape-deformation invariant 3D surface matching using 2D principal component analysis

M. Celenk, I. Al-Jarrah, Ohio Univ.

This paper describes a method that overcomes the problem of internal deformations in three-dimensional (3D) range image identification. Internal deformations can be caused by several factors including stereo camera-pair misalignment, surface irregularities, active vision methods' incompatibilities, image imperfections, and changes in illumination sources. Most 3D surface matching systems suffer from these changes and their performances are significantly degraded unless deformations' effect is compensated. Here, we propose an internal compensation method based on the two-dimensional (2D) principal component analysis (PCA). The depth map of a 3D range image is first thresholded using Otsu's optimal threshold selection criterion to discard the background information. The detected volumetric shape is normalized in the spatial plane and aligned with a reference coordinate system for rotation-, translation- and scaling-invariant classification. The preprocessed range image is then divided into 16x16 sub-blocks, each of which is smoothed to minimize the local variations. The 2DPCA is applied to the resultant range data and the corresponding principal vectors are used as the characteristic features of the object to determine its identity in the database of pre-recorded shapes. The system's performance is tested against the several 3D facial images possessing arbitrary deformation. Experiments have resulted in 92% recognition accuracy for the GavaDB 3D-face database entries and their Gaussian- or Poisson-type noisy versions.

6056-14, Session 3

Digital Hammurabi: design and development of a 3D scanner for cuneiform tablets

D. V. Hahn, D. Duncan, K. Baldwin, J. Cohen, B. Purnomo, Johns Hopkins Univ.

Cuneiform is an ancient form of writing in which wooden reeds were used to impress shapes upon moist clay tablets. Upon drying, the tablets preserved the written script with remarkable accuracy and durability. There are many problems associated with studying these artifacts. For example, photographic records of the tablets many times prove to be inadequate as they lack the ability to alter the lighting conditions and view direction. As a solution, we describe a 3D scanner capable of acquiring the shape, color, and reflectance of a tablet as a complete 3D object. This data set could then be stored in an online library and manipulated by rendering software that would allow a user to obtain any view and lighting direction. The scanner utilizes a camera and telecentric lens to acquire images of the tablet under varying controlled illumination conditions. Image data are processed using photometric stereo and structured light techniques to determine the tablet shape; color information is reconstructed from primary color monochrome image data. The scanned surface is sampled at 26.8 μm lateral spacing and the height information is calculated on a much smaller scale. Scans of adjacent tablet sides are registered together to form a 3D surface model.

6056-15, Session 3

Three-dimensional surface reconstruction for evaluation of the abrasion effects on textile fabrics

A. O. Mendes, P. T. Fiadeiro, R. A. Miguel, Univ. da Beira Interior (Portugal)

The evaluation of the abrasion effects becomes important on the textile industry because abrasion is responsible for many surface changes that occur in garments. In particular, the pilling formation is a phenomenon caused by abrasion that affects fabrics more significantly altering their surface severely. The present work presents an optical method that enables topographic reconstructions of textile fabric samples and consequently, it is possible to evaluate and quantify the pilling formation resulted from their topographic changes. The proposed method is based on optical triangulation basically operating like a scanning system (digitiser) or a 3D scanner. A fabric sample is held by a linear motorized stage and, when is on movement, a thin light stripe performs a full scan of the fabric sample surface. Simultaneously, images of the light stripe profile are being acquired and stored on a computer for further processing. The procedures for image data acquisition, storage and processing are carried out using specific algorithms written in the MatLab programming language. Finally, with the available processed data, it is possible a three-dimensional surface reconstruction and a quantification of the pilling formation of the analyzed fabric samples.

6056-16, Session 3

3D environment capture from monocular video and inertial data

R. Clark, M. Lin, C. J. Taylor, Acuity Technology

This paper presents 3D environment reconstruction from monocular video augmented with 6-DOF inertial data. One application targets sparsely furnished room interiors using high quality, normal field of view, handheld video, and linear accelerations and angular velocities from an attached inertial measurement unit. A second application

targets natural terrain with manmade structures, using heavily compressed, narrow field of view, aerial video, and position and orientation data from the aircraft navigation system. In both applications, the 6-DOF spatial offsets between the camera and inertial data are initially unknown, and only a small fraction of the scene is visible in any one video frame.

We start by estimating sparse structure and motion from 2D feature tracks using a Kalman filter and/or bundle adjustment. The first application additionally incorporates a weak assumption of bounding perpendicular planes (estimated via RANSAC) to minimize a tendency to drift, while the second application requires tight integration of the navigational data to alleviate the poor conditioning caused by the narrow field of view. This is followed by dense structure recovery via graphcut-based multiview stereo. Finally, input images are texture-mapped onto the meshed 3D surface for rendering. We show sample experimental results from novel viewpoints.

6056-18, Session 3

The effects of different shape-based metrics on identification of military targets from 3D ladar data

G. J. Meyer, J. Weber, Air Force Research Lab.

The choice of shape metrics is important to effectively identify three-dimensional targets. The performance (expressed as a probability of correct classification) of three metrics using point clouds of military targets rendered using Irma, a government tool that simulates the output of an active ladar system, is compared across multiple ranges, sampling densities, target types, and noise levels. After understanding the range of operating conditions a classifier is expected to see in the field, a process for determining the upper-bound of a classifier and the significance of this result is assessed. Finally, the effect of sampling density and variance in the position estimates on classification performance will be examined to make intelligent system level design tradeoffs.

6056-19, Session 4

Digital 3D reconstruction of George Washington

A. Razdan, Arizona State Univ.

PRISM is a focal point of interdisciplinary research in geometric modeling, computer graphics and visualization at Arizona State University. Many projects in the last ten years have involved laser scanning, geometric modeling and feature extraction from such data as archaeological vessels, bones, human faces, etc. This talk will briefly outline the history and development of work at PRISM followed by a recently completed project on the 3D reconstruction of George Washington (GW). The project brought together forensic anthropologist, digital artists and computer scientists in the 3D digital reconstruction of GW at 57, 45 and 19 including detailed heads and bodies. Although many other scanning projects such as the Michelangelo project have successfully captured fine details via laser scanning, our project took it a step further, i.e. to predict what that individual (in the sculpture) might have looked like both in later and earlier years, specifically the process to account for reverse aging. Our base data was GW's face mask at Morgan Library and Hudon's bust of GW at Mt Vernon, both done when GW was 53. Additionally we scanned the statue at the Richmond's Capitol, various dentures, and other items. Other measurements came from clothing and even portraits of GW. The digital GWs were then milled in high density foam for a studio to complete the work. These will be unveiled at the opening of the new education center at Mt Vernon in fall 2006.

6056-20, Session 4

The study of craniofacial growth patterns using 3D laser scanning and geometric morphometrics

M. Friess, Anthrotech Inc.

Throughout childhood, braincase and face grow at different rates and therefore exhibit variable proportions and positions relative to each other. Our understanding of the direction and magnitude of these growth patterns is crucial for many ergonomic applications and can be improved by advanced 3D morphometrics. The purpose of this study is to investigate this known growth allometry using 3D imaging techniques. The geometry of the head and face of 840 children, aged 2 to 19, was captured with a laser surface scanner and analyzed statistically. From each scan, 18 landmarks were extracted and registered using General Procrustes Analysis (GPA). GPA eliminates unwanted variation due to position, orientation and scale by applying a least-squares superimposition algorithm to individual landmark configurations. This approach provides the necessary normalization for the study of differences in size, shape, and their interaction (allometry). The results show that throughout adolescence, boys and girls follow a different growth trajectory, leading to marked differences not only in size, but also in shape. These differences can be observed during early childhood, but become most noticeable after the age of 13 years, when craniofacial growth in girls slows down significantly, whereas growth in boys continues for at least 3 more years.

6056-21, Session 4

A three-dimensional analysis of the geometry and curvature of the proximal tibial articular surface of hominoids

E. K. Landis, P. A. Karnick, Arizona State Univ.

This study uses new three-dimensional imaging techniques to compare the articular curvature of the proximal tibial articular surface in hominoids. It has been hypothesized that the curvature of the anteroposterior contour of the lateral condyle in particular can be used to differentiate humans and apes and reflect locomotor function. This study draws from a large comparative sample of extant hominoids to obtain quantitative curvature data. Three-dimensional models of the proximal tibiae of 26 human, 15 chimpanzee, 15 gorilla, 17 orangutan, 16 gibbon and four Australopithecus fossil casts (AL 129-1b, AL 288-1a, AL 333x-26, KNM-KP 29285A) were acquired with a Cyberware Model 15 laser digitizer. Curvature analysis was accomplished using a software program developed at Arizona State University's Partnership for Research In Stereo Modeling (PRISM) lab, which enables the user to extract curvature profiles and compute the difference between analogous curves from different specimens. Results indicate that the curvature of chimpanzee, gorilla and orangutan tibiae is significantly different from the curvature of human and gibbon tibiae, thus supporting the hypothesized dichotomy between humans and great apes. The non-significant difference between humans and gibbons is surprising given locomotor differences between these taxa. All four Australopithecus tibia were aligned with the great apes.

6056-22, Session 4

New approach in curve matching technique and its implications on human evolution research

H. Vahdati, P. A. Karnick, Arizona State Univ.

Our research focuses on midfacial prognathism (MFP) a well-documented Neanderthal trait. Understanding the pattern of MFP should help to answer questions arising from the modern human origins controversy in that well-studied area. This research should help to determine whether or not continuity is apparent in the midfacial region of the European Middle and Upper Pleistocene hominids that bracket Neanderthals in time.

This research produces geometric morphometric three-dimensional analyses of the surface data. The data are collected from the mid-face of modern humans and fossil humans using a computer scanner. An original software (designed for this purpose), which inputs laser-scanned data from the surface of the skulls, has been employed to transform the raw facial data to the comparable curves to investigate degrees of similarity and matching between the mid facial curves of different humans. Our initial study (samples including of modern humans and fossil humans) provides us with a not very significant divergent between Neanderthals and early modern humans in Europe.

6056-23, Session 4

Point cloud-based 3D head model classification using optimized EGI

X. Tong, H. Wong, B. Ma, City Univ. of Hong Kong (Hong Kong China)

In this paper, we apply a new approach into the classification of the 3D head models, which are represented in the format of point cloud, and get a satisfying result. In the experiment, we have the following classification rates: 71.3% for the original EGIs, 70.6% for 2D FDA and 81.7% for the 2D PCA. As a summary, the contributions of this paper mainly include the following two aspects: first, we extend the application of 2D subspace analysis to 3D object recognition by characterizing a 3D object model with a 2D image; second, for the 3D head model classification problem, by using 2D subspace analysis, we can achieve higher classification rate, and more importantly reduce the computation cost. The reduction in computation cost is embodied at two aspects: One is that optimized EGI has smaller dimension than the original EGI does which facilitates the subsequent classification, and the other is that only solving an eigen-system with a small dimension is required.

6056-24, Session 4

3D face structure extraction using shape matching morphing model

F. Xue, X. Ding, Tsinghua Univ. (China)

In general, the point correspondence and automatic face structure extraction are challenging problems. This is due to the fact that automatic extraction and matching of a set of significant feature points on different image views on the face, which are needed to recover the individual's 3-D face modal, is a very hard machine task. In this paper, in order to bypass this problem, our method recovers both the pose and the 3-D face coordinates using shape matching morphing model and iterative minimization of a metric based on the structure matching. A radial basis function (RBF) in 3-D is used to morph a generic face into the specific face structure and shape context (SC) is used to describe point shape. Basing on RBF and SC, shape distance is used to measure the similarity of two shapes. Experiment results are shown for images of real faces and promising result are obtained.

6056-25, Session 5

Posture and re-positioning considerations of a torso imaging system for assessing scoliosis

P. O. Ajemba, N. G. Durdle, Univ. of Alberta (Canada); D. L. Hill, J. V. Raso, Glenrose Rehabilitation Hospital (Canada)

The influence of posture and re-positioning (sway and breathing) on the accuracy of a torso imaging system for assessing scoliosis was evaluated. The system comprised of a rotating positioning platform and two laser digitizers. It required four partial-scans taken at 900 intervals over 10 seconds to generate four complete torso scans. Its accuracy was previously determined to be 1.1 ± 0.9 mm. Ten evenly spaced cross-sections obtained from forty scans of five volunteers in four postures (free-standing, holding side supports, holding front supports and with their hands on their shoulders) were used to assess the variability due to posture. Twenty cross-sections from twenty scans of two volunteers holding side supports were used to assess the variability due to positioning. The variability due to posture was less than 4mm at each cross-section for all volunteers. Variability due to sway ranged from 0-3.5mm while that due to breathing ranged from 0-3mm for both volunteers. Holding side supports was the best posture. Taking the four shots within 12 seconds was optimum. As major torso features that are indicative of scoliosis are larger than 4mm in size, the system could be used in obtaining complete torso images used in assessing and managing scoliosis.

6056-26, Session 5

Reverse engineering and rapid prototyping techniques to innovate prosthesis socket design

G. Magrassi, G. Colombo, M. Bertetti, D. Bonacini, Politecnico di Milano (Italy)

The paper investigates an innovative approach totally based on digital data to optimize lower limb socket prosthesis design. This approach uses a stump's detailed geometric model and provides to substitute the plaster cast obtained through the traditional manual methodology with a physical model, realized with Rapid Prototyping technologies; this physical model will be used for the socket lamination. We present a methodology for stump's digital geometric model 3D reconstruction able to describe with high accuracy and detail the complete structure subdivided into bones, soft tissues, muscular masses and dermis. Some different technologies are used for stump imaging and acquisition: non contact laser technique for external geometry acquisition, CT and MRI imaging technologies for the internal structure, the first one devoted to bones geometrical model, the last fit for soft tissues and muscles. We discuss about problems related to 3D geometric reconstruction: the relative position of patient and stump for the different acquisitions, markers' definition on the stump to identify landmarks, alignment's strategies for the different digital models, in order to define a protocol procedure answering for the requested accuracy for socket's realization. Some case-studies demonstrate the methodology and the obtained results.

6056-27, Session 5

4D data processing for dynamic human body analysis

R. Sitnik, A. M. Filipczak, Politechnika Warszawska (Poland)

It seems that the next generation of a full 3D optical scanning systems will be able to measure objects in motion. According to this it will be necessary to use other data processing and representation methods. We propose our own solution which is based on using an

arbitrary mesh which is scaled and wrapped around a merged point clouds obtained from the measurements instead of a standard point cloud representation. This method was invented for a project of motion analysis of human legs. The first step of our 4D data processing chain is scanning and merging points clouds obtained from four directions. After that we detect some selected areas on the object's surface and its approximate pose/position. We create a simple bone system and using it we deform an arbitrary mesh to match the point cloud. The last step is wrapping this mesh around the point cloud. This is performed by calculating the best fitting surfaces to the selected points of the cloud and projecting each vertex of the mesh onto them. This kind of scanning data representation can have a very wide range of application - industry, medicine and multimedia. We present some details of our solution, exemplary results and finally some conclusions with a short discussion of our future work in this field.

6056-28, Session 5

Measuring human movement for biomechanical applications using markerless motion capture

L. Mündermann, S. Corazza, A. M. Chaudhari, T. P. Andriacchi, Stanford Univ.; A. Sundaresan, R. Chellappa, Univ. of Maryland/College Park

The development of methods for the capture of human movement is motivated by the desire to understand normal and pathological joint mechanics without the artifacts associated with standard marker-based motion capture techniques such as soft tissue artifacts and the risk of artificial stimulus of taped-on or strapped-on markers. In this study, the advancement of markerless human motion capture is described in the context of biomechanical applications. Several algorithms for accurate markerless motion capture are explored systematically in both a virtual and experimental environment, and results for real data are presented. The implementation of this new technology offers the promise for simple, time-efficient, and potentially more meaningful assessments of human movement in research and clinical practice.

6056-29, Poster Session

Development of measurement system of three-dimensional shape and surface reflectance

T. Miyasaka, K. Araki, Chukyo Univ. (Japan)

We describe a three-dimensional measurement system which can acquire not only three-dimensional shapes of target objects but also these surface reflectance parameters.

The system is constructed by one or some digital cameras, digital projector, and a computer which controls camera and projector. For 3-D geometrical reconstruction, we use well known gray code structured light method. The method projects gray code light patterns from the projector and obtain illuminated scenes by a camera. We add additional light patterns for surface reflectance measurement. These patterns are all white and gray light pattern. To recover complete shape of the target object, the object is measured from various viewpoints repeatedly, or measured repeatedly from fixed viewpoint while be moving by hand or turn table. To end the measurement, relative positions of each obtained range data are calculated by ICP algorithm. For each small region of the target object surface, we calculate reflectance parameters from surface normals, viewpoint (camera viewpoint), and light position (the projector viewpoint). Enough sampling of these three information sources are obtained for each small surface, we estimate reflectance parameters for each surface points.

We demonstrate this geometrical and reflectance measurement method by experiments for fewer objects.

6056-30, Poster Session

Use of laser 3D digitizer in data collection and 3D modeling of anatomical structures

K. Tse, Univ. of New South Wales (Australia); H. Van Der Wall, Concord Repatriation General Hospital (Australia); D. H. Vu, Univ. of New South Wales (Australia)

A laser digitizer (Konica-Minolta Vivid 910) is used to obtain 3-dimensional surface scans of anatomical structures with a maximum resolution of 0.1mm. Placing the specimen on a turntable allows multiple scans all-around because the scanner only captures data from the portion facing its lens. A computer model is generated using 3D modeling software such as Geomagic.

The 3D model can be manipulated on screen for repeated analysis of anatomical features, a useful capability when the specimens are rare or inaccessible (museum collection, fossils, imprints in rock formation...). As accurate measurements can be performed on the computer model, instead of taking measurements on actual specimens only at the archeological excavation site e.g., a variety of quantitative data can be later obtained on the computer model in the laboratory as new ideas come to mind.

Our group had used a mechanical contact digitizer (Microscribe) for this purpose, but with the surface digitizer, we have been obtaining data sets more accurately and more quickly.

6056-31, Poster Session

Volume intersection with imprecise camera parameters

S. Sakamoto, K. Shoji, H. Iwase, F. Toyama, J. Miyamichi, Utsunomiya Univ. (Japan)

Volume intersection is one of the simplest techniques for reconstructing 3D shapes from 2D silhouettes. 3D shapes can be reconstructed from multiple view images by back-projecting them from the corresponding viewpoints and intersecting the resulting solid cones. The camera position and orientation (extrinsic camera parameters) of each viewpoint with respect to the object are needed to accomplish reconstruction. However, even a little variation in the camera parameters makes the reconstructed 3D shape smaller than that with the exact parameters. The problem of optimizing camera parameters deals with determining exact ones from approximate ones and multiple silhouette images. This paper examines attempts to optimize camera parameters by reconstructing a 3D shape via the method of volume intersection. Reprojecting the reconstructed 3D shape to image planes, the camera parameters are determined by finding the projected silhouette images that result in minimal lost area when compared to the original silhouette images. For relatively large displacement of camera parameters we propose a method repeating the optimization using dilated silhouettes which gradually shrink to original ones. Results of simulation experiments using a VRML model show the effect of it.

6056-32, Poster Session

Development of ultrathin three-dimensional image capturing system

K. Yamada, H. Mitsui, T. Asano, Hiroshima Institute of Technology (Japan); H. Takahashi, Osaka City Univ. (Japan); J. Tanida, Osaka Univ. (Japan)

We have developed the ultra thin three dimensional image capture system. The system uses a micro-lens array to form multiple images, which are captured on a photo-detector array. Digital processing of

the captured multiple images is used to extract the surface profile. Preliminary experiments were executed on an evaluation system to verify the principles of the system. The system consists of three components: a micro-lens array, a signal separator, and a photo-detector array. Each micro-lens sends optical signals to the multiple photosensitive cells on the photo-detector array, which comprises an imaging unit. To prevent cross talk between adjacent lens units, an opaque wall is inserted as the signal separator. For the photo-detector array, conventional CCD chip or a CMOS image sensor is used. An experimental system consists of a compound imaging system and a CCD image sensor. The diameter and the focal length of micro-lens are 500 μ m and 1.3mm, respectively. The high and thickness of the signal separator are 800 μ m and 20-30 μ m, respectively. In this paper, a compound-eye imaging system and post-processing are employed. Experimental results verify the principle of the proposed method and show the potential capability of the proposed system architecture.

6056-33, Poster Session

Run-based volume intersection for shape recovery of objects from their silhouettes

K. Shoji, S. Sakamoto, H. Iwase, F. Toyama, J. Miyamichi, Utsunomiya Univ. (Japan)

Volume intersection (VI) is a successful technique for reconstructing 3D shapes from 2D images (silhouettes) of multiple views. It consists of intersecting the cones formed by back-projecting each silhouette. The 3D shapes reconstructed by VI are called visual hull (VH). In this paper we propose a fast method obtaining the VH. The method attempts to reduce the computational cost by using a run representation for 3D objects called "SPXY table" that is previously proposed by us. It makes cones by back-projecting the 2D silhouettes to the 3D space through the centers of the lens and intersects them keeping the run representation. To intersect the cones of multiple views keeping the run representation, we must align the direction of runs representing the cones. To align them we use the method of swapping two axes of a run-represented object at the time cost of $O(n)$ where n is a number of runs, which is also previously proposed by us. The results of experiments using VRML objects such as human bodies show that the proposed method can reconstruct a 3D object in less than 0.17 s at the resolution of 220 x 220 x 220 voxels from a set of silhouettes of 8 viewpoints on a single CPU.

6056-34, Poster Session

A prototype system for 3D measurement using flexible calibration method

M. Fukuda, T. Miyasaka, K. Araki, Chukyo Univ. (Japan)

We developed an easy-to-use calibration method that may calibrate a projector-camera-system with high accuracy at short time, and implemented the measurement system based on that calibration method were implemented. In our system, the camera and the projector are calibrated in advance by Zhang's calibration method. The measurement procedure in our system is as follows. The calibrated camera and the calibrated projector are put suitably in front of the calibration plane. And the relative pose between the camera and the projector is may compute by just projecting some light patterns (the horizontal and vertical gray-code pattern) from the projector onto the plane and taking those images by the camera. Then, this system measures by the gray-code pattern projection. Since the calibration of the system is easy, the layout of the system may change freely depending on the measurement target and the measurement location. In spite of that this system may be calibrated easily, this system may obtain range data in high accuracy of an error about 0.1%.

6056-35, Poster Session

Estimation of object motion with known structure in moving camera

H. J. Kwon, N. Hur, S. Lee, Electronics and Telecommunications Research Institute (South Korea)

In this paper, we have proposed a method to estimate object's motion in a dynamic environment. Structure from Motion (SfM), the traditional method, has assumed that camera or object is fixed and extracts its motion. However, in case of both of them moving, SfM is not working in object area because a moving object prevents structure recovery from triangulation between two views. To solve this problem, traditional methods use stereo camera or calibrated camera. We focus on a possibility of uncalibrated camera setting using only minimum 3D information, relative scale of the scene and object. We have tested our methods with synthetic images and real images. To estimate object's 3D motion, we just used relative scale of background and object, and did not necessarily use other information such as metric scale of the scene and the object. In our simulation results for test images, proposed method has estimated object's motion successfully. Main contribution in the proposed method is the estimation of object's 3D motion and then the registration of moving objects and a moving camera in a single space, which is not clearly shown in traditional uncalibrated SfM and pose estimation.

6056-36, Poster Session

Synthesizing wide-angle and arbitrary viewpoint images from a circular camera array

N. Fukushima, T. Yendo, T. Fujii, M. Tanimoto, Nagoya Univ. (Japan)

We propose a technique of Imaged-Based Rendering using a circular camera array. Recording a scene as surrounding, we can synthesize a more dynamic arbitrary viewpoint images and wide-angle images like a panorama.

This method is based on Ray-Space, one of the image-based rendering. Ray-Space is described by the position (x, y) and a direction (θ, ϕ) of the ray's parameter that passes a reference space. Thus, the user can change viewpoint freely. However, rigorous Ray-Space rule require so many images, thousands of images.

In this research, we focus the case of lack of ray in Ray-Space for the problem of huge amount of data. Thus, rays interpolation technique becomes the key. We want to interpolate these rays along the source of ray in the 3D field. 3D modeling method solve this problem, however, moldering is too difficult to rendering photo-realistic image.

Thus, we propose the novel method of estimating the depth of ray in the virtual view. This technique search the source of ray using a periodic function on Ray-Space established by circular camera array. Finally, we can synthesize quality images with low cost like Image-Based Rendering.

6056-37, Poster Session

3D urban scene reconstruction from high-resolution IKONOS stereo images

M. Fedi, T. Riadh, B. Ziad, SUPCOM (Tunisia)

High resolution IKONOS stereo imagery is very useful for 3D feature extraction. The IKONOS stereo product can provide a 1-meter resolution stereo pairs in epipolar geometry. The provided epipolar geometry simplifies considerably the matching step of the two

images allowing the end user to process directly the stereo pairs without additional re-sampling or rectification of the original images. However, having a very high-resolution rectified stereo image pair of an urban scene, the matching of the content of the scene remains still a difficult problem. Depth discontinuities, large occluded areas, mixture of textured and non-textured areas present in the urban scenes, are some of the problems to take care of.

Many different approaches were overtaken to resolve these problems with all the constraints that can be brought with. We can classify these approaches in two large categories: area based and feature based stereo. Dealing with area based algorithms we can talk about cross-correlation based or region growing. While for feature based algorithms can deal with edge and/or corner detection and texture region based. Each of these approaches had its merits and disadvantages dependent on the nature of the matching problem. Many suggested combining the relevant approaches in a cooperative fashion.

In this paper, we propose a cooperative method between many approaches to get the better of each one. The algorithm consists first on a pre-treatment of the stereo pair by applying an anisotropic diffusion on them. Then, we used non-redundant complex wavelet to get the coarse scales in order to perform the matching process in a hierarchical way. Gabor filters are then applied at each scale to get texture based segmentation. This segmentation is combined with an edge detection to extract the different existing urban objects in the images and features vectors that describe them. Finally and using their feature vectors, we performed the matching process of the obtained objects from the coarsest scale to the finest one to get the disparity card. Results show that, in the case of 3D urban scenes reconstruction, combining texture features with edge features is well suited for matching the stereo images.

6056-38, Poster Session

Procedure and algorithm of 3D reconstruction of large-scale ancient architecture

S. Xia, Y. Zhu, X. Li, Wuhan Univ. (China)

Techniques of 3D reconstruction and photogrammetry provide an efficient way for documentation and protection of ancient architecture. Close-range photogrammetry can be used to survey geometric figure of 3D model accurately. Photos of 3D object (such as granite) are taken with a metric camera, which has known and adjusted elements of interior orientation. Sufficient feature points on 3D object are marked to represent the profile of the solid. Then DLT (Direct Linear Transform) sets up direct linear relation between the photo coordinates and object space coordinates. Space coordinates of the object are input into CAD to restore the profile. At this stage, a new algorithm for generating spatial convex polyhedron is presented and realized in our research. 3D TIN (Triangulated Irregular Network) of the object can be obtained efficiently. Model connection and optimization are performed to reduce duplicate storage of points and edges of the model. Realistic material can be attached to the 3D model in 3DMAX. At last rendering and animation of the 3D model are completed and we got the reconstructive model. After assembly of 3D component model of the architecture, we can realize the 3D reconstruction of large-scale ancient architecture successfully.

6056-41, Poster Session

Real-time 3D image-guided patient positioning in radiation therapy

D. Liu, Henry Ford Health System; G. Yin, Genex Technologies, Inc. (China); S. Li, Henry Ford Health System

Patient positioning in modern radiotherapy is becoming far more important because a small positioning error may result in missing target and irradiating normal tissues in treatment of small lesions. Clinical outcome of radiotherapy can potentially be improved by increasing the precision of tumor localization and dose delivery during the treatment. In this paper an accurate and precise patient positioning system has been achieved through alignment of real-time three dimensional (3D) surface images with a reference surface image. The real-time 3D surface is captured using a state-of-art 3D stereovision system, and then is matched with the pre-defined reference image generated from treatment planning data. Positioning parameters are calculated by automatically aligning the real-time surface and the reference surface via a modified Iterative Closest Points (ICP) algorithm. Results from phantom experiments and clinical applications demonstrated the excellent efficacy of <2 minutes and the desired accuracy and precision of <1 mm in isocenter shifts and of <1 degree in rotations.

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6057-01, Session 2

Local luminance effect on spatial summation in the foveal vision and its implication on image artifact classification

C. Chen, S. Y. Lin, H. G. Han, National Taiwan Univ. (Taiwan)

We investigated the spatial summation effect on pedestals with difference luminance. The targets were luminance modulation defined by Gaussian functions. The size of the Gaussian spot was determined by the scale parameter ("standard deviation", σ) which ranged from 0.075° to 0.6° . The local luminance pedestal (2° radius) had mean luminance ranged from 2.9 to 29cd/m². The no-pedestal condition had a mean luminance 58cd/m². We used a QUEST adaptive threshold seeking procedure and 2AFC paradigm to measure the target contrast threshold at different target sizes (spatial summation curve) and pedestal luminance. The target threshold decreased as the target area increased with a slope -1 on log-log coordinates. However, if the target size was large enough ($\sigma > 0.15^\circ$), there was little, if any, threshold reduction as the target size further increased. The spatial summation curve had the same shape at all pedestal luminance levels. The effect of the pedestal was to shift the summation curve vertically on log-log coordinates. Hence, the size and the luminance effects on target detection are separable. The visibility of the Gaussian spot can be modeled by a function with a form $f(L) \cdot g(\sigma)$ where $f(L)$ is a function of local luminance and $g(\sigma)$ is a function of size.

6057-02, Session 2

Evaluating contrast sensitivity

S. Kitagura, L. W. MacDonald, London College of Communication (United Kingdom)

The problem for proper rendering of spatial frequencies in digital imaging applications is to establish the relative contrast sensitivity of observers at suprathreshold contrast levels in typical viewing environments. In an experimental study two methods of evaluating spatial contrast sensitivity were investigated, using targets of graded tonal modulation, at which observers were asked to point to the perceived threshold locations. The results produced by these two methods were rather different from those of the classical methods of vision science, showing a much lower sensitivity over a broader range of spatial frequencies. These may be regarded as complementary to CSF data derived from single-frequency Gabor stimuli and may prove to be better suited to the needs of practical imaging applications.

6057-03, Session 2

Spatio-velocity CSF as a function of retinal velocity using unstabilized stimuli

J. L. Laird, M. R. Rosen, J. B. Pelz, E. D. Montag, Rochester Institute of Technology; S. J. Daly, Sharp Labs. of America, Inc.

LCD televisions have LC response times and hold-type data cycles that contribute to the appearance of blur when objects are in motion on the screen. New algorithms based on studies of the human visual system's sensitivity to motion are being developed to compensate for these artifacts. This paper describes a series of experiments that incorporate eye-tracking in the psychophysical determination of spatio-velocity contrast sensitivity in order to build on the 2D spatio-velocity contrast sensitivity function (CSF) model first described by

Kelly and later refined by Daly. We explore whether the velocity of the eye has an effect on sensitivity and whether the model can be used to predict sensitivity to more complex stimuli. There were a total of five experiments performed in this research. The first four experiments utilized Gabor patterns with three different spatial and temporal frequencies and were used to investigate and/or populate the 2D spatio-velocity CSF. The fifth experiment utilized a disembodied edge and was used to validate the model. All experiments used a two interval forced choice (2IFC) method of constant stimuli guided by a QUEST routine to determine thresholds. The results showed that sensitivity to motion was determined by the retinal velocity produced by the Gabor patterns regardless of the type of motion of the eye. Based on the results of these experiments the parameters for the spatio-velocity CSF model were optimized to our experimental conditions.

6057-04, Session 2

A basis for cones

B. V. Funt, W. Xiong, Simon Fraser Univ. (Canada)

Why do the human cones have the spectral sensitivities they do? We hypothesize that the cones may have evolved to their present form because their sensitivities are optimal in terms of the amount of information they capture about the spectrum of incident light. As evidence in favor of this hypothesis, we compare the accuracy with which the incoming spectrum can be approximated by a three-dimensional linear model based on the cone responses and compare this to the optimal approximations defined by models based on principal components analysis, independent component analysis, non-negative matrix factorization and non-negative independent component analysis. We introduce a new method of reconstructing spectra from the cone responses and show that the cones are almost as good as these optimal methods in estimating the spectrum.

6057-05, Session 2

Computational model of lightness perception in HDR imaging

G. Krawczyk, K. Myszkowski, H. Seidel, Max-Planck-Institut für Informatik (Germany)

An anchoring theory of lightness perception by Gilchrist et al. [1999] explains many characteristics of human visual system such as lightness constancy and its spectacular failures which are important in the perception of images. The principal concept of this theory is the perception of complex scenes in terms of groups of consistent areas (frameworks). Such areas, following the gestalt theorists, are defined by the regions of common illumination. The key aspect of the image perception is the estimation of lightness within each framework through the anchoring to the luminance perceived as white, followed by the computation of the global lightness. In this paper we provide a computational model for automatic decomposition of HDR images into frameworks. We derive a tone mapping operator which predicts lightness perception of the real world scenes and aims at its accurate reproduction on low dynamic range displays. Furthermore, such a decomposition into frameworks opens new grounds for local image analysis in view of human perception.

6057-47, Session 2

High-dynamic range scene compression in humans

J. J. McCann, McCann Imaging

Single pixel compression alters a particular input value to a unique output value, a look-up table. It is used in chemical and most digital photographic systems, having an S-shaped transforms to render high-range scenes onto low-range media. Post-receptor neural processing is spatial. (Dowling, Barlow, Kuffler, Hubel & Wiesel). Human vision does not render particular receptor-quanta catch as a unique response. Instead, because of spatial processing, the response to a particular quanta catch can be any color. Visual response is scene dependent.

Stockham proposed an approach to model human-range compression using low-spatial frequency filters. Campbell, Ginsberg, Wilson, Watson, Daly and many others have developed independent spatial-frequency channel models. This paper describes experiments measuring suitable spatial-frequency filters for a variety of scenes. Given the radiances of each pixel in the scene and the observed appearances of objects in the image, one can solve for the best filters for that individual image. Low-dynamic range images with many white areas need no spatial filtering. High-dynamic-range images with many blacks or deep shadows require strong spatial filtering. Sun on the right and shade on the left requires directional filters. These experiments show that variable scene-dependent filters are necessary to mimic human vision. Although multiple-channel spatial-frequency filters can model human appearances, the problem still remains that an analysis of the scene is still needed to calculate the scene-dependent strengths of each of the channel filters.

6057-06, Session 3

A new metrics for definition of gaze area from the geometrical structures of picture composition

M. Yamazaki, M. Kameda, Iwate Prefectural Univ. (Japan)

The gaze area is changed by timeline when human observes picture. A change of this gaze area is defined as dynamic gaze flow. The dynamic gaze flow is used picture coding, image evaluation and computer vision effectively. Our purpose is to analyze the dynamic gaze flow by image only. We propose a new analysis method for the analysis of the gaze area which is analyzed the human visual characteristics to apply image processing. By the way, the technique with composition is the photograph and fine arts. Composition has the function which attract the human attention in some specific area. It is supposed that the dynamic gaze flow has a relationship with composition in picture. Our proposed method analyzes the composition which is based on the brightness of still picture as the primary factor of gazing, is evaluated by comparing the dynamic gaze flow of human which is measured with eye-mark recorder. As a result, it is clarified using several pictures that a course of the dynamic gaze flow is obtained by the analysis of picture composition.

6057-43, Session 3

Target salience and visual search on novel and familiar backgrounds

K. McDermott, University of Nevada Reno; J. Mulligan, NASA Ames Research Center; G. Bebis, M. Webster, University of Nevada Reno

The visual salience of a target depends on how the target differs from its background. We examined whether salience and the properties of visual search also depend on whether the backgrounds are novel or familiar. Eye movements were monitored while observers searched for a circular or elliptical element placed at random locations within a 30 by 40 deg background composed of a dense array of ellipses. The colors in the background varied randomly along either the LM or S cardinal axes, and also varied in luminance. On different trials the contrast of the target color relative to the background ranged from low (near or within the background color distribution) to high (far removed from the background color axis). Observers searched for the targets on a given background after adapting for 2 min to a sequence of LM or S varying backgrounds. Fixations during search were recorded with a CRS video eyetracker. On each background search times decreased with increasing target to background contrast, but were consistently faster when searching on backgrounds defined by the adapted color axis than by the orthogonal color axis. These results are consistent with an adaptation effect that increases the salience of novel colors by reducing the effective contrast of the background axis, and we analyze the distribution of eye movements to assess whether there are, in addition, changes in the search patterns on novel and familiar backgrounds.

6057-46, Session 3

Larry Stark and scan path

S. R. Ellis, NASA Ames Research Ctr.

No abstract available

6057-49, Session 3

Guiding the mind's eye: improving communication and vision by external control of the scanpath

E. Barth, M. Dorr, M. Böhme, Univ. zu Lübeck (Germany); K. Gegenfurtner, Justus-Liebig-Univ. Giessen (Germany); T. Martinetz, Univ. zu Lübeck (Germany)

Larry Stark has emphasized that what we visually perceive is very much determined by the scanpath, i.e. the pattern of eye movements. Inspired by his view, we have studied the implications of the scanpath for visual communication and came up with the idea to not only sense the gaze but also guide it by using a special kind of gaze-contingent information display.

Our goal is to integrate gaze into visual communication systems by measuring and guiding eye movements. We currently work with high-resolution natural videos. For guidance, we first predict a set of about 10 salient locations. We then change the probabilities for one of these candidates to be attended: for one candidate the probability is increased, for the others it is decreased. To increase saliency, for example, we add red dots that are displayed very briefly such that they are hardly perceived consciously. We experiment with further possibilities such as local zoom or jiggle. To decrease the probability we locally reduce the spatial and/or temporal frequency content. Again, if performed in a gaze-contingent fashion with low latencies, these manipulations of the video remain unnoticed. Overall, the goal is to find that real-time transformation of the video, which minimizes the difference between the actual and the desired scanpath. Applications are in the area of vision-based communication (better

control of what information is conveyed) and augmented vision (guide a person's gaze by the gaze of an expert or a computer-vision system). We believe that our research is very much in the spirit of Larry Stark's views on visual perception and the close link between vision research and engineering.

The research is based on collaboration between the Universities of Lübeck and Gießen and Sensomotoric Instruments GmbH in Teltow/Berlin, and is supported by the German Federal Ministry of Education and Research as part of the interdisciplinary project ModKog - for details see <http://www.inb.uni-luebeck.de/ltap/>

6057-07, Session 4

Effects of spatial correlations and global precedence on the visual fidelity of distorted images

D. M. Chandler, K. H. S. Lim, S. S. Hemami, Cornell Univ.

This study presents the results of a subjective rating experiment designed to investigate the effects of spatial correlations and the disruption of global precedence on the visual fidelity of distorted images. Using a psychophysical scaling paradigm, subjects placed distorted images along a linear, one-dimensional "distortion axis" in which physical distance corresponded to perceived distortion. The images were distorted at fixed levels of total distortion contrast via JPEG and JPEG-2000 compression, via Gaussian blurring, via additive white noise, and via direct quantization of the DWT subbands in a manner specifically designed to disrupt the global-to-local integration of structure across scale-space; these methods were chosen to provide a reasonable representation of commonly encountered distortions. Results revealed that, at highly suprathreshold distortions contrasts, distortions which were spatially correlated with the images gave rise to lower visual fidelity as compared to additive white noise. Furthermore, among the types of distortions tested, those which disrupted the global precedence effect generally gave rise to the lowest visual fidelity. Based on these data, an algorithm is presented which estimates visual fidelity by using a measure of the degree to which the distortions are suprathreshold, and a measure of the degree to which the distortions disrupt global precedence.

6057-08, Session 4

Pseudo no reference image quality metric using perceptual data hiding

A. Ninassi, P. Le Callet, F. Atrousseau, Univ. de Nantes (France)

Regarding the important constraints due to subjective quality assessment, objective image quality assessment has recently been extensively studied. Such metrics are usually of three kinds, they might be Full Reference (FR), Reduced Reference (RR) or No Reference (NR) metrics. We focus here on a new technique, which recently appeared in quality assessment context: data-hiding-based image quality metric. Regarding the amount of data to be transmitted for quality assessment purpose, watermarking based techniques are considered as pseudo no-reference metric: A little overhead due to the embedded watermark is added to the image. Unlike most existing techniques, the proposed embedding method exploits an advanced perceptual model in order to optimize both the data embedding and extraction. A perceptually weighted watermark is embedded into the host image, and an evaluation of this watermark leads to assess the host image's quality. In such context, the watermark robustness is crucial; it must be sufficiently robust to be detected after very strong distortions. The watermark distortion must be proportional to the image's distortion. Our work is compared to existing standard RR and NR metrics in terms of both the correlation with subjective assessment and of data overhead induced by the mark.

6057-09, Session 4

Attention-based color correction

F. W. M. Stentiford, Univ. College London (United Kingdom)

The color of illumination of a scene can have a dramatic affect on the performance of image retrieval systems. In addition different imaging devices will produce widely different responses. As there is normally no control over the camera characteristics, image preprocessing, the brightness or the color of the illumination, and the surface reflectances, this becomes a serious problem for object recognition and will lead to apparently identical images being assessed as different by the machine. This paper proposes a new algorithm that extracts color correction parameters from pairs of images and enables the perceived illumination of one image to be imposed on the other. The algorithm does not rely upon prior assumptions regarding illumination constancy and operates between images that can be significantly different in content. The work derives from related research on visual attention and similarity in which the performance distributions of large numbers of randomly generated features reveal characteristics of images being analysed. Results are reported using structurally identical images as well as cropped images and those with different content.

6057-10, Session 4

Contrast enhancement of medical images using multiscale decomposition

M. A. Trifas, J. M. Tyler, O. S. Pianykh, Louisiana State Univ.

This paper presents the enhancement of images with multiscale methods. The methods are based on the Laplacian Pyramid and 2D wavelets. The basic approach in multiscale enhancement is to decompose the image into components that represent individual details, and to improve the contrast by operating on the details rather than on the whole original image.

The human visual system is sensitive to the different spatial frequencies in an image. In particular, the plots for human visual frequency indicate that some frequencies effect visualization more than others and some frequencies are not important at all. Removing certain frequencies can even help emphasize those that remain (keeping the total image "energy" constant), and improve the quality of the image.

We have studied the effects of the most common artifacts (such as blurring and noise) on the frequency content of each image. We have compared (using statistical parameters) the multiscale decompositions corresponding to a blurred or sharp medical image with that corresponding to an "ideal" image. Based on these comparisons, we have computed values of coefficients in different frequency bands that when applied to the components of the blurred or extremely sharp images, enhances the visualization of these images.

6057-11, Session 4

Human visual alpha stable models for digital halftoning

A. J. González, J. Bacca Rodríguez, G. R. Arce, Univ. of Delaware; D. L. Lau, Univ. of Kentucky

Human visual system (HVS) modeling has become a critical component in the design of digital halftoning algorithms. Methods which exploit the characteristics of the HVS include the direct binary search (DBS) and optimized tone-dependent halftoning approaches. Several HVS models have been proposed in the literature, among them, the broadly used Näsänen's exponential model. As shown experimentally by Kim and Allebach, Näsänen's model is constrained in shape and richer models are needed in order to attain

better halftone attributes and to control the appearance of undesired patterns. As an alternative, they proposed a class of HVS models based on mixtures of bivariate Gaussian functions. In this work, alpha stable functions, an elegant class of models richer than mixed Gaussians, are exploited. These are more efficient than Gaussian mixtures as they use less parameters to characterize the tails and bandwidth of the model. It is shown that a decrease in the model's bandwidth leads to homogeneous halftone patterns and conversely, models with heavier tails yield smoother textures. A frequency domain analysis of the halftones will show that this observation agrees with the blue noise model. These characteristics, added to their simplicity, make alpha stable models a powerful tool for HVS characterization.

6057-12, Session 4

Study of asthenopia caused by the viewing of stereoscopic images

H. Hagura, Tokyo Institute of Technology (Japan)

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Recently the various glassless 3D imaging technologies for 3D TV, PC, PDA(Personal Digital Assistant) and cellular phone have been developed. The 3D images in these devices are often watched for long time. However, most of the observers who watch 3D images for long time are suffered from asthenopia, eye fatigue, or eyestrain. This study tries to find the fundamental reasons of the symptom by using MEG (magnetoencephalography) and other apparatus like a 3D optometer.

Until now, many types of three dimensional (3D) imaging devices have been done. Especially in these days without troublesome by utilizing special 3D glasses the promising stereoscopic displays we can watch with naked eyes (glassless) have been widely used.

Even if using such glassless 3D displays, there are not a few people who feel fatigue in their eyes by observing the 3D images for long time.

The several studies regarding such asthenopia (eye fatigue) have been already done, and the verification experiments by using various ophthalmological devices have been conducted. However, there are so far no definitive theories or reasons for this kind of fatigue which have been clearly described.

Generally speaking, it is said that it is due to the unnatural viewing with the different positions between accommodation and convergence of the eyes is needed on watching 3D images, in comparison with usual observation of 2D images. There are many cases that the person who has not been accustomed to such viewing feels fatigue.

The researches have been mainly subjective and qualitative until now. Quantitative analyses in strict sense were not made yet.

In this study, in order to verify what has happen inside eyes and brain on observing 3D images and how substantial asthenopia is occurred, the highest performance MEG with 440 channels (brain magnetic measurement equipment) which was newly developed has been used.

Depending upon observation of 3D Images, it is hard to avoid the fact that asthenopia occurs in some extend, but in order to lighten, it is a necessity to show some kind of guideline for 3D image production. As for one of the last goal of this study, the guideline will be proposed by presenting the objective results measured as the foundation.

6057-13, Session 5

Perceptual image quality improvement for large screen displays

F. Lebowsky, Y. Huang, H. Wang, STMicroelectronics (France)

As large-scale direct view TV screens such as LCD flat panels or plasma displays become more and more affordable, consumers not only expect to buy a 'big screen' but to also get 'great picture quality' especially when the screen resolution reaches or exceeds the well known HDTV standard. But for quite some time we will still face a limited bandwidth for video over IP networks for example. Therefore, many images will be available at low resolution only. In addition, due to the size of the screen, its viewing distance is often reduced. To display the low resolution images on a large screen, it is desirable to re-scale to the screen resolution. Consequently, more artifacts related to digital signal processing, such as blurriness or jaggedness, easily show above the threshold of visual detection. Since the human visual system shows a non-linear behavior towards the detection of these artifacts we elaborate some simple image operations that better adapt to the image quality constraints of the human visual system. As a result, low resolution images look more pleasing on large screen displays in terms of sharpness and show less ringing than common traditional approaches such as cubic spline interpolation or bi-cubic interpolation filters.

6057-14, Session 5

LCD motion-blur analysis, perception, and reduction using synchronized backlight flashing

X. Feng, Sharp Labs. of America, Inc.

One of the image quality issues of LC TV is the motion blur caused by (1) LCD slow temporal response, and, (2) non-impulse, "hold" characteristics of the display. In this paper, the LCD motion blur was mathematically modeled using a frequency domain analysis, where the motion of an object causes temporal component in the spatial/temporal spectrum. The combination of eye tracking and the display temporal low pass filtering causes the perception of the motion blur. One way to reduce the motion blur is backlight flashing, where the shorter "on" duration reduces the display temporal aperture function, thus improves the temporal transfer function of the display. We implemented backlight flashing on a LCD with a backlight system consisting of an array of light emitting diodes (LED). The LED can be flashed on for a short duration after LCD reaches the target level. The effect of motion blur reduction was evaluated both objectively and subjectively. The objective experiment involves with a model of eye tracking and a sequence captured images using a high speed camera. The subjective study compares the motion blur to an edge with a simulated edge blur. The comparison of objective and subjective experiments shows a good agreement.

6057-15, Session 5

Human vision-based algorithm to hide defective pixels in LCDs

T. R. Kimpe, S. Coulier, Barco N.V. (Belgium)

Producing displays without pixel defects or repairing defective pixels is technically not possible at this moment. This paper presents a new approach to solve this problem: defects are made invisible for the user by using image processing algorithms based on characteristics of the human eye.

The performance of this new algorithm has been evaluated using two different methods. First of all the theoretical response of the human eye was analyzed on a series of images and this before and after applying the defective pixel compensation algorithm. These results show that indeed it is possible to mask a defective pixel. A

second method was to perform a psychovisual test where users were asked whether or not a defective pixel could be perceived. The results of these user tests also confirm the value of the new algorithm.

Our “defective pixel correction” algorithm can be implemented very efficiently and cost-effectively as pixel-data-processing algorithms inside the display in for instance an FPGA, a DSP or a microprocessor. The described techniques are also valid for both monochrome and color displays ranging from high-quality medical displays to consumer LCD-TV applications.

6057-16, Session 5

Using optimal rendering to visually mask defective subpixels

D. S. Messing, L. J. Kerofsky, Sharp Labs. of America, Inc.

Visually Optimal Rendering is a subpixel-based method of rendering imagery on a colour matrix display that jointly maximises displayed resolution and minimises attendant colour aliasing. This paper first outlines the Constrained Optimisation framework we have developed for the design of Optimal Rendering Filters. This framework takes into account the subpixel geometry and colour primaries of the panel, and the luminance and chrominance Contrast Sensitivity Functions of the visual system. The resulting Optimal Rendering Filter Array can be designed for any regular 2D lattice of subpixels, including multi-primary lattices.

The mathematical machinery of Visually Optimal Rendering is then applied to the problem of visually masking defective subpixels on the colour matrix display. The rendering filters that result are able to reduce single subpixel black defects for any primary colour to the point of near invisibility at normal viewing distances. These filters have the interesting property of being spatially varying. This property allows the Optimal Filter Array to intelligently modify the values surrounding a defect in a way that takes advantage of the visual system’s different sensitivities to luminance and chrominance detail in order to best mask a defect.

6057-17, Session 6

Perceptual study of the impact of varying frame rate on motion imagery interpretability quality

C. P. Fenimore, National Institute of Standards and Technology; J. M. Irvine, Science Applications International Corp.; D. Cannon, National Geospatial-Intelligence Agency; J. W. Roberts, I. Aviles, National Institute of Standards and Technology; S. A. Israel, Science Applications International Corp.; M. Brennan, The Boeing Co.; L. Simon, J. R. Miller, D. S. Haverkamp, Science Applications International Corp.; P. F. Tighe, M. Gross, Booz Allen Hamilton Inc.

As part of development of a quality scale for motion imagery interpretability, this perceptual study measures frame rate effects for simple interpretation tasks. Using synthetic imagery permits full control of the contrast and speed of moving objects, motion complexity, the number of confusers, and the noise structure. To explore the detectability threshold, contrast between the moving objects and the background is set at 5%, 2%, and 1%. Nine viewers detect or identify a moving synthetic “bug” in each of 288 10-second clip. Frame rate, contrast, and confusers have a significant effect on image interpretability, while the speed and background show no significant effect. Generally, there is a significant loss in correct detection and identification for frame rates below (but not above) 10 F/s. Increasing contrast improves detection and at high contrast, confusers do not affect detection. Confusers reduce detection of higher speed objects. Higher speed improves detection, but complicates identification, although this effect was small. Higher

speed makes detection harder at 1 Frame/s, but improves detection at 30 F/s. The low loss of quality at moderately lower frame rates may have implications for bandwidth limited systems.

6057-18, Session 6

Color preference and perceived color naturalness of digital videos

C. C. Koh, J. M. Foley, S. K. Mitra, Univ. of California/Santa Barbara

Five second clips of color chroma scaled digital videos were presented to naïve subjects. The subjects rated either the level of preference or naturalness produced by the color manipulation. Color chroma was manipulated in the CIE 1976 ($L^*u^*v^*$)-space; no other color attributes were modified. The objectives were: (1) to determine how the scaling of color chroma affected color preference and how it affected the judged naturalness of colors, and (2) to determine what relationship exists between preference and naturalness.

The mean opinion score (MOS) functions for preference (PMOS) and naturalness (NMOS) increased to a maximum and decreased as the mean chroma (MC) of the videos was increased. Both PMOS and NMOS peaked at relatively high MC levels, with NMOS peaking at the same or lower MC than PMOS for all video contents. The PMOS and NMOS functions for individual videos were approximated relatively well by simple Gaussians. However, the functions for different videos were displaced relative to one another on the chroma axis and the displacement between the naturalness and preference functions also varied with the video contents.

6057-19, Session 6

Stabilizing viewing distances in subjective assessments of mobile video

M. D. Brotherton, British Telecommunications plc (United Kingdom); K. Brunnström, Acreo AB (Sweden); D. Hands, British Telecommunications plc (United Kingdom)

Improvements in audio and video compression techniques, handset display capabilities allied to improved network transmission speeds have resulted in the emergence of mobile video services. These new video services will have to meet the expectations of customers in terms of pricing, content and reproduction quality. The perceptual quality of mobile video is affected by a number of factors, including network performance, image size, frame rate, handset specification coding scheme and bit-rate. Given the options associated with generating and transmitting mobile video, there is an industry requirement for video quality measurement tools. These tools will be used to determine the best means of preparing and delivering video for quality-critical mobile services. To provide this measurement capability, there is activity aimed at developing objective perceptual quality measurement models. The Video Quality Experts Group (VQEG) is presently working on defining a series of multimedia subjective quality tests. The results from these subjective tests will be used to evaluate the performance of alternative multimedia perceptual quality methods, including methods for mobile video. This paper describes a subjective study aimed at identifying differences between stabilising or not stabilising viewing distances in subjective quality tests of low resolution video. A series of subjective tests conducted over two laboratories, employing either fixed viewing distances with a chin rest or not, were investigated. The focus of this work is to determine whether fixing viewing distances in subjective quality tests of mobile video will provide more reliable subjective data, especially when considering the aggregation of results between laboratories.

6057-20, Session 6

Predicting subjective video quality from separated spatial and temporal assessment

R. R. Pastrana-Vidal, J. Gicquel, J. Blin, France Telecom R&D (France); H. Cherifi, Univ. de Bourgogne (France)

During real time video communications over packet networks, various degradations can occur on spatial or temporal signal axes. The end-user may perceive loss of image clearness-sharpness and fluidity impairments on visual information. The overall perceived degradation may indeed be seen as a combined contribution of both perceptual axes. A significant perceptual interaction between spatial and temporal quality has been highlighted by a set of subjective quality assessment tests. We show that, at least in our experimental conditions, the overall visual quality can be estimated from independent spatial (clearness-sharpness) and temporal (fluidity) quality assessments. Four visual quality prediction models are presented. The models' predictions show significant correlation with mean opinion scores from a group of observers. The model showing the highest performance takes into account non linear human assessment characteristics. Our results lead to a better understanding of spatiotemporal interactions and they could be useful for the conception of automatic video quality metric.

6057-21, Session 6

Handling of annoying variations of performances in video algorithm optimization

M. M. Nicolas, STMicroelectronics (France)

Evaluation and optimization, with an ever increasing variety of material, are getting more and more time-consuming tasks in video algorithm development. An additional difficulty in moving video is that frame-by-frame perceived performance can significantly differ from real-time perceived performance. This paper proposes a way to handle this difficulty in a more systematic and objective way than with usual long tuning procedures. We take the example of interpolation algorithms where variations of sharpness or contrast look annoying in real-time whereas the frame-by-frame performance looks well acceptable. These variations are analyzed to get an objective measure for the real-time annoyance. We show that the reason for the problem is that most interpolation algorithms are optimized across intraframe criteria ignoring that the achievable intrinsic performance may vary from frame to frame. Our method is thus based on interframe optimization taking into account the measured annoyance. The optimization criteria are steered frame by frame depending on the achievable performance of the current interpolation and the achieved performance in previous frames. Our policy can be described as "better be good all time than very good from time to time". The advantage is that it is automatically controlled by the compromise wished in the given application.

6057-22, Session 6

Structural similarity quality metrics in a coding context: exploring the space of realistic distortions

A. Brooks, T. N. Pappas, Northwestern Univ.

Perceptual image quality metrics have explicitly accounted for perceptual characteristics of the human visual system (HVS) by modeling sensitivity to subband noise as thresholds above which distortion is just-noticeable. Another class of quality metrics, known as Structural SIMilarity (SSIM), account for perception more implicitly with the assumption that the HVS is adapted for extracting

structural information (relative spatial covariance) from images. We evaluate the effectiveness of the Complex Wavelet SSIM (CWSSIM), a translation-insensitive SSIM extension, in the context of realistic distortions that arise from compression and error concealment in video transmission applications. In order to better explore the space of distortions, we propose models for typical distortions encountered in video compression/transmission applications. We also derive a multi-scale CWSSIM that effectively handles local mean shift distortions. Finally, we use CWSSIM to evaluate traditional DCT image compression (JPEG) versus modern wavelet-based algorithms (SPIHT, JPEG2000) and find that CWSSIM generally agrees with perceptual intuition.

6057-23, Session 6

Lossy compression of high dynamic range images and video

R. Mantiuk, K. Myszkowski, H. Seidel, Max-Planck-Institut für Informatik (Germany)

Most common image and video formats have been designed to work with existing output devices, like LCD or CRT monitors. As the display technology makes a huge progress, these formats can no longer represent the data that the new devices can display. Therefore a shift towards higher precision image and video formats seems to be imminent.

To overcome limitations of the common image and video formats, such as JPEG, PNG or MPEG, we propose two compression algorithms for High Dynamic Range (HDR) visual data: for static images and for video. The static image compression is intended for the OpenEXR format. They are both based on the well established standards, such as JPEG and MPEG, but use a novel color space, which can accommodate an extended dynamic range and guarantees the precision that is below the threshold of contrast detection. We show that only minor changes are required to the existing encoding algorithms to significantly enhance information content of the visual data. We argue that the HDR representation is a simple and universal way to encode visual data independently of the display or capture technology. We show usefulness of HDR data on the examples of post-processing effects.

6057-34, Poster Session

Psychophysical measurement for perceptual image brightness enhancement based on image classification

I. Kim, W. Choe, S. Lee, SAMSUNG Advanced Institute of Technology (South Korea)

The purpose of this study is to examine the difference in perceptual brightness enhancement per image category through perceptual brightness measurement. Perceptual brightness is measured via psychophysical experiment and brightness enhancement is performed by TMF (Tone Mapping Function). The classification process is comprised of two steps. It is possible to classify histograms into six groups. The three different TMFs for each category selected using the criteria and TMF application strengths. A psychophysical experiment to measure perceptual brightness enhancement was carried out. The experiment was to determine the equal perceptual brightness point between an original image and the corresponding set of TMF images. The results showed that the mean luminance for each category is significantly different. The results from brightness matching indicate that perceptual brightness enhancement is dependent on image category. We can propose that image category should be considered for advanced brightness enhancement methods.

6057-35, Poster Session**Visual deficiency and image recognition: an image semantic cartography related to visual performance**

A. Scherlen, J. Da Rugna, Univ. Jean Monnet Saint-Etienne (France)

In this study we test the benefit of an adaptive visual aid called VISAR (Visual Signal Adaptive Restitution) to help patients presenting visual impairment to recognize image. Actually the leading cause of vision disability is age-related macular degeneration (ARMD) affecting high-resolution vision. This pathology appears by the presence of a central scotoma masking the central part of the observed visual scene. Many aids are purposed but patients are still constrained to adapt to their scotomas by exploring and exploiting their remaining functional field of vision. This adaptation takes time, gives random results and requires great efforts on behalf of the patients. To limit this inappropriate behaviour our system will adapt in real time the image to the patient deficiency. By restoring pertinent semantic elements, hidden by the scotoma, to the patient visible zone we facilitate the image comprehension. At the opposite of actually aids, our concept takes into account patient cognitive behaviour during visual information integration. Finally, the results of some experiences show how this system may be useful for low vision rehabilitation. The deepening of the spatial reference integration in our system would improve patient performance during dynamics exploration.

6057-36, Poster Session**Simple color conversion method to perceptible images for color vision deficiencies**

M. Meguro, C. Takahashi, T. Koga, Yamagata Univ. (Japan)

In this paper, we propose a color conversion method for realizing barrier free systems for color-defective vision. Human beings perceive colors by a ratio of reaction values by three kinds of cones on the retina. The three cones have different sensitivity to a wavelength of light. Nevertheless, dichromats, who are lacking of one of the three cones, tends to be difficult for discriminating colors of a certain combination. The proposed techniques make new images by converting color for creating perceptible combination of color. The proposed method has three parts of processes. Firstly, we do image segmentation based on the color space $L^*a^*b^*$. Secondly, we judge whether mean colors of divided regions of the segmented image tend to be confusion or not by using confusion color loci and color vision models of the persons with color-defective vision. Finally, the proposed technique realizes the perceptible images for dichromats by changing the confusion color in several regions of images. We show how effectiveness of the method by some application results.

6057-38, Poster Session**Toward a taxonomy of textures for image retrieval**

J. S. Payne, Buckinghamshire Chilterns Univ. College (United Kingdom); T. J. Stonham, Brunel Univ. (United Kingdom)

Image retrieval remains a difficult task, in spite of the many research efforts applied over the past decade or more, from IBM's QBIC onwards. Colour, texture and shape have all been used for content based image retrieval (CBIR); texture is particularly effective, alone or with colour. The Brodatz photographic album "Textures" is still widely used to provide a relatively small standard test set of images.

Many researchers have expressed the hope that textures can be organised and classified in the way that colour can; however, it seems likely that such an ambition is unrealisable. While the goal of content based retrieval is to retrieve "more images like this one", there is the difficulty of judging what is meant by similarity for images. It seems appropriate to search on what the images actually look like to potential users of such systems. No single computational method for textural classification matches human perceptual similarity judgements. However, since different methods are effective for different kinds of textures, a way of identifying or grouping such classes should lead to more effective retrievals. The perceptual similarity judgements from the experiments carried out in this research are applied to classify the Brodatz textures into eight perceptually matched groups.

6057-39, Poster Session**Using words as lexical basis functions for automatically indexing face images in a manner that correlates with human perception of similarity**

M. Phielipp, J. A. Black, Jr., S. Panchanathan, Arizona State Univ.

To facilitate collaboration between computers and people, computers should be able to perceive the world in a manner that correlates well with human perception. A good example of this is face image retrieval. Mathematically-based face indexing methods that are not based primarily on how humans perceive faces can produce retrievals that are disappointing to human users. This raises the question "Can human faces be automatically indexed in a manner that correlates well with human perception of similarity?" Humans use words to describe faces - words such as bald, bearded, bespectacled, black-eyed, blond, blondish, blue-eyed, braided, brown-eyed, bucktoothed, dark-skinned, earringed, freckled, graybearded, or mustached. Such words represent dimensions that span a shared concept space for faces. Therefore they might provide a useful guide to indexing faces in an intuitive manner. This paper describes research that uses descriptive words such as these to index faces. Each word guides the design of one feature detector that produces a scalar coefficient, and those coefficients collectively define a feature vector for each face. Given these feature vectors, it is possible to compute a similarity measure between pairs of faces, and to compare that computed similarity to the similarity, as perceived by humans.

6057-40, Poster Session**Subjective video quality evaluation for multimedia applications**

Q. Huynh-Thu, Psytechnics Ltd. (United Kingdom); M. Ghanbari, Univ. of Essex (United Kingdom); D. Hands, M. D. Brotherton, British Telecommunications plc (United Kingdom)

Video quality can be measured using both subjective and objective assessment methods. Subjective experiments are important as they constitute a benchmark for evaluating the performance of objective quality metrics. Subjective quality assessment of television pictures has received extensive attention from experts over the past decades. On the other hand, emerging applications such as PC-based and mobile video streaming require new subjective test methodologies. Although some recent work has compared different methodologies and procedures, most concerned television pictures or were designed specifically for comparison of codec performance. No studies really assessed the repeatability and reliability of the experimental procedure. This paper outlines a methodology for conducting subjective evaluation of video quality for multimedia applications in a repeatable and reliable manner across different

laboratories. Using video material at low-resolution, low-bit rate and low-frame rate, the same experiment was conducted by two different laboratories but set-up was slightly different, i.e. different computers and display panels were used, and viewing distance was not enforced to a fixed value. Results show that quality ratings obtained in both experiments are statistically identical. This is an important validation step for the Video Quality Experts Group, which will conduct an ambitious campaign of subjective experiments using many different test laboratories.

6057-41, Poster Session

Texture segmentation using adaptive Gabor filters based on HVS

S. Bi, D. Liang, Dalian Maritime Univ. (China)

A texture segmentation algorithm based on HVS (Human Visual System) is proposed in this paper. Psychophysical and Neurophysiological conclusions have supported the hypothesis that the processing of afferent pictorial information in the HVS (the visual cortex in particular) involves two stages: the preattentive stage, and the focused attention stage. To simulate the preattentive stage of HVS, ring and wedge filtering methods are used to segment coarsely and the texture number in the input image is gotten. As texture is the repeating patterns of local variations in image intensity, we can use a part of the texture as the whole region representation. The inscribed squares in the coarse regions are transformed respectively to frequency domain and each spectrum is analyzed in detail. New texture measurements based on the Fourier spectrums are defined. Through analyzing the measurements of the texture, including repeatability directionality and regularity, we can extract the feature, and determine the parameters of the Gabor filter-bank. Then to simulate the focused attention stage of HVS, the determined Gabor filter-bank is used to filter the original input image to produce fine segmentation regions. This approach performs better in computational complexity and feature extraction than the fixed parameters and fixed stages Gabor filter-bank approaches.

6057-42, Poster Session

Image stability analysis on the human retina

M. I. Baritz, Univ. Transilvania din Brasov (Romania)

In this paper it is presented some aspects about the studies on the human eye, the analyze and studies by simulation mechanism to establish the image stability on the human retina.

In the first part we make an optical analyze on the transparent layers of the eye to obtain the image quality on the human retina. In these conditions, the most important part of the eyeball it's the lens, with its possibilities for accommodation during the visual process.

In some cases a generalized behavior characterized by the optical transfer function (OTF) is sufficient, but more detailed model of the optical system (lens of the eye) is often needed, specially when we want to make a most effectual and better prosthesis for this part.

The entire model of the eye considers an optical system formed by ten (10) centered quadratic refracting surfaces with rotational symmetry. The radius and asphericity define each surface.

The lens of the eye is defined by radius of the first and final surfaces and its thickness on the axis, variable with accommodation. Because in the internal structure of the eye lens there are ten different surfaces, with different refractive index (different biomaterials) a model of this kind of lens have been computed by optical combination optimum method (OCOM).

The relations between curvature radius, thickness of the eye lens and refractive index with value of accommodation are:

where $A = 0 - 10 \text{ m}^{-1}$

To understand the exactly working mechanism of the entire eye in the accommodation process, the elastic behavior of the eye lens is

studied by finite element method (FEM). The lens was considered as an axial-symmetrical structure, so, the problem becomes a 2D one. Five layers with different mechanical properties compose the lens and the external muscles were simulated by a force system having the resultant equal to zero. Initially the problem was considered geometrical non-linear one. And the dependence force-displacement resulted almost linear, therefore in the next runs a linear model was used. It was noticed that Poisson's ratio has an important influence on the elastic behavior of the eye lens; this aspect must be take into account for synthetic eye lens manufacturing.

For understanding how we can obtain a quality image on the retina, it must analyze this complex optical system movement in the axis 3D system. From different medical observations on the visual stability, it can observe a very good concordance between the eye lens accommodation and the movements of the eyeball.

Fig. 1. Fix system coordinates in the space of the surface (X,Y,Z) and the fix system on the eyeball (x,y,z)

For that, each object point $M(X,Y,Z)$ from fix system it is represented, in mobile system, by position vector $r(t)$ like:

(1.)

where: $r(t) = [x(t)/y(t)/z(t)]$; and $B(t)$ is orthogonal matrix 3x3 with its elements: functions a, b, g.

(2.)

The null value of the time variation of the vector $r(t)$ will establish the stability conditions in the systems choosing.

(3)

(4.)

For solve these equations we must choose three different points on the retina surface with the same illuminated function. We consider the illumination function $E=E(X,Y,Z)$, invariable with the time, on observation surface and for the retinal surface another function: $L=L(f, q, t)$. The receiver elements of the retina (cone and) transform this radiant energy into a potential $U=U(q,f,t)$. The relation between L and U is a logarithmic one, but the variations are so little and we neglected the logarithmic variation and we were transform into linear relation $U=kL(q,f,t)$.

In this moment we can establish that the tension variation dU/dt on the two directions are the same, that mean the variations from object plan are formed on the surface of the retina in the same quantities.

From this analyze and demonstration used for less three points in the object plan which are making the image on the retina surface, it can be obviously that there is a invariability of the making mode of the image on the human retina, even the eyeball is moving. Finally we make a simulation on the computer with these determinations of eyeball movement invariability.

6057-24, Session 7

A closer look at texture metrics

H. H. Shenan, V. Interrante, Univ. of Minnesota

This paper presents some insights into perceptual metrics for texture pattern categorization. An increasing number of researchers in the field of visualization are trying to exploit texture patterns to overcome the innate limitations of three dimensional color spaces. However, a comprehensive understanding of the most important features by which people group textures is essential for effective texture utilization in visualization. There have been a number of studies aiming at finding the perceptual dimensions of the texture. However, in order to use texture for multivariate visualization we need to first realize the circumstances under which each of these classification holds. In this paper we discuss the results of our three recent studies intended to gain greater insight into perceptual texture metrics. The first and second experiments investigate the role that orientation, scale and contrast play in characterizing a texture pattern. The third experiment is designed to understand the

perceptual rules people utilize in arranging texture patterns based on the perceived directionality. Finally, in our last section we present our current effort in designing a computational method which orders the input textures based on directionality and explain its correlation with the human study. We will also present a discussion of human subjects' results.

6057-25, Session 7

M-HinTS: mimicking humans in texture sorting

E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands); T. Kok, T. E. Schouten, Radboud Univ. Nijmegen (Netherlands); E. M. van Rikxoort, Univ. Medisch Ctr. Utrecht (Netherlands)

In human perception, computer vision, and image/video processing, texture analysis plays an important role. In this research, we analyzed human texture sorting and compared it with that of an artificial classifier (*k*-means clustering), using the VisTex and OuTex texture databases. Two experiments were done, in which 180 texture images were sorted. Both experiments were identical except for the fact that in one of them the color was removed from the texture images. For the experiments, an online experimental environment was developed: <http://eidetic.ai.ru.nl/M-HinTS/>. The results of the experiments were compared with each other and with those of the artificial classifier that utilized the recently introduced scheme for parallel-sequential texture analysis. A range of analyzes were conducted, which revealed the interpersonal variability and identified the strategies groups of participants used. Moreover, differences in the sorting strategies between the color and gray scale texture images were found, which illustrates the importance of taking color into account when analyzing texture. No generic artificial texture sorting algorithm is introduced since humans themselves disagree; however, human texture sorting is mimicked for several groups of humans, each with their own strategies and characteristics.

6057-26, Session 7

Inference and segmentation in cortical processing

Y. Liu, G. A. Cecchi, A. R. Rao, J. Kozloski, C. Peck, IBM Thomas J. Watson Research Ctr.

We present in this paper a model of cortical architecture and processing aimed at accounting, in a biologically plausible way, for the inference and segmentation capabilities displayed by the visual system. The units of computation in the model represent small localized ensembles of interacting neurons, and their oscillatory dynamics is represented by amplitude and phase variables. The model's architecture is organized in a hierarchy, such that the receptive field size increases as the hierarchy goes up, but the amplitude and phase information are transmitted up and down the hierarchy.

We show that our network, trained using a self-organized paradigm, can: (1) improve recognition robustness upon input degradation due to the effect of top-down information, and (2) solve the superposition problem; explicitly, this is done by clustering in different phases the components, throughout the network, of inputs that are presented simultaneously and recognized as distinct by the upper layers. We believe that this is a significant contribution towards understanding the problem of invariant recognition and segmentation problem of occluded objects by the visual cortex.

6057-28, Session 7

Perceptually based techniques for semantic image classification and retrieval

D. Depalov, T. N. Pappas, Northwestern Univ.

The accumulation of large collections of digital images has created the need for efficient and intelligent schemes for content-based image retrieval. Our goal is to organize the contents semantically, according to meaningful categories. We present a new approach for semantic classification that utilizes a recently proposed color-texture segmentation algorithm (by Chen et al.), which combines knowledge of human perception and signal characteristics to segment natural scenes into perceptually uniform regions. The color and texture features of these regions are used as medium level descriptors, based on which we extract semantic labels, first at the segment and then at the scene level. The segment features consist of spatial texture orientation information and color composition in terms of a limited number of locally adapted dominant colors. The focus of this paper is on region classification. We use a hierarchical vocabulary of segment labels that is consistent with those used in the NIST TRECVID 2003 development set. We test the approach on a database of 5000 segments obtained from 2000 photographs of natural scenes.

For training and classification we use the Linear Discriminant Analysis (LDA) technique. We examine the performance of the algorithm (precision and recall rates) when different sets of features (e.g., one or two most dominant colors versus four quantized dominant colors) are used.

6057-30, Session 8

Symbol discriminability models for improved flight displays

A. J. Ahumada, Jr., M. Trujillo San-Martin, J. Gille, NASA Ames Research Ctr.

Computer models of human vision that predict human visual task performance can provide an objective means for improving flight display design by predicting pilot performance. An important step in the development of airborne traffic management displays is the evaluation of the discriminability of proposed symbol sets. Here we present an image discrimination model for symbol discriminability that includes both size and position compensation. The model takes as input the luminance values for the pixels of two symbol images, the effective viewing distance, and gives as output the discriminability in just-noticeable-differences (d'), the size reduction of the larger symbol, and the horizontal and vertical image offsets in pixels needed to minimize the discriminability.

6057-32, Session 8

Is haptic watermarking worth it?

M. Barni, D. Prattichizzo, G. Menegaz, A. Formaglio, M. Franzini, Univ. degli Studi di Siena (Italy); H. Z. Tan, Purdue Univ.

We propose a psychophysical experiment aiming at investigating the differential sensitivity of the visual and haptic channels in view of the design of a novel perception-driven watermarking technique. A very simple stimulus, composed by a flat surface with a watermark superimposed to it, is presented to the subjects that sense it either visually or haptically. A noise sensitivity paradigm is followed to estimate the detection threshold of the embedded watermark. The characterization of the differential sensitivity of the two perceptual channels in a typical visuo-haptic rendering set up is aimed at determining which of the two considered sensory channels (namely vision and touch) sets the boundary for the detectability of the watermark for given rendering conditions.

6057-33, Session 8

Display conditions that influence wayfinding in virtual environments

R. A. Browse, D. W. S. Gray, Queen's Univ. (Canada)

As virtual environments may be used in training and evaluation for critical real navigation tasks, it is important to investigate the factors influencing navigational performance in virtual environments. We have carried out controlled experiments involving two visual factors known to induce or sustain vection, the illusory perception of self-motion. The first experiment had subjects navigate mazes with either a narrow or wide field of view. We measured the percentage of wrong turns, the total time taken for each attempt, and we examined subjects' drawings of the mazes. We found that a wide field of view can have a substantial effect on navigational abilities, even when the wide field of view does not offer any additional clues to the task, and really only provides a larger view of blank walls on the sides. The second experiment evaluated the effect of perspective accuracy in the scene by comparing the use of displays that were corrected for changing head position against those that were not corrected. The perspective corrections available through head-tracking did not appear have any influence on navigational abilities. Another component of our study suggests that during navigation in a virtual environment, memory for directions may not be as effective as it could be with supplemental symbolic representations.

Tuesday-Thursday 17-19 January 2006

Part of Proceedings of SPIE Vol. 6058 Color Imaging XI: Processing, Hardcopy, and Applications

6058-01, Session 1

Ideal illuminants for rod/L-cone color

J. J. McCann, McCann Imaging

In average moonlight natural objects appear colorless. In these cases there is only sufficient light to excite the rod-shaped receptors in human retina (scotopic vision). The rods are physiologically different from cone-shaped receptors as shown by many psychophysical experiments including: spectral sensitivity, the Stiles-Crawford effect, the flicker-fusion frequency, the shape of dark-adaptation curves, the apparent color and the apparent sharpness. All of these techniques have shown that complex color are seen by the interaction of rods with long-wave cones images at very low radiances, in illuminants rich in long-wave light. This paper measures the spectra of wood-fire and candle flames. Further, it shows that fire is the ideal illuminant for stimulating color with rods and L-cones at minimal radiances. In fact, complex color images are seen with radiances 100 to 1,000 times below M- and S-cone absolute thresholds.

Spectral and DNA studies have shown that primates evolved L-cones in recent primate history. Anthropological studies have currently dated the controlled use of fire to 1.6 million years ago (Mya). The paper will discuss the evidence for dating the evolution of L-cones and the controlled use of fire.

6058-02, Session 1

Accuracy of color transforms

P. J. Green, London College of Communication (United Kingdom)

Colour management systems need to be accurate and repeatable, particularly in graphic arts applications such as converting image data to proofing systems and to final print processes. Modelling and computation errors were analyzed for a number of characterization data sets including single press sheet measurements and reference printing conditions based on SWOP and ISO 12647-3. Errors were calculated at double precision and compared with the AToB, BToA and round trip errors found in ICC profiles generated from the same data sets. Data sets which are averaged from measurements of multiple press sheets consistently performed better than transforms built from single-sheet measurements. A significant part of the transform error lies in the limited precision of computation. BToA transform errors averaging $1 + E^*ab$ appear to be a reasonable expectation for well-formed data sets. This needs to be placed in the context of errors arising from measurement uncertainty and the variation in colour reproduction systems, which are considerably larger.

6058-03, Session 1

Color image dequantization by constrained diffusion

D. Keysers, T. M. Breuel, DFKI GmbH (Germany) and Univ. of Kaiserslautern (Germany)

We propose a simple and effective method for the dequantization of color images, effectively interpolating the colors from quantized levels to a continuous range of brightness values. The method is designed to be applied to images that either have undergone a manipulation like image brightness adjustment, or are going to be processed in such a way. Such operations often cause noticeable color bands in the images. These artifacts can be reduced using the proposed Constrained Diffusion technique.

We use smoothing by isotropic diffusion and constrain the maximum difference to the original image in each step of the diffusion process.

If used before the manipulation, we change the image representation from 8 to 16 bits per channel and apply the diffusion while restricting the maximum change to the width of the quantization interval of the 8 bit values in 16 bit. Thus, the algorithm respects the constraints implied by the original 8 bit data.

We demonstrate the advantages of our method using synthetic and real life images as examples. We also present quantitative results using 8 bit data that has been obtained from original 12 bit sensor data and obtain substantial gains in PSNR using the proposed method.

6058-04, Session 1

Spring-primary mapping: a fast color mapping method for primary adjustment and gamut mapping

H. Zeng, Hewlett-Packard Co.

A gamut mapping method, spring-primary gamut mapping, was developed for device to device color mapping. Instead of performing gamut mapping point-wisely, it selects a small number of the nodes of a lookup table for gamut mapping and determines the color mapping of other nodes by interpolation using color similarity information. Primary adjustment is seamlessly incorporated into the gamut mapping step, therefore it further improves the performance. Because the color similarity information of neighbor colors are used for the primary adjustment and gamut mapping, the color to color relative relationship is well retained. The color mapping for gamut surface colors can be configured for the preference of business graphics or for the tradeoff of business graphics and pictorials. As the processing goes from gamut surface colors to interior colors, the color mapping is gradually adapted to the preference of pictorials.

With this unique property, a color map produced by this method can be used for the color transformation of both photographic images and business graphics. Because gamut mapping is performed only on a small percentage of nodes, the color mapping is highly efficient.

6058-05, Session 1

A framework for image-dependent gamut mapping

J. Giesen, E. Schuberth, ETH Zürich (Switzerland); K. Simon, EMPA (Switzerland); D. Zeiter, ETH Zürich (Switzerland); P. Zolliker, EMPA (Switzerland)

Gamut mapping is a multi-criteria optimization problem with several competing objectives like target gamut exploitation, continuity, contrast-, saturation-, gray axis- and hue preservation. Depending on the application any of these objectives is more or less important. The scenario that we want to address here is image dependent gamut mapping. Since image gamuts can be small and odd shaped of-the-shelf gamut mapping algorithms either cannot be used in this scenario or often result in far from optimal target gamut exploitation. In our approach we formulate image dependent gamut mapping as a parameterized mathematical optimization problem that allows constraining the degree to which objectives like contrast preservation, hue preservation, saturation preservation and the continuity of the mapping can be violated while maximizing the target gamut exploitation. The resulting optimization problem is in a general non convex form and thus not efficiently solvable in practice. But slight modifications of the optimization problem turn it into a convex quadratic program, which can be solved efficiently in

practice. We demonstrate the feasibility of our approach on several benchmark image- and device gamuts.

6058-06, Session 1

Perceptual gamut mapping algorithm development based upon image quality and preference factors

B. Kang, M. Cho, H. Choh, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)

This study has three primary aims circumventing current limitations of color reproduction technologies: firstly, to derive base-line image quality factors from both color printer experts and academic research works. Individual factors were verified by systematic experiments, secondly, to develop a perceptual gamut mapping algorithm covering the image quality and preference factors derived, thirdly, to apply the algorithm to printer driver as acting for a vendor specific perceptual intent. Algorithm of this study tried to optimization between control parameters of gamut mapping and color shifting factors of preference, e.g. skin, sky and green grass. Profile builder using this algorithm outperforms, in industrial and academic aspects, existing commercial tool and CIE recommended algorithms.

6058-07, Session 1

Gamut estimation using 2D surface splines

M. Q. Shaw, Hewlett-Packard Co.

This paper proposes a method of gamut estimation using data segmentation and 2D surface splines. The device data is first segmented into hue intervals, and then each hue interval is analyzed iteratively to construct a 2D gamut boundary descriptor for that hue interval. The accuracy and smoothness of the gamut boundary estimate can be controlled by the number of hue intervals selected and the sampling within each hue interval.

6058-40, Poster Session

High-resolution image viewing on multiprojector distributed parallel rendering display wall

J. Meng, H. Lin, J. Shi, Zhejiang Univ. (China)

We illustrate an application that displays high-resolution images and play panoramas on Multi-Projector Tiled Display Wall, such as photos from satellites and microscopes, or landscape sceneries.

Our prototype is implemented over a local area network with a PC cluster and a monitor. Image data are initially stored in the monitor PC, and then dispatched to the displayer PCs and is projected on to the display wall. In this paper we focus on three main topics:

1) We use a single texture mapped on to each displayer's screen. The texture is from a high resolution image which exceeds the capacity of GPU. To overcome this problem without reducing the resolution, we use a multi-resolution texture hierarchy, and select one of them dynamically depending on which part of the image is requested.

2) We use binary-tree transferring structure to reduce the latency from $O(N)$ to $O(\log_2 N)$ (N is the number of Displayer PCs).

3) To playing the panorama, we use parallel Macro-Micro clocks for system synchronization in order to eliminate accumulated displacement and in the mean time to achieve a high frame-rate.

The result with a 10548×15474 image is shown in the paper.

6058-41, Poster Session

The application of wavelet transforms and mathematics morphology on the processing of infrared satellite cloud image

J. Xue, Z. Liu, P. Wang, Tianjin Univ. (China)

Image segmentation is an important and fundamental task in many digital image processing systems and computer vision. The aim of the intelligent weather forecast system is to forecast disastrous weather such as typhoon and storm exactly. Infrared satellite cloud images (ISCI) are important resources of the system. It is difficult to segment and detect the boundary of cloud images because of the complicated and various shapes and blurry edges of cloud. In this paper, we present an idea and a set of realizable design about self-adaptive segmentation by means of mathematical morphology firstly, which can segment the useful clouds that are larger and have lower temperature from the cloud image. Then, we proposed a boundary detection method base on wavelet transform. This boundary detecting method of the infrared satellite cloud image, which is based on Bubble wavelet function and Gaussian function, is suitable for dealing with the neighborhood processing. Some practices show that the segmentation models are self-adaptive, the whole processing system is general and the algorithm is high efficient in the processing of infrared satellite cloud image.

6058-42, Poster Session

Simulation and parameter optimizing of multielectrode capacitive transducers based on finite element method

D. Chen, Harbin Univ. of Science and Technology (China)

The principle of electrical capacitance tomography (ECT) is introduced and the simulation based on the finite element method (FEM) about the sensitivity distribution of 12-electrode capacitance transducers for oil and water two-phase flow system is discussed. Unequal mesh spacings in cross section of Transducers are adopted in automatic plotting to improve the precision in calculation. The optimal function is presented based on sensitivity distribution which plays an important role in image reconstruction. The influence which the structural parameters of transducers impose on the performance of ECT is studied. EC changes of transducers between empty pipeline and full pipeline can express the global sensitivity of all elements for transducers in the pipeline, therefore EC changing quantity between empty pipeline and full pipeline can be considered as an important index of performance for transducers. A FE simulation analysis is done on performance of transducers which have different structural parameters, and the main analysis is focused on influences that changes of various structural parameters exert on EC and its changing quantity between empty pipeline and full pipeline. The parameter optimizing is achieved by employment orthogonal design method combined with FEM.

6058-43, Poster Session

Digital watermarking of color image

S. C. Chao, Ta Hwa Institute of Technology (Taiwan); H. M. Huang, Tung Nan Institute of Technology (Taiwan); C. Y. Chen, Institute of Nuclear Energy Research (Taiwan)

An analytic method of embedding color watermarks into the color images is proposed. The original image is color image of size 480×640 , and the watermark image is 24-bit-gray scale image of size 120×160 . The quality variations of the embedded image and extracted watermark are analyzed. From the experimental results they appear that the quality of embedded image varies with the quantization index. They also show that the quality of extracted watermark is dependent on the gray-level of the original image. The relationship between the gray-level and the noise of embedded

image has been quantitatively analyzed. The digital quantization method is also important to decrease the noise of embedding image and the error of extracting watermark.

6058-45, Poster Session

Subjective assessment of printed color image quality as saturation of the primary colors RGB decreases

W. Song, H. Seki, Naltec Inc. (Japan); G. Ohashi, Y. Shimodaira, Shizuoka Univ. (Japan)

This study is to obtain the quantitative data of the quality of printed images as a function of the saturation decrease of three primary colors. As the results, decrease of color saturation of three primaries significantly affects the quality of printed images. The saturation decrease of primary B has the most severe influence on the quality impairment of the printed images. According to analysis the results, it is found that the values of the saturation decrease ratio, corresponding to the acceptable limits of image quality, are 13% for primary R, 11% for primary G, and 1% for primary B by proceeding the assessment data which is obtained from the single-stimulus method. Applying these saturation decrease values in CIELAB a^*b^* plane, the value of gamut area ratio of primary R, G, and B, corresponding to the acceptable limits of image quality, are 70%, 80%, and 96% of that of original image gamut. Furthermore, the reliability of the saturation decrease ratios from single-stimulus method is verified by using the paired-comparison method. The results show a way for estimating the amount of saturation decrease according to the quantitative data of quality of a printed image and indicate a capability to control the saturation decrease of three primary colors to keep the printed images quality constantly.

6058-08, Session 2

Uncalibrated color

N. Moroney, Hewlett-Packard Co.

No abstract available

6058-09, Session 2

Geometrical methods for lightness adjustment in YCC color spaces

R. Samadani, G. Li, Hewlett-Packard Labs.

Lightening or darkening an image is a fundamental adjustment used to improve aesthetics or correct exposure. This paper describes new geometrical algorithms for lightness adjustment, implementing fast traversal of colors along lightness-saturation curves, applicable when the data starts naturally in YCC space (JPEG images or MPEG videos). Here, YCC refers generically to color spaces with one luminance and two color difference channels, including linear YCC spaces and CIELAB. Our first solution uses a class of curves that allows closed-form computation. Further assuming that saturation is a separable function of luminance and curve parameter simplifies the computations. This approach reduces clipping and better adjusts lightness together with saturation. Preliminary evaluation with 96 images finds good subjective results, and clipping is reduced to about 5% of a prior approach.

6058-10, Session 3

Measuring gloss by digital photography

P. Kumar, L. W. MacDonald, London College of Communication (United Kingdom)

Gloss is an important attribute of appearance. The most common visual characteristic of a glossy object is that it shows bright highlight details where the incident illumination is reflected in the

specular direction. The measurement of gloss is conventionally made by specialised instruments that determine the ratio of reflected to incident illumination at a single fixed angle. This presentation will describe a study that investigated whether digital photography with flash illumination could be used as an alternative. Multiple exposures were combined by a high dynamic range (HDR) imaging technique to produce a two-dimensional intensity profile of the reflectance around the specular point. The method was tested for six paper samples of varying gloss, and the results were found to correlate well with instrumental measurements. The image gloss profiles, however, provided more information about the distribution of the reflection over a range of angles and also gave an indication of the surface texture.

6058-11, Session 3

Ubiquitous image processing: a novel image-enhancement facility for consumers

R. Shaw, P. Johnson, White Rose Digital

While the number of digital photographs is still growing exponentially, experience shows that more than fifty-per-cent of all acquired pictures could be significantly enhanced for increased consumer satisfaction. Thus, while the market potential for user-friendly image-enhancement software is huge, most existing image-enhancement software is either over-simplistic, user-hostile, or both. The authors will describe a novel approach to this practical problem, based on the definition of a fundamental set of physical vectors representing any digital image. These independent vectors are then placed within an overall logical hierarchy, and practical linear visual ranges are established for a comprehensive sample of digital color images. Finally increments are set within these ranges in terms of just-appreciable visual differences. This methodology typically produces a hierarchy of separate image-states of the order of a hundred thousand or more for a typical digital photograph, and the problem remains of presenting these to the user for personal choice of optimum enhanced image-quality. By implementation of a critical comparative hierarchy of image choices, itself based on an information-theoretic sorting-matrix, the user is presented with a relatively small number of images in navigating through very this large number of independent image states. Software has been developed whereby an unskilled user may enhance and optimize the image quality of any digital photograph to personal choice in a matter of several seconds, and, based on the manner in which the independent vectors are defined, without the introduction of any unwanted image artifacts that are typical of many software packages. A practical demonstration will be given of this software, which by its simple user-interface, real-time computation, and lack of any user learning-curve, naturally lends itself to many practical imaging applications in addition to a stand-alone software package, including digital cameras, printers, scanners and photo-kiosks, or provision as a web-service.

6058-12, Session 3

Color constancy on Japanese animation

Y. G. Ichihara, Hosen-Gakuen College (Japan)

This paper focuses on Imagined Color System in Japanese animation. We measured the color constancy and luminance of two scenes from a Japanese animation film. The data show that the color system used in the film is not natural but an imagine and artistic appearance system. Color constancy of human vision can tell the difference in skin and hair colors between under moonlight and daylight. Human brain generates a match to the memorized color of an object from daylight viewing conditions to the color of the object in different viewing conditions. For example, Japanese people always perceive the color of the Rising Sun in the Japanese flag as red even in a different viewing condition such as under moonlight. Color images captured by a camera cannot present those human perceptions. However, Japanese colorists in Animation

succeeded in painting the effects of color constancy not only under moonlight but also added the memory matching colors to increase the effect of the scenes on the viewers' perceptions. Its importance is that it could also provide an explanation on how human brain perceives the same color under different viewing conditions.

6058-13, Session 3

Convincing non-printers to become future customers

R. Fageth, W. Schmidt-Sacht, CeWe Color AG & Co. OHG (Germany)

The number of images taken by digital still cameras (DSC) and camera phones is rising dramatically but the number of digital images being transferred onto paper is not keeping up with that rate of increase. This paper tries to evaluate why this is the case and offers suggestions on how to encourage consumers to print their most valuable memories while using convenient solutions both at home and professionally. Paths from a digital file to a print are evaluated and the diversity of possibilities for the consumer are described.

An approach to offer the consumers all possibilities of products from classical silver halide prints up to semi-professional photo books printed on electro photography digital presses is presented. This approach offers also the possibility - compared to classical approaches of transferring PDFs from the client to the digital press - to optimize every image separately before printing.

6058-14, Session 4

DTV color and image processing: past, present, and future

C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)

No abstract available

6058-15, Session 4

Subpixel rendering method for color error minimization on subpixel structured display

W. Choe, S. Lee, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)

This study investigates the color error problem posed by large flat panel displays and proposes a subpixel-rendering algorithm to mitigate the problem. On large subpixel structured displays, the Mach band effect and the convergence error of pixels make the color error, the color band error. The proposed method to reduce the color band error includes three processes: a process of finding the areas or pixels generating the error, an error-estimation process, and an error-correction process. To correct the color band error, we take an error erosion approach, an error concealment approach, and a hybrid of the erosion and concealment approaches.

In this paper, we devised a psychophysical method to determine the detection threshold of color band error by the human vision. In addition, we applied our proposed method to a commercial 42" plasma display to confirm the effects. The results show that all observers see the color band error at sharp edges having above 64-gray difference and the corrected test images by our algorithm are preferred to the original test images.

Finally, this paper reports that the Mach band effect and the convergence error on large subpixel structured displays produce color band errors on images having sharp edges and the proposed method effectively corrects the color band errors.

6058-16, Session 4

Compensation method for color defects in PDP due to different time responses of phosphors

H. Oh, H. Lee, D. Park, S. Kim, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)

On a plasma display panel (PDP), luminous elements of red, green, and blue have different time responses. This difference generates a greenish colored trail and bluish edge behind and in front of a bright object moving on a dark background, respectively, or the opposite. Due to such phosphor lag effect, the quality of an image sequence deteriorates inevitably. The human eyes are usually less sensitive to gray than color variation on moving images. Therefore, in order to reduce the color artifacts, this paper proposes a motion-based discoloring method. To compensate for greenish trails, the video values of the blue and red sub-pixels located behind the object are increased artificially, based on the motion magnitude and direction, to match the afterimage of the green sub-pixel. For bluish edges, the values of the blue and red sub-pixels in front of the object are decreased artificially. Discoloring values are modeled as linear functions of a motion vector to reduce hardware complexity. Experimental results show that the proposed method has effectively removed the colored trails and edges of moving objects. Moreover, the clear image sequences have been observed compared to the conventional ones.

6058-17, Session 4

Six-primary-color LCD monitor using six-color LEDs with an accurate calibration system

H. Sugiura, H. Kaneko, S. Kagawa, J. Someya, H. Tanizoe, Mitsubishi Electric Corp. (Japan)

The authors have successfully developed a six-primary-color liquid crystal display using six-color LEDs. More specifically, a prototype of a six-primary-color liquid crystal display having a color gamut of 170% or wider than that of conventional techniques has been constructed. In order to obtain highly stable image quality for these high performance monitors with a wide color gamut, we considered the fluctuation of white balance. Some fluctuation factors are listed below, (1) Temperature dependency of luminance intensity of LEDs, (2) Temperature dependency of emission wavelength of LEDs, (3) Degradation of luminance intensity resulting from variations per hour. The key factor in temperature change is an LED's own generation of heat. When the LEDs temperature changes, the luminescence intensity and the dominant wavelength of the LEDs are also changed accordingly, which have a severe effect on the color reproduction characteristics of the monitor. These LEDs characteristics lead to the fluctuation of the white balance of the backlight. This monitor has a newly developed calibration system using an integrated color sensor, so that it can keep its white point chromaticity stable.

This research was organized in part by the New Energy and Industrial Technology Development Organization, Japan (NEDO).

6058-18, Session 5

A color control method for image output with projection displays

S. Tominaga, K. Kumamoto, Osaka Electro-Communication Univ. (Japan)

The present paper proposes a nonlinear approach using a neural network for color control of projection displays, including the LCD and DLP types. This approach accepts variations in primary color coordinates and coupling among RGBW channels. We regard a

display system as an unknown nonlinear system with RGB signal inputs and XYZ tristimulus outputs. We determine the RGB values so that the projector outputs the desired XYZ values. The neural network is used for estimating adaptively an inverse mapping from the XYZ space to the RGB space. Because of a direct mapping, we can eliminate the need to predict white channel separation. Moreover, we present a method for correcting the emitted luminance, according to the spatial location and the surface color of a screen. The spatial correction is needed because a color image from a computer is not displayed uniformly on the screen. The screen color correction makes it possible to reproduce accurate color images on a colored wall.

6058-19, Session 5

Illuminant-adaptive color reproduction for a mobile display

J. M. Kim, K. Park, M. Lee, Y. Cho, Y. Ha, Kyungpook National Univ. (South Korea)

Mobile displays, such as PDAs and cellular phones, are viewed under various lighting conditions. In particular, images displayed in mobile under outdoor environment are perceived as quite a bit dark due to the light adaptation of the human visual system. In addition, flare phenomena decrease the color gamut of a mobile display by increasing the luminance of black level and de-saturating. Therefore, this paper presents an illuminant adaptive reproduction method composed of lightness enhancement and chroma compensation. First, the ambient light intensity is measured using a lux-sensor, then the flare is calculated based on the reflection ratio of the display device and the ambient light intensity. Second, lightness is enhanced by linearization of the human's perceived lightness for input digital values, since the relative cone response in human eye is nonlinear to luminance of the scene. Also, lightness enhancement is considered that cone response vary according to ambient light intensity. Next, chroma of the displayed image is reduced by ambient light. Then physically reduced chroma between original image's chroma and added flare image's chroma is compensated for adding chroma difference depending on gamut boundary. Consequently, the proposed algorithm improves the quality of the perceived image adaptive to an outdoor environment.

6058-20, Session 5

Skin color reproduction algorithm for portrait images shown on the mobile display

Y. Kwak, S. Lee, D. Park, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)

The preferred skin color reproduction algorithm is developed for the mobile display especially for a portrait image with one person as a main object occupying most of the screen. According to the developed technique, the skin area in an image is detected using color value of each pixel in YCbCr color space. The skin color boundary is defined as a quadrangle in Cb-Cr plane. The colors of pixels belonging to skin area are shifted toward the preferred colors while there is no color change for the other pixels. The psychophysical experiments are conducted to investigate the optimal model parameters providing the most pleasant image to the users. Then, the performance of developed algorithm is tested using the optimal parameters. The result shows that for more than 95% cases, the observers prefer the images treated with the developed algorithm compared to the original image. It is believed that the developed algorithm can be applied to the mobile application to improve the image quality regardless the input sources.

6058-21, Session 5

Estimating displays' color fidelity based on classified image statistics

P. Sun, C. Lee, Shih Hsin Univ. (Taiwan)

The color fidelity of displays such as LCD and PDP was commonly estimated by a series of color patches. However, no strong evidence showed that these color patches are well correlated to the real-world image characteristics. To minimize the gap between the color patches and the image characteristics, the present study first accumulated the statistics of different classes of image. Then, we chose several of them as reference images, manipulated their colors intentionally to simulate uncalibrated displays, and finally asked observers to compare the reference images with their color-perturbed counterparts. In the end, based on the classified image statistics, an empirical model was derived to predict the overall results of the visual image differences. In the model, the pixel frequencies (probability) of 125 color clusters summarized by a certain type of images were taken into account for predicting the displays' color fidelity on the type of images. The 125 color clusters were linked in a 5x5x5 cellular structure. If the manipulation shifts the colors without disturbing the links, the reproduction still looks fine. Our results showed the variations of the links can be used as weights to enhance the performance of our model.

6058-22, Session 5

End-user display calibration via support vector regression

B. Bastani, Hewlett-Packard Co.; B. V. Funt, W. Xiong, Simon Fraser Univ. (Canada)

The technique of support vector regression (SVR) is applied to the color display calibration problem. Given a set of training data, SVR estimates a continuous-valued function encoding the fundamental interrelation between a given input and its corresponding output. This mapping can then be used to find an output value for a given input value not in the training data set. Here, SVR is applied directly to the display's non-linearized RGB digital input values to predict output CIELAB values. In comparison to some of the existing linear methods for calibrating different display technologies, including the gain-offset-gamma (GOG) and Masking Models, an advantage of using SVR for color calibration is that the end-user does not need to apply a different calibration model for each different display technology. We show that the same model can be used to calibrate CRT, LCD and DLP displays accurately.

6058-23, Session 5

The calibration accuracy of display white point by visual calibrator under various illuminations

T. Sugiyama, Y. Kudo, Dai Nippon Printing Co., Ltd. (Japan)

We have developed a method to calibrate a display to a predetermined state and to make an ICC display profile by visual calibration. Our method adjusts a color of display white point to that of a white object under a viewing illuminant, so our method can calibrate the display white point for any viewing illuminant. In this paper, we evaluated the matching accuracy between display white point and paper white under various illuminances and color temperatures. We found that the matching accuracy was almost the same in all illumination conditions. Furthermore, all subjects calibrated the chromaticity of display white point more bluish than that of paper white in all illumination conditions, and the dispersion of yellow-blue direction was larger than that of red-green direction. This yellow-blue direction was almost the same as the long axis of MacAdam ellipse. We also evaluated the capability of color

discrimination between display and paper. At 500lx or less, many subjects judged color difference correctly, though it was difficult to judge color difference correctly at 1000lx or more. These results suggest that ISO 3664:2000 P2 condition is appropriate to compare the image on computer display with that on paper at the same time.

6058-24, Session 6

Black extraction method using gamut boundary descriptors

M. Cho, B. Kang, H. Choh, SAMSUNG Advanced Institute of Technology (South Korea)

Color data conversion between CMYK and CIEL*a*b* color space is not directly corresponded, that is many CMYK combinations could reproduce the same CIEL*a*b* value. When building a LUT converting from CIEL*a*b* to CMYK for a CMYK color printer, one to one correspondence between CMYK and CIEL*a*b* must be aimed. The proposed method in this paper follows steps: (1) print and measure CIEL*a*b* values of CMYK reference chart, (2) set-up parameters to assign the amount of black extraction, (3) generate gamut boundary descriptors for gamut mapping and for black extraction using CMYK-CIEL*a*b* data under predetermined black extraction parameters, (4) perform gamut mapping for given CIEL*a*b* using the gamut boundary descriptor for gamut mapping, (5) determine K value of the gamut-mapped CIEL*a*b* using the gamut boundary descriptors for black extraction. The suggested method determines K value for given CIEL*a*b* using gamut boundary descriptors in CIEL*a*b* color space. As a result, a color printer using this method can make out accurate black amount and reproduces more consistent CMYK images under different black extraction options.

6058-25, Session 6

Colorimetric characterization based on color correlation in CMYKGO printer

I. Jang, C. Son, T. Park, K. Ko, Y. Ha, Kyungpook National Univ. (South Korea)

This paper proposes a method of colorimetric characterization based on the color correlation between color patches in a CMYKGO printer. Many color patches represents the same tri-stimulus value, in colorimetric characterization beyond three colorants. Therefore, choosing the proper color patches corresponding to each tri-stimulus value is important for a CMYKGO printer characterization process. As such, the proposed method estimates the CIELAB value for many color patches, then selects certain color patches while considering high fidelity and the extension of the gamut. The selection method is divided into two steps. First, color patches are selected based on their global correlation, i.e. their relation to seed patches on the gray axis. Second, if the correlation factor is smaller than the correlation factors for neighboring patches, the color patch is reselected by new seed patch which is the average distribution of eight neighboring selected color patches. The selected color patches are then measured for accuracy, and the relation between the digital value and the tristimulus value for the color patches stored in a lookup table. As a result of this characterization, the gamut is extended in the dark regions and the color difference reduced compared to conventional characterization methods.

6058-26, Session 6

Hardcopy global color correction

Y. Bang, Y. Kim, H. Choh, Samsung Advanced Institute of Technology (South Korea)

As time, temperature or an external environment changes, a laser electrophotographic printer produces quite different color tones from

original ones. To achieve consistent color reproduction, many researchers have tried to characterize printer tone curves and developed methods to correct color tones. Color channel independent methods are most widely used, and there are two approaches in color channel independent method: (1) Instrument-based correction and (2) visual correction. Two approaches provide some trade-offs between cost and accuracy. In this paper we propose a methodology which combines the strengths of these two approaches. We describe how we design a calibration page and how we characterize lightness variation of a reference patch. We then present the procedure of our global tone correction method based on visual appearance match of end-users as well as the predetermined reference lightness model. We simulate tone distortion state by varying hardware parameters, and perform visual appearance match experiments to subjects. Our experimental results show that our method can significantly reduce color difference between the original print and the print at the distortion state. This suggests that we can reliably estimate the distortion parameter, and correct tones close to an original state.

6058-28, Session 6

Efficient document rendering with enhanced run length encoding

G. Feng, Ricoh Innovations, Inc.; C. A. Bouman, Purdue Univ.

Document imaging and transmission systems (typically MFPs) require both effective and efficient image rendering methods that support standard data formats for a variety of document types, and allow for real time implementation. Since most conventional raster formats (e. g. TIFF, PDF and JPEG) are designed for use with either black and white text, or continuous-tone images, more specialized rendering methods are often required for representing mixed content documents. The baseline TIFF format supports a few binary compression options: PackBits, CCITT G3 and G4. Conventionally, halftoning algorithms, such as error diffusion, can be used to create a binary representation of a document image in the TIFF format. However, PackBits, CCITT G3/G4 compression generally do not produce desired compression on halftone images. In this paper, we propose an efficient error diffusion algorithm optimized for PackBits compression. This method, called POED (PackBits optimized error diffusion), is a form of threshold modulation error diffusion which takes advantage of the byte-oriented run length structure of PackBits compression by encouraging repetition of bytes in the binary output. To maintain the sharpness of text, a binary segmentation algorithm is used to switch on Floyd Steinberg error diffusion in text regions. The POED method yields higher PackBits compression ratios than conventional Floyd Steinberg error diffusion, while maintaining desirable visual quality with low computational and memory requirements.

6058-29, Session 7

Model-based clustered-dot screening

S. H. Kim, SAMSUNG Electronics Co., Ltd. (South Korea)

I propose a halftone screen design method based on a human visual system model and the characteristics of the electro-photographic (EP) printer engine. Generally, screen design methods based on human visual models produce dispersed-dot type screens while design methods considering EP printer characteristics generate clustered-dot type screens. In this paper, I propose a cost function balancing the conflicting characteristics of the human visual system and the printer. By minimizing the obtained cost function, I design a model-based clustered-dot screen using a modified direct binary search algorithm. Experimental results demonstrate the superior quality of the model-based clustered-dot screen compared to a conventional clustered-dot screen.

6058-30, Session 7

AM-FM hybrid color screen design to reduce brightness variation

B. M. Kang, B. T. Ryu, C. Kim, Inha Univ. (South Korea); S. H. Kim, SAMSUNG Electronics Co., Ltd. (South Korea)

AM-FM hybrid screen represents a clustered halftone screen whose centers of dot clusters are aperiodic and dot growth pattern is irregular. Compared to the AM ordered screen, AM-FM hybrid screen is free of inter-screen and subjective moirés. However, it results in brightness variation often called as stochastic noise. In this paper, a new screen design technique is presented for the AM-FM hybrid dithering. Centers of dot clusters for each of C, M, Y, K screens are selected by a new method to achieve homogeneous distributions, channel by channel and as combination of color channels. An optimum dot growth filter that is different from donut filter is defined in this paper. Also, a new dot growth algorithm is developed to reduce the brightness variation.

6058-31, Session 7

Frequency domain design of cluster dot screens

M. Fischer, D. Shaked, Hewlett-Packard Labs. (Israel)

Clustered dots screens are widely used in digital printing. Our research focuses on irregular cluster-dot screens. Irregular screens are appealing since there are many more irregular screens than regular ones. As a result, they provide a larger set of multi-separation screen combinations for avoiding interaction between screening frequencies of concurrent screens. Their down side is that they often have harmonic artifacts. Our design challenge is to reduce these artifacts' visual impact. We present frequency-domain based methods to reduce these artifacts' visual impact. State-of-the-art screens incorporate many, predominantly spatial domain, design considerations which we cannot ignore. Accordingly, the proposed methods are designed to introduce minimal modifications to given screens. The proposed methods eliminate, or reduce the few artifacts visible in a set of irregular screens. This work can be generalized to other printing technologies, and to screen design.

6058-32, Session 7

A spatial domain optimization method to generate plan-dependent masks

Y. Wu, Hewlett-Packard Co.

Stochastic screening technique uses a fixed threshold array to generate halftoned images. When this technique is applied to color images, an important problem is how to generate the masks for different color planes. Ideally, a set of plane dependent color masks should have the following characteristics: a) when total ink coverage is less than 100%, no dots in different colors should overlap from each other. b) for each individual mask, dot distribution should be uniform, c) no visual artifact should be visible due to the low frequency patterns.

In this paper, we propose a novel color mask generation method in which the optimal dot placement is searched directly in spatial domain. The advantage of using the spatial domain approach is that we can control directly the dot uniformity during the optimization, and we can also cope with the color plane-dependency by introducing some inter-plane constraints. We will show that using this method, we can generate plane dependent color masks with the characteristics mentioned above.

6058-33, Session 8

Using errors in halftoning to increase reproduction accuracy

S. Herron, Global Graphics Software Inc.

Halftones are point-to-point conversion processes. This solution achieves accurate halftone reproduction by using the errors during the scan conversion process without comparison to the source pixels maintaining the point-to-point scan conversion paradigm.

Two types of density errors encounter in the halftoning process are considered. An error describing the difference between the input pixel value and the halftone threshold value and an error describing the difference between the density level of the output and the reflection density of the tone. Halftone errors are metadata derived from a contone characteristic and communicated to the halftone conversion process. Each error is associated with a device dot maintaining the point-to-point relationship. An approach to achieving accurate halftone reproduction by using the errors is described.

The algorithm is a two-pass process. During the first pass through the image, each pixel value in the image is converted to the threshold value according to the standard scan-conversion method. The difference between the threshold value and the vector or pixel value accumulates. That value is added to the average density increase. The second pass compares the value in the alpha plane with the threshold value. An adjustment is made to the halftone threshold value.

6058-35, Session 8

Analysis of misregistration-induced color shifts in the superposition of periodic screens

B. Oztan, G. Sharma, Univ. of Rochester; R. P. Loce, Xerox Corp.

We present an analysis and model for evaluation of color shifts in halftone printing caused by inter-separation misregistration for periodic clustered dot halftones. Using a lattice framework, we present intuitive analysis that demonstrates conditions under which the average color is asymptotically invariant under inter-separation misregistration. Combining the framework with an analytic representation for the halftone dots, we develop a hybrid analytical-numerical model for quantitatively estimating color shifts as a function of inter-separation misregistration. The model is compared against experimental data for a xerographic printer.

6058-36, Session 8

Analysis of color error diffusion with vector error filters

Z. Z. Fan, Xerox Corp.

As vector error filters are capable of passing errors generated in one color component to other color components, it provides more flexibility in shaping the halftone texture. As a result, it may potentially produce halftones with better image quality. In this paper, we analyze color error diffusion with vector error filters. In particular, we will discuss its halftone spectrum features and its stability conditions with respect to the filter coefficients. For spectrum analysis, we will derive the high-pass and "zero-gain" conditions, which ensure decent image quality. Since error diffusion is a feedback system, the vector error filters may cause instability, if it is not properly designed. This may potentially generate ever-increasing quantization error that masks the input and produces unacceptable output images. The stability conditions we will discuss prevent any instability.

6058-37, Session 8

New halftoning method combining the best of masking and error diffusion algorithms

F. Cittadini, Océ Print Logic Technologies (France) and Univ. Pierre et Marie Curie (France); J. Pervillé, S. Berche, Océ Print Logic Technologies (France); M. Ben Chouikha, G. Alquié, Univ. Pierre et Marie Curie (France)

There are two main families among the halftoning methods: halftoning by masking (i.e. blue noise masking) and error diffusion halftoning. The first family produces neither “worms” nor defects related to stationary regimes but has a limited spatial bandwidth. The error diffusion halftoning method is characterized by a very broad spatial bandwidth allowing good rendition of very thin lines and patterns but this method presents sometimes unpleasant worms or stationary regimes. These methods are complementary with respect to quality. In this paper we propose a halftoning algorithm in black and white, derived from the error diffusion of Floyd Steinberg. By using a new threshold modulation, our new method combines the advantages of both masking and error diffusion algorithms. In order to evaluate our algorithm we defined a set of test images allowing the evaluation of the critical points of quality for the technical imagery: graininess, patterning and spatial bandwidth. The rendering of the presented algorithm has low graininess, no unpleasant patterning and broad spatial bandwidth. Tests were carried out with color images. We compared our algorithm with Floyd Stenberg’s error diffusion with independent bitmaps plans. The improvement is similar to that we noticed in Black and white.

6058-38, Session 8

Graph order dither

A. Hausner, Univ. of New Hampshire

Printing technology produces the illusion of a continuous range of colors on devices that can produce only a few colors. This illusion can be achieved by dithering: arranging printed dots into patterns that the viewer’s eye blends into the desired color. This paper presents a versatile generalization of dispersed-dot dithering that improves traditional dither methods, and also extends artistic screening techniques. Dithering has been studied intensively, but almost all past approaches assume the color dots are arranged in a square matrix. The present method works with arbitrarily-placed color points, and solves the following general problem: given an arbitrary set of 2D points (not necessarily on a grid) order them so that consecutive pairs and triples of points are as far apart as possible.

The algorithm begins by building the adjacency graph of the points, and then obtains a graph ordering by applying graph coloring to its vertices recursively. Vertex coloring, a well-studied problem in graph theory, gives each graph vertex a color (or number) so that any two adjacent vertices will receive different colors. For every color, the subset of vertices with that color is considered. Each vertex in the subset is more separated from its nearest neighbor than nearest neighbors in the superset. The vertices in this subset are colored again, yielding points with even greater inter-neighbor distances; the process continues recursively. For each coloring, a color number is appended to each vertex’s label. When recursion is done, each point has multi-digit label. Sorting these labels produces an ordering for the original points which has the desired consecutive-point separation needed for dispersed dither. The above solution yields many useful results. Bayer’s $2^n \times 2^n$ dither matrices are obtained as a special case of the problem, when the initial points are on a square grid. However, dither matrices of arbitrary width and height can be also constructed. Moreover, since any given graph can be colored in many different ways, it is easy to obtain many different orderings for the same set of points. Using many orderings when printing an image avoids the obvious repetitive

artifacts evident in Bayer dither. In addition, reversing the digits in all the point labels and sorting can yield space-filling curves!

Beyond improving classic dither, this method increases the versatility of existing artistic screening methods like Ostromoukhov’s. His method repeats a single small motif image across the whole desired image, producing a delightful decorative effect that is also useful in counterfeit-resistant printing. His method is restricted to continuous-tone motifs, whereas the present method is more flexible, and works with any motif, including binary (black and white) images.

To generate a dither pattern from a motif image, the present method considers each grey level occurring in the motif image. For each level the subset of pixels with that grey value is obtained. Each subset is treated as an arbitrary collection of 2D points and graph-ordered. Finally, all the ordered subsets are concatenated, yielding an ordering for all the motif’s pixels for artistic dither. As a special case, applying graph ordering to a motif image whose brightness grows radially into its center will yield a dither matrix for clustered-dot dither. Sample images are online at www.cs.unh.edu/~ah/hgc

6058-39, Session 8

Optimal halftoning over hexagonal grids

J. Bacca Rodriguez, A. J. Gonzalez Lozano, G. R. Arce, Univ. of Delaware; D. L. Lau, Univ. of Kentucky

The spectral analysis of blue noise dithering in hexagonal grids provides the desired spectral characteristics one must attain but it does not provide the dithering structures needed to achieve these. In this paper, these optimal dithering mechanisms are developed through modifications of the Direct Binary Search (DBS) algorithm extensively used for rectangular grids. Special attention is given to the effects of the new geometry on the Human Visual System (HVS) models and on the efficient implementation of the hexagonal-grid DBS. This algorithm provides the best possible output at the expense of high computational complexity, and while the DBS algorithm is not practical in most applications, it provides a performance benchmark for other more practical algorithms. Finally, a tone-dependent, hexagonal-grid, error-diffusion algorithm is developed, where the DBS algorithm is used to optimize the underlying filter weights. The characteristics of the HVS are thus implicitly used in the optimization. Extensive simulations show that hexagonal grids do indeed reduce disturbing artifacts, providing smoother halftone textures over the entire gray-scale region. Results also show that tone-dependent error-diffusion can provide comparable results to that of the DBS algorithms but at a significantly lower computational complexity.

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6059-36, Poster Session

Image quality assessment based on textual structure and noise normalization

C. Zhang, Z. Qiu, Beijing Jiaotong Univ. (China)

Considering the popular concept of objective image quality assessment models based on error sensitivity and Wang's assumption that HVS is highly adapted for extracting structural information, this paper proposed an objective image quality assessment SNPSNR based on textural structure and normalized noise. Taking time-frequency advantages of wavelet transform, SNPSNR describes the contribution of a coefficient by its energy proportion to corresponding approximation sub-band or detail sub-bands of a transform level, i.e., a frequency channel. The proportion is utilized to measure the distortion caused by the noise on that coefficient. HVS is also taken into consideration by weighting noises differently according to corresponding frequency channel. Due to the energy distribution property of wavelet transform, the noise quantity difference on each transform level is quite large and is not proportional to the influence caused by them. We normalize the structural noise on different levels by normalizing the coefficients on each level. Noise normalization on different frequency channels provides a consistent prediction of DMOS for images with different contents under different distortions. Finally the form of peak signal-to-noise is used to compute SNPSNR. By comparisons with MSSIM, HVSNR and PSNR from fitting goodness with DMOS it turns out that SNPSNR models HVS better.

6059-37, Poster Session

Quality models for audiovisual streaming

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Quality metric is an essential factor in multimedia communication, especially in compression and adaptation. Quality metric so far is mostly for a single modality (video, audio). There is a need to measure the quality of multimedia (i.e. multimodality) contents. Moreover, so far quality is just considered from the perceptual perspective. In practice, the content may be drastically adapted, even converted to another modality. In this case, we should consider the quality from semantic perspective as well. Previously, we show that multimedia quality has two aspects: perceptual quality and semantic quality. The former refers to user's satisfaction in perceiving the content, regardless of what information the content contains; the latter, which is crucial in modality conversion, refers to the amount of conveyed information, regardless of how the content is presented. Different applications may focus on different quality aspects (perceptual, semantic, or both). In this research, we consider the semantic quality of audiovisual contents; specifically, we estimate the amount of information conveyed by a videophone content where both video and audio channels may be strongly degraded, even audio is converted to text. We also consider the perceptual quality model of audio visual content, so as to see the difference with semantic quality model.

To model the semantic quality of multimedia quality, we apply the concept of "conceptual graph", which consists of semantic nodes and relations between the nodes. Each node is attributed by a weight and the semantic quality of that node. And each relation is attributed by the strength of that relation. The semantic quality of an adapted content with respect to the original content is computed based on the similarity measure between the conceptual graphs of the adapted content and the original content.

An audiovisual content can be modeled by a simple graph of two nodes (one for video and one for audio) and one relation between the nodes. The audiovisual semantic quality based on similarity

measure is essentially a parametric function (model) of the semantic quality of audio and the semantic quality of video. As shown in a previous work of ours, the semantic quality of a single modality (video, audio) can be modeled by some analytical function. Our focus here is how the semantic quality of audiovisual contents can be combined from the individual qualities of audio and video.

To find the semantic quality model of audiovisual contents in videophone service, we design and carry out extensive subjective tests to measure semantic qualities of audio channel, video channel, and the audiovisual combination. The selected content type is head-shoulder with speech, configured specifically for the practical videophone over wireless network. For an original audiovisual content, the video channel is adapted with four different frame-rates, while the audio channel is adapted with four different sampling rates and also converted to a textual transcription. Then 4 scores for video versions, 5 scores for audio versions, and 20 scores for audiovisual versions are recorded for each original audiovisual content. Finally, we obtain the specific quality model by multiple regression analysis with the subjective training data.

Compared to a previous work on the perceptual quality model for audiovisual contents, the semantic quality model obtained in this work shows that the audio channel has very high impact on the overall quality of audiovisual quality. This can be explained by the fact that from the semantic perspective, the user is more interested in the audio channel. In addition, if we can quantify the semantic quality of textual transcription with respect to original audio channel, the obtained quality model can still be applied to measure the quality of adapted text-visual content. Further, the inter-subject reliability based on confidence intervals suggests that the obtained quality model can be reliably used in practical videophone service at low bandwidth. In the future, we will study the quality of other multimodality applications like e-learning, virtual reality.

6059-38, Poster Session

Research on the analysis and measurement of MTF of staring imaging system

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The staring imaging technique is one of the main research directions in the field of the opto-electronic imaging. In order to design a thermal imaging system with good quality, a set of parameters are required for an objective evaluation of both static and dynamic performance of the imaging system. Static performance parameters are used to evaluate the static object imaging characteristics, namely, assuming that the object's spatial distribution does not vary with time (or the variation is negligible), whereas the dynamic ones describe the dynamic imaging capability. In general, following parameters are introduced to evaluate the thermal imaging system: MTF, NETD, MRTD, SNR, SiTF, uniformity, dynamic range, etc., among which MTF is one of the most important parameters in evaluating the performance of the detector and the system. In the MTF analysis, the object's spatial distribution is mapped to image's spatial distribution via convolution, which is one of the most important factors in the course of analyzing and evaluating the imaging performance. In this paper, we report a thorough analysis on the characteristics of MTF from the spatial and frequency spectrum. This Fourier transform based analysis was performed on the dynamic imaging characteristics of staring imaging system. In detail, two methods are introduced for MTF testing of the imaging system: the slit target and step target. Furthermore, abundant experiments are made on the measurement of MTF of visible CCD and IRFPA, thereby the results are obtained for the staring imaging system, and preliminary analysis is stated.

6059-39, Poster Session

Quantification method of the color break-up phenomena: evaluation of next-generation color wheels for field sequential color displays

J. Thollot, K. Sarayeddine, Thomson R&D France (France); A. Trémeau, Univ. Jean Monnet Saint-Etienne (France)

While projection display market is growing up, micro-display based optical engines (e.g. DMD, LCD, LCOS) are continuously improved in order to make this technology competitive versus emergent large screen Liquid Crystal Displays and Plasma Displays .

One of the main challenge is to make use of temporal integration capacity of Human Visual System by using only one single micro-display. In such a case, the optical engine must include an illumination system that allows to time sequentially delivers a colored light flux which is then modulated by the micro-display. This illumination system can be based on a lamp to which a mechanical device (e.g. color wheel) is added in order to filter sequentially the emitted light flux.

In any case, field sequential color displays exhibit a disturbing artifact known as the rainbow effect which is perceived as image content that breaks up into color components particularly next to high contrast edges.

The present paper describes a psychophysical method developed by Thomson that quantifies the phenomena according to frame frequency, eye movement velocity and display technologies. Sample results are discussed for three and six primary field sequential color projection systems, showing that color ordering is a key to decrease the rainbow effect.

6059-40, Poster Session

No-reference jerkiness evaluation method for multimedia communications

M. Carli, D. Guida, A. Neri, Univ. degli Studi di Roma Tre (Italy)

In this contribution, we present an objective assessment method for the evaluation, without reference, of the degradation of the video quality induced by the reduction of the temporal resolution.

Jerkiness (or jerky motion) is a video coding artefact produced by temporal sub-sampling. In essence the motion of an object on the scene, that appears as smooth when played at the original frame rate, becomes stepwise with instantaneous abrupt changes when frame rate is drastically reduced. Subjective tests show that human observers are particularly sensitive to jerkiness. Several full reference techniques for jerkiness assessment have been presented in literature. The proposed assessment of the jerkiness perceived by a human observer is performed by feeding a multilayer neural network with the statistical distributions of the kinematics data (speed, acceleration and jerk of objects on the image plane) evaluated on a video shot. To identify the neural network (architecture and parameters) that best fit the human behaviour, a subjective experiment has been performed. Validation of the model on the test set indicate a good match between the Mean Opinion Score (MOS) and the jerkiness indicator computed by the neural network.

6059-01, Session 1

Fundamental questions related to print quality

P. J. Mangin, M. Dubé, Univ. du Québec à Trois-Rivières (Canada)

The concept of print quality is elusive, since it depends on objective measurable quantities such as contrast, graininess, etc., but also on the subjective appreciation of potential observers. It is far from

obvious that print quality (PQ) can be defined in terms of good or bad, so that every one will agree on this definition, and the question of its measurement, with objective and subjective measures, remains open.

In this Communication, we would first like to propose a set of fundamental questions related to the definition and measurement of PQ. Specifically, we are interested in the definition of PQ in terms of quality concept and quality criteria, on the minimal dimension space of PQ, and on the functional relations that should be satisfied by the metrics of PQ.

In the second part, we focus on the simpler case of print mottle and try to answer some of these questions. We show that wavelet transforms can be used to obtain a measure of PQ that correlates very well with the subjective evaluation of observers and use this measure to discuss the functional form of a metric of Print Quality.

6059-02, Session 1

What do users really perceive: probing the subjective image quality

G. S. Nyman, J. Radun, T. Leisti, Univ. of Helsinki (Finland); J. Oja, H. J. Ojanen, J. Olives, T. Vuori, Nokia Research Ctr. (Finland); J. P. Häkkinen, Univ. of Helsinki (Finland) and Nokia Research Ctr. (Finland)

Image evaluation schemes must satisfy both objective and subjective requirements. Objective image quality evaluation models are often preferred over subjective quality evaluation, because of their fastness and cost-effectiveness. However, the correlation between subjective and objective estimations is often poor. One of the key reasons for this is that it is not known what image features subjects use when they evaluate image quality. We have studied subjective image quality evaluation in the case of image sharpness. We used an Interpretation-Based Quality (IBQ) approach, which combines both qualitative and quantitative analysis of subjective data to probe the observer's quality experience. The combined data are obtained from the studies of subjective image sharpness, using five image contents (ISO 12640) and MTF manipulations of the test targets. We examine how naïve subjects experienced and classified natural images, whose sharpness was changing. Together the psychometric and qualitative information obtained allows the correlation of quantitative evaluation data with its underlying subjective attribute sets. This offers guidelines to product designers and developers who are responsible for image quality. Combining these methods makes the end-user experience approachable and offers new ways to improve objective image quality evaluation schemes.

6059-03, Session 2

The effect of image sharpness on quantitative eye-movement data and on image quality evaluation while viewing natural images

T. Vuori, M. Olkkonen, Nokia Corp. (Finland)

The aim of the study is to test both customer image quality rating (subjective image quality) and physical measurement of user behavior (eye movements tracking) to find customer satisfaction differences in imaging technologies. Methodological aim is to find out whether eye movements could be quantitatively used in image quality preference studies. In general, we want to map objective or physically measurable image quality to subjective evaluations and eye movement data. We conducted a series of image quality tests, in which the test subjects evaluated image quality while we recorded their eye movements. Results show that eye movement parameters consistently change according to the instructions given to the user, and according to physical image quality, e.g. saccade duration

increased with increasing blur. Results indicate that eye movement tracking could be used to differentiate image quality evaluation strategies that the users have. Results also show that eye movements would help mapping between technological and subjective image quality. Furthermore, these results give some empirical emphasis to top-down perception processes in image quality perception and evaluation by showing differences between perceptual processes in situations when cognitive task varies.

6059-04, Session 2

Assessing the enhancement of image sharpness

S. Bouzit, Univ. of St. Andrews (United Kingdom); L. W. MacDonald, London College of Communication (United Kingdom)

A psychophysical experiment was conducted to investigate the performance of four different image sharpness enhancement methods. Two were based on the power spectrum adjustment method using the human visual contrast sensitivity function and the other two methods applied PhotoShop's standard sharpening filters. The results of the experiments are presented and discussed. Five major conclusions are drawn from this experiment: (1) Performance of sharpening methods; (2) Image dependence; (3) Influence of two different colour spaces on sharpness manipulation; (4) Correlation between perceived image sharpness and image preference; and (5) Effect of image sharpness enhancement on the image power spectrum.

6059-05, Session 2

Reference-free quality metric using a region-based attention model for JPEG2000 compressed images

R. Barland, A. Saadane, Univ. de Nantes (France)

At high compression ratios, JPEG-2000 coding introduces distortions (blurring, ringing) that potentially cause an embarrassment for a human observer. However, the Human Visual System does not carry out a systematic and local research of these impairments in the whole image, but rather, it identifies some regions of interest for judging the perceptual quality. In this paper, we propose to use both of these distortions (ringing and blurring effects), locally weighted by an importance map generated by a region-based attention model, to design a new reference free quality metric for JPEG-2000 compressed images.

For the blurring effect, the impairment measure depends on spatial information contained in the whole image while, for the ringing effect, only the local information localized around strong edges is used. To predict the regions in the scene that potentially attract the human attention, a stage of the proposed metric consists to generate an importance map issued from the Osberger's attention model. The produced importance map is used to locally weight each distortion measure. The predicted scores have been compared on one hand, to the subjective scores and on other hand, to previous results, only based on the artefact measurements. This comparative study demonstrates the efficiency of the proposed quality metric.

6059-06, Session 2

Comparison of various subjective video quality assessment methods

C. Lee, H. Choi, E. Lee, S. Lee, J. Choe, Yonsei Univ. (South Korea)

As multimedia services, such as video on demand and video phones, over noisy channels are widely available to consumer market, quality monitoring emerges as an important topic. In this paper, we present comparison of three subjective testing methods: the double stimulus continuous quality scale (DSCQS) method, the

single stimulus continuous quality evaluation (SSCQE) method and the absolute category rating (ACR) method. The DSCQS method was used for validate objective models in the VQEG Phase II FR_TV test [1]. The SSCQE method is chosen to be used in the VQEG RRTV test [2]. The ACR method is chosen to be used in the VQEG Multimedia test [4]. Since a different subjective test method is used in each test, in-depth analyses of the three methods will provide helpful information in understanding human perception of video quality.

In the double stimulus continuous quality scale method (DSCQS) recommended by ITU-R [3], evaluators are shown two video sequences: one is the original (source) video sequence (SRC) and the other is a processed video sequence (PVS). Without knowing which is the source video, the evaluators are shown the video sequences two times and is asked to provide their subjective scores by marking their subjecting rating in the provided form. Then, DMOS (Differential Mean Opinion Score) is computed by subtracting the score of the processed video sequence from that of the source video sequence.

In the SSCQE method, a video sequence is shown only once to evaluators. The SSCQE method was conducted following the guideline of the VQEG RRTV test plan [2]. According to the test plan, video sequences may or may not contain impairments. Furthermore, there is a source video sequence for every PVS (processed video sequence) so that a hidden reference procedure can be implemented. In the SSCQE method, evaluators evaluate the video quality in real time using a slider which has a continuous grading scale.

In accordance with the RRTV test plan [2], a test tape was created, which has a total of 60 video sequences. Each video sequence lasts one minute. The video sequences was generated by processing source video sequences (SRCs) using various HRCs (hypothetical reference circuits). Using test tape, subjective testing using the SSCQE method was conducted. Since source video sequences are always included, DMOS (Differential Mean Opinion Score) is also computed by subtracting the score of the processed video sequence from that of the source video sequence.

In order to perform the DSCQS method, 64 8-second video sequences were taken from the 60-minutes test tape. Then, subjective test using the DSCQS was performed. These DSCQS scores were compared with the corresponding SSCQE scores, which were obtained by averaging the scores of the corresponding 8-second clip. It is noted that the SSCQE scores are MOS (mean opinion score). We can also compute SSCQE-DMOS by subtracting the score of the processed video sequence from that of the source video sequence. Using the 8-second video sequences, we also performed subjective testing using the ACR method. In the paper, we present statistical analyses of the three subjective testing methods.

[1] VQEG, "Final Report from the Video Quality Experts Group on the Validation of Objective Models of Video Quality Assessment, Phase II (FR-TV2)," Aug 2003.

[2] ITU-R Recommendation BT.500-10, Methodology for the subjective assessment of the quality of television pictures, 2000.

[3] VQEG, "RRNR-TV Group TEST PLAN," www.vqeg.org, 2005.

[4] VQEG, "Multimedia Group Test Plan," www.vqeg.org, 2005.

6059-07, Session 3

Selecting significant colors from a complex image for image quality modeling

K. J. Leeming, P. J. Green, London College of Communication (United Kingdom)

Judgements of complex images differ from those of uniform colour samples in several important respects. One such difference is that a complex image is formed of a large number of discrete colour elements. Observer judgements are based not on assessment of

each discrete element but of a much smaller number of salient features. The judgement process can be considered as the selection of such features followed by the judgement of particular quality attributes for these features. Modelling the judgement process thus requires a set of well-defined quality attributes together with a methodology for the selection of salient features and their relative importance. In this project, a method of selecting colours within an image was considered. A number of measurement locations within a complex image were selected, and the colour of these locations was measured on a series of reproductions. Measurements were carried out by registering each reproduction on an xy table and programming a 0:45 spectrophotometer with a 4mm aperture. The reproductions were judged by a panel of expert observers for their match to a proof, using a category scaling of several image quality attributes. By comparing the measured colour differences with the visual judgements it was possible to determine which locations carried the greatest weight in the assessments. It was also possible to make a limited prediction of the visual judgements from the measurements. By eliminating colour locations with the smallest weightings in predicting the visual judgements, the number of measurement locations was reduced to eight. Further analysis of the data looked at the tolerance to colour change when compared to the visual judgements for each of the selected areas. Caucasian skin tones were more tolerant to slight increases in red, having a central tendency of $+1+ a^*$. Conversely the blue areas selected had a central tendency of $-1+ a^*$. In a second phase of the project, further images were analysed to evaluate the ability of the salient colours identified in the first phase to predict the visual judgements of these images. In this phase, images were selected to have salient colours from phase 1 with both similar and different semantic content to phase 1. For both images it was determined that fewer colours were required to represent the image. It was deduced that this was due to both images being less complex than the image in phase 1. It was concluded that some image quality judgements can be predicted from a small number of salient colours, where the colours measured have similar semantic content. It was also found that the number of colours is to some extent image dependent.

6059-08, Session 3

Comparison of three full-reference color image quality measures

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Image quality assessment plays a major role in many image processing applications. Although much effort has been made in recent years towards the development of quantitative measures, the relevant literature does not include many papers that have produced accomplished results. Ideally, a useful measure should be easy to compute, independent of viewing distance, and able to quantify all types of image distortions. In this paper, we will compare three full-reference full-color image quality measures (M-DFT, M-DWT, and M-DCT). Assume the size of a given image is $n \times n$. The transform (DFT, DWT, or DCT) is applied to the luminance layer of the original and degraded images. The transform coefficients are then divided into four bands, and the following operations are performed for each band: (a) obtain the magnitudes M_{oi} , $i=1, \dots, (n \times n)/4$ of original transform coefficients, (b) obtain the magnitudes M_{di} , $i=1, \dots, (n \times n)/4$ of degraded transform coefficients, (c) compute the absolute value of the differences: $|M_{oi} - M_{di}|$, $i=1, \dots, (n \times n)/4$, and (d) compute the standard deviation of the differences. Finally, the mean of the four standard deviations is obtained to produce a single value representing the overall quality of the degraded image. In our experiments, we have used five degradation types, and five degradation levels. The three proposed full-reference measures outperform the Peak-Signal-to-Noise Ratio (PSNR), and two state-of-the-art metrics Q and MSSIM.

6059-09, Session 3

Influence of ambient illumination on adapted and optimal white point

I. Vogels, J. Berentsen, Philips Research Labs. (Netherlands)

The white point recommended by the European Broadcasting Union (EBU) for TV displays, which corresponds to illuminant D65, does not always yield optimal color rendering. Previous research has shown that the most preferred white point strongly depends on image content. This study investigates the effect of the chromaticity and intensity of the ambient illumination on the adapted white point of a homogeneous image (i.e. the chromaticity that is perceived as achromatic) and on the optimal white point of natural images (i.e. the white point with the most preferred color rendering). It was found that the adapted white point and the optimal white point shift towards the chromaticity of the ambient illumination. The effect of illuminant color was approximately 2.5 times larger for the adapted white point than for the optimal white point. The intensity of the ambient illumination had no effect on the adapted white point and the optimal white point, except for images with face content. In agreement with previous studies, the optimal white point was found to depend on image content. The results indicate that the optimal color rendering of natural images is a complex relation of image content and ambient illumination.

6059-10, Session 4

Characterization of digital image noise properties based on RAW data

H. H. Hytti, Tampereen Teknillinen Yliopisto (Finland)

Noise properties of digital cameras are under intensive research all around the world. In current research project between TUT/MIT and Nokia corporation, image noise characterization based on digital camera RAW data is being studied.

Digital image has several different noise sources. Separating these from each other, if possible, helps to improve image quality by reducing or even eliminating some noise components. It is impossible to completely separate the noise components from each other by analyzing RAW data, but by applying several different measurement and analysis procedures their nature and relative impact on image quality can be evaluated.

In this paper, three different imaging technologies are compared. The three digital cameras used are Canon EOS D30 with CMOS sensor, Nikon D70 with CCD sensor and Sigma SD10 with Foveon X3 Pro 10M CMOS sensor. Due to different imaging sensor constructions, these cameras have rather different noise characteristics. The applicability of different analysis methods to these different sensor types is also studied. The analysis methods used in this research project include for example photon transfer curve method and ISO 15739 standard noise analysis methods.

6059-12, Session 4

An evaluation of sharpness in different image displays used for medical imaging

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X-ray film systems have been widely used for a diagnosis of various diseases since a long time ago. In recent years, many kinds of displays and recording systems for X-ray medical images have been used including inkjet printer, silver halide film, CRT and LCD, by the development of the digital X-ray image capturing systems. In this paper, image quality of X-ray images displayed onto high accurate

monochrome CRT and LCD monitors are analyzed and compared. Images recorded on the exclusive film and coated paper by inkjet printer and the wet type and dry type photo printers using a silver halide material are also analyzed and compared. The modified Gan's method is introduced to calculate the MTF (Modulation Transfer Function) from the knife ESF (edge spread function). The results show that the MTFs of the inkjet image on the transparency and the wet type silver halide film image have fairly similar and good response in comparison with the inkjet image on the coated paper and the dry type silver halide film. It is also shown that the CRT has the worse response over the spatial frequency range. It was well correlated between the MTF and observer rating value. From here, we consider the proposed method is effective.

6059-13, Session 5

Characterization of printer MTF

W. Jang, Hewlett-Packard Co.; J. P. Allebach, Purdue Univ.

We develop a comprehensive procedure for characterizing the modulation transfer function (MTF) of a digital printer. Especially designed test pages consisting of a series of patches, each with a different 1-D sinusoidal modulation, enable measurement of the dependence of the MTF on spatial frequency, bias point, modulation amplitude, spatial direction of modulation, and direction of modulation in the color space. Constant tone patches also yield the extreme and center color values for the input modulation. After calibrating the scanner specifically for the direction of modulation in the color space, we spatially project the scanned test patches in the direction orthogonal to the modulation to obtain a 1-D signal, and then project these sample points onto a line in the CIE $L^*a^*b^*$ color space between the extreme color values to obtain a perceptually relevant measure of the frequency response in a specific color direction. Appropriate normalization of the frequency response followed by compensation for the scanner MTF completes the procedure. For a specific inkjet printer using a dispersed-dot halftoning algorithm, we examine the impact of the above-mentioned parameters on the printer MTF, and obtain results that are consistent with the expected behavior of this combination of print mechanism and halftoning algorithm.

6059-14, Session 5

PSF estimation by gradient descent fit to the ESF

E. H. Barney Smith, Boise State Univ.

Calibration of scanners and cameras usually involves measuring the point spread function (PSF). When edge data is used to measure the PSF, the differentiation step amplifies the noise. A parametric fit of the functional form of the edge spread function (ESF) directly to the measured edge data is proposed to eliminate this. Experiments used to test this method show that the Cauchy functional form fits better than the Gaussian or other forms tried. The effect of using a functional form of the PSF that differs from the true PSF is explored by considering bilevel images formed by thresholding. The amount of mismatch seen can be related to the difference between the respective kurtosis factors.

6059-15, Session 5

Printer banding estimation using the generalized spectrum

N. A. Rawashdeh, I. Shin, K. D. Donohue, Univ. of Kentucky; S. T. Love, Lexmark International, Inc.

This paper compares multi-step algorithms for estimating banding parameters of a harmonic signature model. The algorithms are based on two different spectral measures, the power spectrum (PS) and the collapsed average (CA) of the generalized spectrum. The

generalized spectrum has superior noise reduction properties and is applied for the first time to this application. Simulations compare estimation performances of profile (or coherent) averaging and non-coherent spatial averaging for estimating banding parameters in grain noise. Results demonstrate that profile averaging has superior noise reduction properties, but is less flexible in applications with irregular banding patterns. The PS-based methods result in lower fundamental frequency estimation error and greater peak height stability for low SNR values, with coherent averaging being significantly superior to non-coherent. The CA has the potential of simplifying the detection of multiple simultaneous banding patterns because its peaks are related to intra-harmonic distances; however, good CA estimation performance requires sufficiently regular harmonic phase patterns for the banding harmonics so as not to undergo reduction along with the noise. The algorithms are applied to samples from inkjet and laser printers to demonstrate the model's ability to separate banding from grain and other artifacts.

6059-16, Session 5

Scanner-based macroscopic color variation estimation

C. Kuo, L. Di, E. K. Zeise, NexPress Solutions, Inc.

Flatbed scanners have been adopted successfully in the measurement of microscopic image artifacts, such as granularity and mottle, in print samples because of their capability of providing full color, high resolution images. Accurate macroscopic color measurement relies on the use of colorimeters or spectrophotometers to provide a surrogate for human vision. The very different color response characteristics of flatbed scanners from any standard colorimetric response limits the utility of a flatbed scanner as a macroscopic color measuring device. This metamerism constraint can be significantly relaxed if our objective is mainly to quantify the color variations within a printed page or between pages where a small bias in measured colors can be tolerated as long as the color distributions relative to the individual mean values is similar. Two scenarios when converting color from the device RGB color space to a standardized color space such as CIE Lab are studied in this paper, blind and semi-blind color transformation, depending on the availability of the black channel information. We will show that both approaches offer satisfactory results in quantifying macroscopic color variation across pages while the semi-blind color transformation further provides fairly accurate color prediction capability.

6059-17, Session 6

Viewing conditions, colorimetric measurements, and profile making: the conundrum of standards vs. practical realities

D. Q. McDowell, Standards Consultant

The standards that define colorimetric measurements (ISO 13655) and viewing conditions (ISO 3664) for graphic arts and photography, and ICC profile building (ISO 15076-1) must all be consistent with each other. More importantly they must be consistent with current industry practice and be technically sound. However, as we begin the process of revising the color measurement and viewing standards we find that that is easier said than done.

A black backing has traditionally been used for both measurement and viewing to minimize the effect of back printing and to be consistent with the black backing specified for densitometry. For profile building the color management community feels that measurements with white backing produce better results. The measurement community wants to compute both density and colorimetry from a single spectral reflectance measurement.

Colorimetric measurements and viewing should match so the same backing needs to be used for viewing and measurement.

Similarly the spectral power distribution of the illuminant needs to match between viewing and measurement. It is virtually impossible to make a measurement source that matches D50 in the UV. However, most papers used for proofing and printing use UV brighteners. Without UV these have no effect.

Joint working groups have been formed by both ISO TC130 and ISO TC42 to find a solution to the conundrum that these issues present to the graphic arts, photographic and color management communities.

6059-18, Session 6

Progress in digital color workflow understanding in the ICC workflow WG

A. L. McCarthy, Lexmark International, Inc. and International Color Consortium

The ICC Workflow WG serves as a bridge between ICC color management technologies and use of those technologies in real world color reproduction applications. ICC color management is applicable to and is used in a wide range of color systems, from highly specialized digital cinema color effects to high volume publications printing to home use photography applications. The ICC Workflow WG works to align ICC technologies so that the color management needs of these diverse use case systems are addressed in an open, platform independent, manner.

Over the past few years, the ICC Workflow WG has worked to formalize an understanding of color imaging and printing workflows. The focus of this presentation is a high level summary of the ICC Workflow WG objectives and work to date, as they impact image quality and color systems performance. Consider the questions, "How much of dissatisfaction with color management today is driven by 'the wrong color transformation at the wrong time' or 'I can't get to the right conversion at the right point in my work processes?'" Put another way, consider how image quality through a workflow can be affected by the coordination and control level of the color management system.

6059-19, Session 6

Recent progress in the development of ISO 19751

S. Farnand, Eastman Kodak Co.; E. N. Dalal, Xerox Corp.; Y. S. Ng, NexPress Solutions, Inc.

A small number of general visual attributes have been recognized as essential in describing image quality. These include micro-uniformity, macro-uniformity, colour rendition, text and line quality, gloss, sharpness, and spatial adjacency or temporal adjacency attributes. The multiple-part International Standard discussed here was initiated by the INCITS W1 committee on the standardization of office equipment to address the need for unambiguously documented procedures and methods, which are widely applicable over the multiple printing technologies employed in office applications, for the appearance-based evaluation of these visually significant image quality attributes of printed image quality. The resulting proposed International Standard, for which ISO/IEC WD 19751-1 presents an overview and an outline of the overall procedure and common methods, is based on a proposal that was predicated on the idea that image quality could be described by a small set of broad-based attributes. Five ad hoc teams were established (now six since a sharpness team is in the process of being formed) to generate standards for one or more of these image quality attributes. Updates on the colour rendition, text and line quality, and gloss attributes are provided.

6059-20, Session 6

ISO 19751 macro-uniformity

R. S. Rasmussen, Xerox Corp.; K. D. Donohue, Univ. of Kentucky; Y. S. Ng, NexPress Solutions, Inc.; W. C. Kress, Toshiba America DSE; S. Zoltner, Xerox Corp.; F. Gaykema, OCE Technologies BV (Netherlands)

The ISO WD 19751 macro-uniformity team works towards the development of a standard for evaluation of perceptual image quality of color printers. The team specifically addresses the types of defects that fall in the category of macro-uniformity, such as streaks, bands and mottle. The first phase of the standard will establish a visual quality ruler for macro-uniformity, using images with simulated macro-uniformity defects. A set of distinct, parameterized defects has been defined, as well as a method of combining the defects into a single image. The quality ruler will be a set of prints with increasing magnitude of the defect pattern. The paper will discuss the creation and printing of the simulated images, as well as initial tests of subjective evaluations using the ruler.

6059-21, Session 7

Edge-raggedness evaluation using slanted-edge analysis

P. D. Burns, Eastman Kodak Co.

The standard ISO 12233 method for the measurement of spatial frequency response (SFR) for digital still cameras and scanners is based on the analysis of slanted-edge image features. The procedure, which applies a form edge-gradient analysis to an estimated edge spread function, requires the automated finding of an edge feature in a digital test image. A frequently considered (e.g., ISO 13660 and 19751) attribute of printed text and graphics is edge raggedness. There are various metrics aimed at the evaluation of the discontinuous imaging of nominally continuous features, but they generally rely on an estimation of the spatial deviation of edge or line boundaries, the tangential edge profile (TEP). In this paper, we describe how slanted-edge analysis can be adapted to the routine evaluation of line and edge quality. After locating and analyzing the edge feature, the TEP is estimated. The estimation of RMS deviation and edge spectrum are described.

6059-22, Session 7

Statistical interpretation of ISO TC42 dynamic range: risky business

D. R. Williams, P. D. Burns, Eastman Kodak Co.

Recently, two ISO electronic imaging standards aimed at digital capture device dynamic range metrology have been issued. Both ISO 15739 (digital still camera noise) and ISO 21550 (film scanner dynamic range) adopt a signal-to-noise ratio (SNR) criterion for specifying dynamic range. The exposure levels that correspond to threshold-SNR values are used as endpoints to determine measured dynamic range. While these thresholds were developed through committee consensus with generic device applications in mind, the methodology of these standards is flexible enough to accommodate different application requirements. This can be done by setting the SNR thresholds according to particular signal-detection requirements. We provide an interpretation of dynamic range that can be related to particular applications based on contributing influences of variance, confidence intervals, and sample size variables. In particular, we introduce the role of the spatial-correlation statistics for both signal and noise sources, not covered in previous discussions of these ISO standards. It is this frequency aspect to dynamic range evaluation that may well influence future standards. This is important when comparing systems with different sampling settings, since the above noise statistics are currently computed on a per-pixel basis.

6059-25, Session 8

The influence of statistical variations on image quality

B. O. Hultgren, D. W. Hertel, Consultant; J. Bullitt, Polaroid Corp.

For more than thirty years imaging scientists have constructed metrics to predict psychovisually perceived image quality. Such metrics are based on a set of objectively measurable basis functions such as Noise Power Spectrum (NPS), Modulation Transfer Function (MTF), and characteristic curves of tone and color reproduction. Although these basis functions constitute a set of primitives that fully describe an imaging system from the standpoint of information theory, we found that in practical imaging systems the basis functions themselves are determined by system-specific primitives, i.e. technology parameters. In the example of a printer MTF and NPS are largely determined by dot structure. In addition MTF is determined by color registration, and NPS by streaking and banding. Since any given imaging system is only a single representation of a class of more or less identical systems, the family of imaging systems and the single system are not described by a unique set of image primitives. For an image produced by a given imaging system, the set of image primitives describing that particular image will be a singular instantiation of the underlying statistical distribution of that primitive. If we know precisely the set of imaging primitives that describe the given image we should be able to predict its image quality. Since only the distributions are known, we can only predict the distribution in image quality for a given image as produced by the larger class of 'identical systems'. We will demonstrate the combinatorial effect of the underlying statistical variations in the image primitives on the objectively measured image quality of a population of printers as well as on the perceived image quality of a set of test images. We also will discuss the choice of test image sets and impact of scene content on the distribution of perceived image quality.

6059-26, Session 8

The use of a virtual printer model for the simulation of imaging systems

B. O. Hultgren, Consultant

A companion paper discusses the impact of statistical variability on perceived image quality. Early in a development program, systems may not be capable of rendering images suitable for quality testing. This does not diminish the program need to estimate the perceived quality of the imaging system. During the development of imaging systems, simulations are extremely effective for demonstrating the visual impact of design choices, allowing both the development process to prioritize these choices and management to understand the risks and benefits of such choices. Where the simulation mirrors the mechanisms of image formation, it not only improves the simulation but also informs the understanding of the image formation process. Clearly the simulation process requires display or printing devices whose quality does not limit the simulation. We will present a generalized methodology. When used with common profile making and color management tools, it will provide simulations of both source and destination devices. The device to be simulated is modeled by its response to a fixed set of input stimuli. In the case of a digital still camera (DSC), these are the reflection spectra of a fixed set of color patches -e.g. the MacBeth DCC, and in the case of a printer, the set of image RGBs. We will demonstrate this methodology with examples of various print media systems.

6059-27, Session 8

Improved pen alignment for bidirectional printing

E. Bernal, J. P. Allebach, Z. Pizlo, Purdue Univ.

The advent of low-cost, photo-quality inkjet printers has raised the need for an objective means of determining print quality that is consistent with what the end-user perceives. The ultimate objective of automated quality assessment processes is to provide the ability to measure a large volume of prints and at the same time, achieve the repeatability and objectivity that visual inspection-based processes lack. While some literature discusses metrics for the objective evaluation of print quality, few of the efforts have combined automated quality tests with subjective assessment. We develop an algorithm for analyzing printed dots and study the effects of the dot characteristics on the perceived print alignment. We demonstrate, via a set of psychophysical experiments, that the human viewer judges alignment of two line segments based on the position at which the edges of the segments reach a certain level of absorbance, rather than on the position of the segment centroids. We also show that the human viewer is less sensitive to changes in alignment as the irregularity of the dots that compose the line segments grows.

6059-28, Session 9

Further image quality assessment in digital film restoration

M. Chambah, Univ. de Reims Champagne-Ardenne (France); C. Saint Jean, Univ. de La Rochelle (France); F. Helt, Independent Consultant (France)

Several digital film restoration techniques have emerged during the last decade and became more and more automated but restoration evaluation still remains a rarely tackled issue. In the sphere of cinema, the image quality is judged visually. In fact, experts and technicians judge and determine the quality of the film images during the calibration (post production) process. As a consequence, the quality of a movie is also estimated subjectively by experts in the field of digital film restoration.

On the other hand, objective quality metrics do not necessarily correlate well with perceived quality. Plus, some measures assume that there exists a reference in the form of an "original" to compare to, which prevents their usage in digital restoration field, where often there is no reference to compare to. That is why subjective evaluation is the most used and most efficient approach up to now. But subjective assessment is expensive, time consuming and does not respond, hence, to the economic requirements. After presenting the several defects that can affect cinematographic material, and the film digital restoration field, we present in this paper the issues of image quality evaluation in the field of digital film restoration and suggest some reference free objective measures.

6059-29, Session 9

Development of picture quality monitoring system for IPTV service based on the reduced reference framework

O. Sugimoto, R. Kawada, A. Koike, KDDI R&D Labs. (Japan)

With the rapid spread of high speed Internet access lines such as ADSL and FTTH, various novel network applications have been presented recently. IPTV (Internet Protocol based Television) service is one of these novel network applications. IPTV service has the advantage of offering lower cost broadcasting service via a high speed and low-cost Internet access line; however, it also has a

disadvantage in that picture quality degradation is caused by quality degradation of the transmission line such as IP packet loss. From the standpoint of application service providers, it is important to constantly monitor picture quality degradation to comprehend user level QoS and thus the demand for technologies and systems that enable automatic picture quality measurement has been increasing recently.

The Reduced Reference (RR) method is especially effective among the currently available frameworks for picture quality assessment. The RR method is a framework for objective picture quality measurement that extracts image features from the baseband signal of the transmitted and received pictures and transmits them to a remote monitoring facility to compare the transmitted image features. This framework is being endorsed by ITU study groups and is currently under study for standardization. We previously studied a method to estimate the objective picture quality of PSNR based on the RR framework. The proposed method utilizes spread spectrum and orthogonal transform to extract image features and enables PSNR estimation with 0.984 correlation coefficient just by extracting image features at a rate of 320bit/frame (corresponding to a data channel's bitrate of 9.6kbps) from transmitted and received pictures. This shows the proposed method has sufficient estimation accuracy to monitor the picture quality of IPTV services.

In this paper, we attempt to prove the effectiveness of the proposed method by developing a system based on the previous study and monitoring objective picture quality of the commercial IPTV service. As the contents delivery network (CDN) for the target IPTV service consists of connections of certain numbers of ring networks and the broadcasting contents are transmitted by IP Multicast, the picture quality on each receiver (user) side is different; it depends on the quality of the network route, i.e. packet loss rate at the users' terminal. Therefore, the proposed system monitors frame-by-frame PSNR between the sender side and a number of receivers simultaneously and the network operators are alerted when a transmission failure occurs.

One of the advantages of the proposed system is that the proposed system reduces computational complexity by the method shown in the previous study and can be entirely implemented by PC software. This means the system can run in real time without any additional hardware whereas most of the existent picture quality assessment methods do not consider real-time operation.

In this paper, we first describe the method to estimate PSNR based on the previous study and then describe the configuration of the proposed system. Finally, the results of the experiment, which continuously monitors the PSNR of the transmitted pictures at four different receiver points over 48 hours, are presented to demonstrate the effectiveness of the proposed system.

6059-30, Session 9

An image quality evaluation method for DOE-based camera lenses

S. Lee, Y. Jin, H. Jeong, Samsung Electro-Mechanics Co., Ltd. (South Korea); S. Song, Hanyang Univ. (South Korea)

A novel image quality evaluation method based on the rigorous grating diffraction theory and the ray-optic method is proposed and is applied for design optimization and tolerance analysis of DOE-based optical imaging system. First, diffraction efficiencies for various diffracted orders were calculated for RGB wavelengths. Secondly, a virtual resolution chart was generated to form an object and the output image was obtained by the CODE V(tm). The final image was obtained by summation of all images obtained above weighted by their diffraction efficiencies. Effects of fabrication errors such as the profile thickness and the shoulder on image quality are shown to be effectively predicted by this method. A DOE-based 2M-resolution phone-camera lens module shows ~15% MTF

improvement compared with a design through CODE V(tm) without such an optimization. Additional analysis shows ~12% degradation in MTF for the 150 lp/mm with a 6 micron shoulder length for the lens module.

6059-32, Session 10

Visibility and annoyance of LCD defective subpixels of different colors and surrounds at different positions

H. Ho, J. M. Foley, S. K. Mitra, Univ. of California/Santa Barbara

In this study we investigate the visibility and annoyance of simulated defective sub-pixels in a liquid crystal display (LCD). We carried out a psychophysical experiment to examine the effects of four variables: surround luminance, surround type, defect sub-pixel color and defect-pixel position. The stimulus was a rectangular image containing one centered object with a gray surround and a single defective pixel. The surround was either uniform gray or a gray-level texture. The target was a simulated discolored pixel with one defective sub-pixel (green, red or blue) and two normally functioning sub-pixels. On each trial, it was presented at a random position. Subjects were asked to indicate if they saw a defective pixel, and if so, where it was located and how annoying it was. For uniform surrounds, our results show that detection probability falls slowly for green, faster for red, and fastest for blue as background luminance increases. When detection probability is plotted against luminance contrast green defective pixels are still most detectable, then red, then blue. Mean annoyance value falls faster than detection probability as background luminance increases, but the trends are the same. A textured surround greatly reduces the detection probability of all defective pixels. Still, green and red are more detectable than blue. With the textured surround the mean annoyance tends to remain high even when detection probability is quite low. For both types of surrounds, probability of detection is least for targets in the bottom region of the image.

6059-33, Session 10

Robust detection of defects in imaging arrays

J. Dudas, C. G. Jung, G. H. Chapman, Simon Fraser Univ. (Canada); Z. Koren, I. Koren, Univ. of Massachusetts/Amherst

As digital imagers continue to increase in size and pixel density, the detection of faults in the field becomes critical to delivering high quality output. Traditional schemes for defect detection utilize specialized hardware at the time of manufacture and are impractical for use in the field, while previously proposed software-based approaches tend to lead to quality-degrading false positive diagnoses. This paper presents an algorithm that utilizes statistical information extracted from a sequence of normally captured images to identify the location and type of defective pixels. Building on previous research, this algorithm utilizes data local to each pixel and Bayesian statistics to more accurately infer the likelihood of each defect, which successfully improves the detection time. Several defect types are considered, including pixels with one-half of the typical sensitivity and permanently stuck pixels. Monte Carlo simulations have shown that for defect densities of up to 0.5%, 50 ordinary images are sufficient to accurately identify all faults without falsely diagnosing good pixels as faulty. Testing also indicates that the algorithm can be extended to higher resolution imagers and to those with noisy stuck pixels, with only minimal cost to performance.

6059-34, Session 10

Objective video quality assessment method for freeze distortion based on freeze aggregation

K. Watanabe, J. Okamoto, T. Kurita, NTT Service Integration Labs. (Japan)

With the development of the broadband network, video communications such as videophone, video distribution, and IPTV services are beginning to become common. In order to provide these services appropriately, we must manage them based on subjective video quality, in addition to designing a network system based on it. Currently, subjective quality assessment is the main method used to quantify video quality. However, it is time-consuming and expensive. Therefore, we need an objective quality assessment technology that can estimate video quality from video characteristics effectively. Video degradation can be categorized into two types: spatial and temporal. Objective quality assessment methods for spatial degradation have been studied extensively, but methods for temporal have hardly been examined even though it occurs frequently due to network degradation and has a large impact on subjective quality. In this paper, we propose an objective quality assessment method for temporal. Our approach is to aggregate multiple freeze distortions into an equivalent freeze distortion and then derive the objective video quality from the equivalent freeze distortion. We also propose a method using the perceptual characteristics of short freeze distortions. We verified that our method can estimate the objective video quality well within the deviation of subjective video quality.

6059-35, Session 10

Film grain synthesis and its applications for re-graining

P. Schallauer, R. Mörzinger, JOANNEUM RESEARCH GmbH (Austria)

Digital film restoration and special effects compositing require more and more automatic procedures for movie re-graining. Missing or inhomogeneous grain decreases perceived quality. For the purpose of grain synthesis an existing texture synthesis algorithm has been evaluated and optimized. We show that this algorithm can produce synthetic grain which is perceptually similar to a given grain template, which has high spatial and temporal variation and which can be applied to multi-spectral images. Furthermore a re-grain application framework is proposed, which synthesises based on an input grain template artificial grain and composites this together with the original image content. Due to its modular approach this framework supports manual as well as automatic re-graining applications. Two example applications are presented, one for re-graining an entire movie and one for fully automatic re-graining of image regions produced by restoration algorithms. Low computational cost of the proposed algorithms allows application in industrial grade software.

Monday-Tuesday 16-17 January 2006

Part of Proceedings of SPIE Vol. 6060 Visualization and Data Analysis 2006

6060-01, Session 1

Multiscale image based flow visualization

A. C. Telea, Technische Univ. Eindhoven (Netherlands); R. Strzodka, Research Ctr. Caesar (Germany)

We present MIBFV, a method to produce real-time, multiscale animations of flow datasets. MIBFV extends the attractive features of the Image-Based Flow Visualization (IBFV) method, i.e. dense flow domain coverage with flow-aligned noise, real-time animation, implementation simplicity, and few (or no) user input requirements, to a multiscale dimension. We generate a multiscale of flow-aligned patterns using an algebraic multigrid method and use them to synthesize the noise textures required by IBFV. We demonstrate our approach with animations that combine multiple scale noise layers, in a global or level-of-detail manner.

6060-02, Session 1

Visualizing oceanic and atmospheric flows with streamline splatting

Y. Sun, E. Ess, D. Sapirstein, M. Huber, Purdue Univ.

The investigation of the climate system is one of the most exciting areas of scientific research today. In the climate system, oceanic and atmospheric flows play a critical role. Because these flows are very complex in the span of temporal and spatial scales, effective computer visualization techniques are crucial to the analysis and understanding of the flows. However, the existing techniques and software are not sufficient to the demand of visualizing oceanic and atmospheric flows. In this paper, we use a new technique called streamline splatting to visualize 3D flows. This technique integrates streamline generation with the splatting method of volume rendering. It first generates segments of streamlines and then projects and splats the streamline segments onto the image plane. The projected streamline segments can be represented using a Hermite parametric model. Splatted curves are achieved by applying a Gaussian footprint function to the projected streamline segments and the results are blended together. Thus the user can see through a volumetric flow field and obtain a 3D representation view in one image. This work has potential to be further developed into visualization software for regular PC workstations to help researchers explore and analyze climate flows.

6060-03, Session 1

View-dependent multiresolutional flow texture advection

L. Li, H. Shen, The Ohio State Univ.

Existing texture advection techniques will produce unsatisfactory rendering results when there is a discrepancy between the resolution of the flow field and that of the output image. This is because many existing texture advection techniques such as Line Integral Convolution (LIC) are inherently none view-dependent, that is, the resolution of the output textures depends only on the resolution of the input field, but not the resolution of the output image. When the resolution of the flow field after projection is much higher than the screen resolution, aliasing will happen unless the flow textures are appropriately filtered through some expensive post processing. On the other hand, when the resolution of the flow field is much lower than the screen resolution, a blocky or blurred appearance will be present in the rendering because the flow texture does not have enough samples. In this paper we present a view-dependent multiresolutional flow texture advection method for structured recti- and curvi-linear meshes. Our algorithm is based on a novel intermediate representation of the flow field, called trace slice, which allows us to compute the flow texture at a desired resolution

interactively based on the run-time viewing parameters. As the user zooms in and out of the field, the resolution of the resulting flow texture will adapt automatically so that enough flow details will be presented while aliasing is avoided. Our implementation utilizes mipmapping and programmable GPUs available on modern programmable graphics hardware.

6060-04, Session 2

Volumetric depth peeling for medical image display

D. M. Borland, J. P. Clarke, J. R. Fielding, R. M. Taylor II, The Univ. of North Carolina at Chapel Hill

Volumetric depth peeling (VDP) is an extension to volume rendering that enables display of otherwise occluded features in volume data sets. VDP decouples occlusion calculation from the volume rendering transfer function, enabling independent optimization of settings for rendering and occlusion. The algorithm is flexible enough to handle multiple regions occluding the object of interest, as well as object self-occlusion, and requires no pre-segmentation of the data set. VDP was developed as an improvement for virtual arthroscopy for the diagnosis of joint trauma, and has been generalized for use in non-invasive urology studies. In virtual arthroscopy, the surfaces in the joints often occlude each other, allowing limited viewpoints from which to evaluate these surfaces. In urology studies, the physician would like to position the virtual camera outside the kidney collecting system and see inside it. By rendering invisible all voxels between the observer's point of view and objects of interest, VDP enables viewing from unconstrained positions. Radiologists using VDP display have been able to perform evaluations of pathologies more easily and more rapidly than with clinical arthroscopy, standard volume rendering, or standard MRI/CT slice viewing.

6060-05, Session 2

Adaptive border sampling for hardware texture-based volume visualization

E. C. LaMar, Institute for Scientific Research, Inc.

We introduce a technique to properly sample volume boundaries in hardware texture-based Volume Visualization. Prior techniques render a volume with a set of uniformly-spaced proxy geometries that sample (and represent) a set of uniform-depth slices. While this is sufficient for the core of a volume, it does not consider a sample's *partial* overlap at the boundaries of a volume; and this failing can lead to significant artifacts at these boundaries. Our technique computes the non-unit depth contributions of the volume at the boundaries. We use fragment programs to compute the partial sample contributions and to match sampling-planes at the volume boundaries to the sampling geometry in the core of the volume.

6060-06, Session 2

Ray-casting time-varying volume data sets with frame-to-frame coherence

D. Tost, S. Grau, Univ. Politècnica de Catalunya (Spain); M. Ferre, Univ. Rovira i Virgili (Spain); A. Puig, Univ. de Barcelona (Spain)

The goal of this paper is the proposal and evaluation of a ray-casting strategy for time-varying volume data, that takes advantage of the spatial and temporal coherence in image-space as well as in object-space in order to speed up rendering. The proposed algorithm is based on a double structure: in image-space, a temporal buffer that stores for each pixel the next instant of time in which the pixel must be recomputed and, in object-space, a Temporal Run-Length Encoding of the voxel values through time.

The algorithm skips empty and unchanged pixels through three different space-leaping strategies. It can compute the images sequentially in time or generate them simultaneously in batch. In addition, it can handle simultaneously several data modalities. Finally, an on-purpose out-of-core strategy is used to handle large datasets. The tests performed on two medical datasets and various phantom datasets show that the proposed strategy significantly speeds-up rendering.

6060-07, Session 3

Theoretical analysis of uncertainty visualizations

T. D. Zuk, M. S. T. Carpendale, Univ. of Calgary (Canada)

Although a number of theories and principles have been developed to guide the creation of visualizations, it is not always apparent how to apply the knowledge in these principles. We describe the application of perceptual and cognitive theories for the analysis of uncertainty visualizations. General principles from Bertin, Tufte, and Ware are outlined and then applied to the analysis of eight different uncertainty visualizations. The theories provided a useful framework for analysis of the methods, and provided insights into the strengths and weaknesses of various aspects of the visualizations.

6060-08, Session 3

A visualization framework for design and evaluation

B. J. Blundell, S. Pettifer, The Univ. of Manchester (United Kingdom); G. Ng, Cerebra, Inc.

The creation of compelling visualisation paradigms is a craft often dominated by intuition and issues of aesthetics, with relatively few models to support good design. The majority of problem cases are approached by simply applying a previously evaluated visualisation technique. A large body of work exists covering the individual aspects of visualisation design such as the human cognition aspects visualisation methods for specific problem areas, psychology studies and so forth, yet most frameworks regarding visualisation are applied after-the-fact as an evaluation measure.

We present an extensible framework for visualisation aimed at structuring the design process and increase decision traceability, delineating the notions of function, aesthetics and usability. The framework can be used to deriving a set of requirements for good visualisation design, and evaluating existing visualisations, presenting possible improvements. Our framework achieves this by being both broad and general, built on top of existing works, with hooks for extensions and customizations. This paper shows how existing theories of information visualisation fit into the scheme, share our experience in the application of this framework on several designs, and offering our evaluation of the framework and the designs studied.

6060-09, Session 4

Visual analytics and the NVAC

P. C. Wong, Pacific Northwest National Lab.

No abstract available

6060-10, Session 5

Maximum entropy lighting for physical objects

T. Malzbender, E. Ordentlich, Hewlett-Packard Labs.

This paper presents a principled method for choosing informative lighting directions for physical objects. An ensemble of images of an

object or scene is captured, each with a known, predetermined lighting direction. Diffuse reflection functions are then estimated for each pixel across such an ensemble. Once these are estimated, the object or scene can be interactively relit as it would appear illuminated from an arbitrary lighting direction. We present two approaches for evaluating images as a function of lighting direction. The first uses image compressibility evaluated across a grid of samples in lighting space. Two compression techniques are evaluated, the first being Huffman encoding, the second being JPEG-LS. Highly compressible images using either algorithm have low information content, and lighting directions associated with these images fail to be informative. The second approach for choosing lighting directions uses image variance and prediction error variance, which are monotonically related to compressibility for Gaussian distributions. The advantage of the variance approach is that both image variance and prediction error variance can be analytically derived from the scene reflection functions, and evaluated at the rate of a few nanoseconds per lighting direction.

6060-11, Session 5

Pre-computed illumination for isosurfaces

K. M. Beason, Florida State Univ.; J. Grant, Pixar Animation Studios; D. C. Banks, B. Futch, M. Y. Hussaini, Florida State Univ.

Commercial software systems are available for displaying isosurfaces (also known as level sets, implicit surfaces, varieties, membranes, or contours) of 3D scalar-valued data at interactive rates, allowing a user to browse the data by adjusting the isovalue. We present a technique for applying global illumination to the resulting scene by pre-computing the illumination for level sets and storing it in a 3D illumination grid. The technique permits globally illuminated surfaces to be rendered at interactive rates on an ordinary desktop computer with a 3D graphics card. We demonstrate the technique on datasets from magnetic resonance imaging (MRI) of the human brain, confocal laser microscopy of neural tissue in the mouse hippocampus, computer simulation of a Lennard-Jones fluid, and computer simulation of a neutron star.

6060-12, Session 5

Retro-rendering with vector-valued light: producing local illumination from the transport equation

D. C. Banks, K. M. Beason, Florida State Univ.

We demonstrate that local illumination (without shadows or inter-reflections) can be interpreted as the correct solution to the equation for light transport by offering a novel interpretation of luminaire emittance and surface reflectance.

6060-13, Session 6

Bit-plane based analysis of integer wavelet coefficients for image compression

A. F. Abu-Hajar, Digitavid, Inc.

This paper presents bit-plane based statistical study for integer wavelet transforms commonly used in image compression. In each bit-plane, the coefficients were modeled as binary random variables. Experimental results indicate the probability of the significant coefficients (P_1), in each bit-plane, monotonically increases from $P_1 \approx 0$ at the most significant bits (MSB) to $p_1 \approx 0.5$ at the least significant bits (LSB). Then, a parameterized model to predict p_1 from the MSB to the LSB was proposed. Also, the correlation among the different bit-planes within the same coefficient was investigated. In addition, this study showed correlation of the significant coefficients in the same spatial orientation among different subbands. Finally, clustering within the each subband and across the different subband with the same spatial orientation was

investigated. Our results show strong correlation of previously coded significant coefficients at higher levels and the significant coefficients in future passes at lower levels. The overall study of this paper is useful in understanding and enhancing existing wavelet-based image compression algorithms such as SPIHT and EBC.

6060-14, Session 6

Two-dimensional reduction PCA: a novel approach for feature extraction, representation, and recognition

R. M. Mutelo, W. L. Woo, S. S. Dlay, Univ. of Newcastle Upon Tyne (United Kingdom)

Recently, an image based technique coined two-dimensional principal component analysis (2DPCA) was developed for image representation and recognition. Although 2DPCA is superior to PCA in terms of computational efficiency for feature extraction and recognition accuracy, 2DPCA-based image representation is not as efficient as PCA in terms of storage requirements, since 2DPCA requires more coefficients for image representation than the feature vector for PCA. Our work shows that the feature matrix for 2DPCA has very little noise and a redundancy between its columns and the relevant data is compressed within a few columns. Therefore the noise and redundancy between the feature matrix rows still exist leading not only a large storage requirement but also to poor classification accuracy and large classification time. Therefore, we design a sequential optimal compression mechanism which eliminating redundancies and noise in two directions, rows and columns. Thus resulting in computational efficient, greater recognition accuracy, more efficient memory storage and lastly reduced classification time. The superiority of our algorithm is further demonstrated by the experimental results conducted on the ORL face database where an accuracy of 95.0% using a 9 by 5 for the proposed and 93.0% using 112 by 7 for 2DPCA.

6060-15, Session 7

Energetically optimal travel across terrain: visualizations and a new metric of geographic distance with archaeological applications

B. Wood, Harvard Univ.; Z. Wood, California Polytechnic State Univ.

We present a visualization and computation tool for modeling the caloric cost of pedestrian travel across three dimensional terrains. This tool is being used in ongoing archaeological research that analyzes how costs of locomotion affect the spatial distribution of trails and artifacts across archaeological landscapes. Throughout human history, traveling by foot has been the most common form of transportation, and therefore analyses of pedestrian travel costs are important for understanding prehistoric patterns of resource acquisition, migration, trade, and political interaction. Traditionally, archaeologists have measured geographic proximity based on "as the crow flies" distance. We propose new methods for terrain visualization and analysis based on measuring paths of least caloric expense, calculated using well established metabolic equations. Our approach provides a human centered metric of geographic closeness, and overcomes significant limitations of available Geographic Information System (GIS) software. We demonstrate such path computations and visualizations applied to archaeological research questions. Our system includes tools to visualize: energetic cost surfaces, comparisons of the elevation profiles of shortest paths versus least cost paths, and the display of paths of least caloric effort on Digital Elevation Models (DEMs). These analysis tools can be applied to calculate and visualize 1) likely locations of prehistoric trails and 2) expected ratios of raw material types to be recovered at archaeological sites.

6060-16, Session 7

Real-time 3D visualization of DEM combined with a robust DCT-based data-hiding method

A. Martin, Univ. Montpellier II (France); G. Gesquiere, Univ. de Provence (France); W. Puech, Univ. Montpellier II (France); S. Thon, Univ. de Provence (France)

Using aerial photography, satellite imagery, scanned maps and Digital Elevation Models implies to make storage and visualization strategy choices.

To obtain a three dimensional visualization, we have to link these images called texture with the terrain geometry named Digital Elevation Model.

These information are usually stored in three different files (One for the DEM, one for the texture and one for the geo-referenced coordinates). In this paper we propose to store these information in only one file.

In order to solve this problem, we present a technique for color data hiding of images, based on DC components of the DCT-coefficients. In our application the images are the texture, and the elevation data are hidden in each block. This method mainly protects against JPEG compression and cropping.

6060-17, Session 8

Hierarchical causality explorer: making complementary use of 3D/2D visualizations

S. Azuma, Ochanomizu Univ. (Japan); I. Fujishiro, Tohoku Univ. (Japan); H. Horii, The Univ. of Tokyo (Japan)

Hierarchical causality relationships reside ubiquitously in the reality. Since the relationships take intricate forms with two kinds of links — hierarchical abstraction and causal association, there exists no single visualization style that allows the user to comprehend them effectively. This paper introduces a novel information visualization framework which can change existing 3D and 2D display styles interactively according to the user's visual analysis demands. The two visualization styles play a complementary role, and the change in the style relies on morphing so as to maintain the user's cognitive map. Based on this framework, we have developed a general-purpose prototype system, which provides the user with an enriched set of functions not only for supporting fundamental information seeking, but bridging analytic gaps to accomplishing high-level analytic tasks such as knowledge discovery and decision making. The effectiveness of the system is illustrated with an application to the analysis of a nuclear-hazard cover-up problem.

6060-18, Session 8

InvIncrements: incremental software to support visual simulation

D. C. Banks, W. Blanco, Florida State Univ.

We describe a set of incremental software modules, based on Open Inventor, that support an interdisciplinary course in interactive 3D simulation.

6060-19, Session 9

Plot of plots and selection glass

H. Chen, SAS Institute Inc.

Modern dynamic data visualization environments often feature complex displays comprised of many interactive components, such as plots, axes, and others. These components typically contain attributes or properties that can be manipulated programmatically or

interactively. Component property manipulation is usually a two-stage process. The user first selects or in some way identifies the component to be revised and then invokes some other technique or procedure to modify the property of interest. Until recently, components typically have been manipulated one at a time, even if the same property is being modified in each component. How to effectively select multiple components interactively in multiple-view displays remains an open issue.

This paper proposes modeling the display components with conventional data sets and reusing simple dynamic graphics, such as a scatter plot or a bar chart, as the graphical user interface to select these elements. This simple approach, called plot of plots, provides a uniform, flexible, and powerful scheme to select multiple display components. In addition, another approach called selection glass is also presented. The selection glass is a tool glass with click-on and click-through selection tool widgets for the selection of components. The availability of the plot of plots and selection glass provides a starting point to investigate new techniques to simultaneously modify the same properties on multiple components.

6060-20, Session 9

Navigation techniques for large-scale astronomical exploration

C. Fu, The Hong Kong Univ. of Science and Technology (Hong Kong China); A. J. Hanson, E. A. Wernert, Indiana Univ.

Navigating effectively in virtual environments at human scales is a difficult problem. However, it is even more difficult to navigate in large-scale virtual environments such as those simulating the physical Universe; the huge spatial range of astronomical simulations and the dominance of empty space make it hard for users to acquire reliable spatial knowledge of astronomical contexts. This paper introduces a careful combination of navigation and visualization techniques to resolve the unique problems of large-scale real-time exploration in terms of travel and wayfinding. For large-scale travel, spatial scaling techniques and constrained navigation manifold methods are adapted to the large spatial scales of the virtual Universe. We facilitate large-scale wayfinding and context awareness using visual cues such as power-of-10 reference cubes, continuous exponential zooming into points of interest, and a scalable world-in-miniature (WIM) map. These methods enable more effective exploration and assist with accurate context-model building, thus leading to improved understanding of virtual worlds in the context of large-scale astronomy.

6060-21, Session 10

Reducing InfoVis cluttering through non uniform sampling, displacement, and user perception

E. Bertini, G. Santucci, L. Dell'Aquila, Univ. degli Studi di Roma/La Sapienza (Italy)

Clutter affects almost any kind of visual technique and can obscure the structure present in the data even in small datasets, making it hard for users to find patterns and reveal relationships. In this paper we present a general strategy to analyze and reduce clutter using a special kind of sampling, together with an ad-hoc displacement technique and perceptual issues collected through a user study. The method, defined for 2D scatter plots, is flexible enough to be used in quite different contexts. In particular, in this paper we prove its usefulness against scatter plot, radviz, and parallel coordinates visualizations.

6060-22, Session 10

Diverse information integration and visualization

S. L. Havre, A. R. Shah, C. Posse, B. M. Webb-Robertson, Pacific Northwest National Lab.

This paper presents and explores a technique for visually integrating and exploring diverse information. Researchers and analysts seeking knowledge and understanding of complex systems have increasing access to related, but diverse, data. These data provide an opportunity to simultaneously analyze entities of interest from multiple informational perspectives through the integration of diverse but related data. Our approach visualizes an entity set across multiple perspectives; each is an alternate partitioning of the entity set. The partitioning may be based on inherent or assigned attributes such as meta-data or prior knowledge. The partitioning may also be derived directly from entity data, for example, through unsupervised classification, or clustering. The same entities may be clustered on data from different experiment types or processing approaches. This reduction of diverse data/information on an entity to a series of partitions, or discrete (and unit-less) categories, allows the user to view the entities across diverse data without concern for data types and units. Parallel coordinate plots typically visualize continuous data across multiple dimensions. We adapt parallel coordinate plots for discrete values such as partition names to allow comparison of entity patterns across multiple dimensions to identify trends and outlier entities. We illustrate this approach through a prototype.

6060-23, Session 10

WordSpace: visual summary of text corpora

U. Brandes, M. Hofer, J. Lerner, Univ. of Konstanz (Germany)

In recent years several well-known approaches to visualize the topical structure of a document collection have been proposed. Most of them feature spectral analysis of a term-document matrix with influence values and dimensionality reduction. We generalize this approach by arguing that there are many reasonable ways to project the term-document matrix into low-dimensional space in which different features of the corpus are emphasized. Our main tool is a continuous generalization of adjacency-respecting partitions called structural similarity. In this way we obtain a generic framework in which influence weights in the term-document matrix, dimensionality-reducing projections, and the display of a target subspace may be varied according to nature of the text corpus.

6060-24, Session 11

Information architecture: why design matters

J. Agutter, Univ. of Utah

No abstract available

6060-25, Session 12

Trees in a treemap: visualizing multiple hierarchies

M. Burch, S. Diehl, Katholische Univ. Eichstätt (Germany)

This paper deals with the visual representation of a particular kind of structured data: trees where each node is associated with an object (leaf node) of a taxonomy. We introduce a new visualization technique that we call Trees in a Treemap. In this visualization edges can either be drawn as straight or orthogonal edges. We compare our technique with several known techniques. To demonstrate the

usability of our visualization techniques, we apply them to two kinds of real world data: software project data and network routing data. We show both patterns and anomalies which can be found by using our visualization. To improve the readability of the graphical representation we use different color codings for nodes and edges. Furthermore we try to minimize the number of edge crossings, the number of edge direction changes and the length of the edges, three contrary goals.

6060-26, Session 12

Focus-based filtering + clustering technique for power-law networks with small world phenomenon

F. Boutin, J. Thièvre, M. Hascoët, Univ. Montpellier II (France) and CNRS (France)

Realistic interaction networks usually present two main properties: power-law degree distribution and small world behaviour. Few nodes are linked to many nodes and adjacent nodes are likely to share common neighbours. Moreover, graph structure usually presents a dense core that is difficult to explore with classical filtering and clustering techniques. In this paper, we propose a new filtering technique that takes into account a user-focus. This technique extracts a tree-like graph that also has power-law degree distribution and small world behaviour. Resulting structure is easily drawn with classical force-directed drawing algorithms. It is also quickly organised and displayed into a nested tree of clusters from any user-focus. We built a new graph filtering + clustering + drawing API and report a case study.

6060-27, Session 12

Enhancing scatterplot matrices for data with ordering or spatial attributes

Q. Cui, M. O. Ward, E. A. Rundensteiner, Worcester Polytechnic Institute

The scatterplot matrix is one of the most common methods used to project multivariate data onto two dimensions for display. While each off-diagonal plot maps a pair of non-identical dimensions, there is no prescribed mapping for the diagonal plots. In this paper, histograms, 1D plots and 2D plots are drawn in the diagonal plots of the scatterplots matrix. In 1D plots, the data are assumed to have order, and they are projected in this order. In 2D plots, the data are assumed to have spatial information, and they are projected onto locations based on these spatial attributes using color to represent the dimension value. The plots and the scatterplots are linked together by brushing. Brushing on these alternate visualizations will affect the selected data in the regular scatterplots, and vice versa. Users can also navigate to other visualizations, such as parallel coordinates and glyphs, which are also linked with the scatterplot matrix by brushing. Ordering and spatial attributes can also be used as methods of indexing and organizing data. Users can select an ordering span or a spatial region by interacting with 1D plots or with 2D plots, and then observe the characteristics of the selected data subset. 1D plots and 2D plots provide the ability to explore the ordering and spatial attributes, while other views are for viewing the abstract data. In a sense, we are linking what are traditionally seen as scientific visualization methods with methods from the information visualization and statistical graphics fields. We validate the usefulness of this integration by providing two case studies, time series data analysis and spatial data analysis.

6060-28, Session 13

Content-based text mapping using multidimensional projections for exploration of document collections

R. Minghim, F. V. Paulovich, A. de Andrade Lopes, Univ. de São Paulo (Brazil)

This paper presents a technique for generation of maps of documents targeted at placing similar documents in the same neighborhood. As a result, besides being able to group (and separate) documents by their contents, it runs at very manageable computational costs. Based on multi-dimensional projection techniques and an algorithm for projection improvement, it results in a surface map that allows the user to identify a number of important relationships between documents and sub-groups of documents via visualization and interaction. Visual attributes such as height, color, isolines and glyphs as well as aural attributes (such as pitch), help add dimensions for integrated visual analysis. Exploration and narrowing of focus can be performed using a set of tools provided. This novel text mapping technique, named IDMAP (Interactive Document Map), is fully described in this paper. Results are compared with dimensionality reduction and cluster techniques for the same purposes. The maps are bound to support a large number of applications that rely on retrieval and examination of document collections and to complement the type of information offered by current knowledge domain visualizations.

6060-29, Session 13

Mapping texts through dimensionality reduction and visualization techniques for interactive exploration of document collections

A. d. A. de Andrade Lopes, R. Minghim, V. Melo, F. V. Paulovich, Univ. de São Paulo (Brazil)

This paper presents a methodology to create a meaningful graphical representation of documents corpora targeted at supporting exploration of correlated documents. The purpose of such an approach is to produce a map from a document body on a research topic or field based on the analysis of their contents, and similarities amongst articles. The document map is generated, after text pre-processing, by projecting the data in two dimensions using Latent Semantic Indexing. The projection is followed by hierarchical clustering to support sub-area identification. The map can be interactively explored, helping to narrow down the search for relevant articles. Tests were performed using a collection of documents pre-classified into three research subject classes: Case-Based Reasoning, Information Retrieval, and Inductive Logic Programming. The map produced was capable of separating the main areas and approaching documents by their similarity, revealing possible topics, and identifying boundaries between them. The tool can deal with the exploration of inter-topics and intra-topic relationship and is useful in many contexts that need deciding on relevant articles to read, such as scientific research, education, and training.

6060-30, Session 14

Visualizing brain rhythms and synchrony

K. A. Robbins, D. Veljkovic, E. Pilipaviciute, The Univ. of Texas at San Antonio

Patterns of synchronized brain activity have been widely observed in EEGs and multi-electrode recordings, and much study has been devoted to understanding their role in brain function. We introduce

the problem of visualization of synchronized behavior and propose visualization techniques for assessing temporal and spatial patterns of synchronization from data. We discuss spike rate plots, activity succession diagrams, space-time activity band visualization, and low-dimensional projections as methods for identifying synchronized behavior in populations of neurons and for detecting the possibly short-lived neuronal assemblies that produced them. We use wavelets conjunction with these visualization techniques to extract the frequency and temporal localization of synchronized behavior. Most of these techniques can be streamed, making them suitable for analyzing long-running experimental recordings as well as the output of simulation models. The visualizations shown in this paper have been implemented in DAVIS (Data Viewing System: <http://visual.cs.utsa.edu/research/Davis/index.html>), visualization software that supports a large number of simultaneous synchronized views of data with different sampling rates. The results of this paper show the usefulness of visualization in studying synchronization of neuronal populations on the order of a thousand neurons. Wavelet-based spatial multiscale techniques may also be useful in tackling larger populations.

6060-31, Session 14

Automatic feature-based surface mapping for brain cortices

L. Linsen, Ernst Moritz Arndt Univ. Greifswald (Germany)

We present a method that maps a complex surface geometry to an equally complicated, similar surface. One main objective of our effort is to develop technology for automatically transferring surface annotations from an atlas brain to a subject brain. While macroscopic regions of brain surfaces often correspond, the detailed surface geometry of corresponding areas can vary greatly. We have developed a method that simplifies a subject brain's surface forming an abstract yet spatially descriptive point cloud representation, which we can match to the abstract point cloud representation of the atlas brain using an approach that iteratively improves the correspondence of points. The generation of the point cloud from the original surface is based on surface smoothing, surface simplification, surface classification with respect to curvature estimates, and clustering of uniformly classified regions. Segment mapping is based on spatial partitioning, principal component analysis, rigid affine transformation, and warping based on the thin-plate spline (TPS) method. The result is a mapping between topological components of the input surfaces allowing for transfer of annotations.

6060-32, Poster Session

Blogviz: mapping the dynamics of information diffusion in blogspace

M. S. Lima, Parsons School of Design

Blogviz is a visualization model for mapping the transmission and internal structure of top links across the blogosphere. It explores the idea of meme propagation by assuming a parallel with the spreading of most cited URLs in daily weblog entries.

The main goal of Blogviz is to unravel hidden patterns in the topics diffusion process. What's the life cycle of a topic? How does it start and how does it evolve through time? Are topics constrained to a specific community of users? Who are the most influential and innovative blogs in any topic? Are there any relationships amongst topic proliferators?

6060-33, Poster Session

Organizing and visualizing database data using parallel coordinates

C. G. Presser, Gettysburg College

In this paper, we describe a data organization and axis grouping technique for managing parallel coordinate plots. A database visualization model is created as an intermediary between the data and the visualization. On the visualization side, axes within a parallel coordinate plot are put into groups which can be represented by a new axis in the plot, while the members of the group are hidden. Methods are presented for building these groups and displaying their axes, each with their own advantages and disadvantages. Lastly, a working system which uses these techniques to visualize data from a database is presented.

6060-35, Poster Session

Visualizing 3D vector fields with splatted streamlines

E. Ess, Y. Sun, Purdue Univ.

We present a novel technique called streamline splatting to visualize 3D vector fields interactively. This technique integrates streamline generation with the splatting method of volume rendering. The key idea is to create volumetric streamlines using geometric streamlines and a kernel footprint function. To optimize the rendering speed, we represent the volumetric streamlines in terms of a series of slices perpendicular to the principal viewing direction. Thus 3D volume rendering is achieved by blending all slice textures with support of graphics hardware. This approach allows the user to visualize 3D vector fields interactively such as by rotation and zooming on regular PCs. This new technique may lead to better understanding of complex structures in 3D vector fields.

6060-36, Poster Session

SRS browser: a visual interface to the sequence retrieval system

K. K. Mane, K. Borner, Indiana Univ.

This paper presents a novel approach to the visual exploration and navigation of complex association networks of biological data sets, e.g., published papers, gene or protein information. The generic approach was implemented in the SRS Browser as an alternative visual interface to the highly used Sequence Retrieval System (SRS) [1]. SRS supports keyword-based search of about 400 biomedical databases. While the SRS presents search results as rank-ordered lists of matching entities, the SRS Browser displays entities and their relations for interactive exploration. A formal usability study was conducted to examine the SRS Browser interface's capabilities to support knowledge discovery and management.

6060-39, Poster Session

Tracing parallel vectors

J. Sukharev, Univ. of California/Santa Cruz

Feature tracking algorithms usually rely on operators for identifying regions of interest. One of these commonly used operators is to identify parallel vectors introduced by Peikert and Roth. In this paper, we propose a new and improved method for finding parallel vectors in 3D vector fields. Our method uses a two-stage approach where in the first stage we extract solution points from 2D faces using Newton-Raphson method, and in the second stage, we use analytical tangents to trace solution lines. The distinct advantage of our method over the previous method lies in the fact that our

algorithm does not require a very fine grid to find all the important topological features. As a consequence, the extraction phase does not have to be at the same resolution as the original dataset. More importantly, the feature lines extracted are topologically consistent. We demonstrate the tracing algorithm with results from several datasets.

6060-40, Poster Session

Output-sensitive volume tracking

L. Jiang, Rutgers Univ.

Feature tracking is a useful technique for studying the evolution of phenomena (or features) in time-varying scientific datasets. Time-varying datasets can be massive and are constantly becoming larger as more powerful machines are being used for scientific computations. To interactively explore such datasets, feature tracking must be done efficiently. For massive datasets, which do not fit into memory, tracking should be done out-of-core. In this paper, we propose an "output-sensitive" feature tracking, which uses the pre-computed metadata to (1) enable out-of-core processing structured datasets, (2) expedite the feature tracking processing, and (3) make the feature tracking less threshold sensitive. With the assistance of the pre-computed metadata, the complexity of the feature extraction is improved from $O(m \lg m)$ to $O(n)$, where m is the number of cells in a timestep and n is the number of cells in just the extracted features. Furthermore, the feature tracking's complexity is improved from $O(n \lg n)$ to $O(n \lg k)$, where k is the number of cells in a feature group. The metadata computation and feature tracking can easily be adapted to the out-of-core paradigm. The effectiveness and efficiency of this algorithm is demonstrated using experiments.

6060-41, Poster Session

Visualization of force fields in protein structure prediction

S. N. Crivelli, Lawrence Berkeley National Lab. and California Institute for Quantitative Biomedical Research; C. Crawford, O. Kreylos, B. Hamann, Univ. of California/Davis

One of the challenges of protein structure prediction and folding is the uncertainty of modeling the energetic forces causing the folding. This is particularly important because the native structure of a protein corresponds to the global minimum of its energy function. There is a need to develop interactive visualization tools that allow researchers to study, compare, and minimize energy functions. Unfortunately, these energy functions are mathematically defined in ways that do not facilitate a straightforward application of visualization techniques. To visualize energy, it is necessary to define a spatial mapping for these force fields. Such a mapping would allow generating volume renderings of the internal energy states of a molecule. We describe the spatial mapping that we use for energy, and the visualizations that we produce from this mapping. We integrated energy visualization into ProteinShop, an interactive graphical environment for the manipulation of protein structures that are used as initial configurations for further minimization. This enables us to manipulate protein configurations guided by energy and to observe changes in gradient during minimization. We will provide images and animations offering insight into the biological behavior of the proteins as well as the computational behavior of the energy optimization algorithms we use.

6060-42, Poster Session

Correspondence-based visualization techniques

M. J. Gerald-Yamasaki, NASA Ames Research Ctr.

A visual representation model is an abstract pattern used to create images which characterize quantitative information. By using a texture image to define a visual representation model, correspondence of color to denote similarity, and correspondence of image location over multiple images to associate information into collections, highly effective visualization techniques are made possible.

One such technique for two-dimensional texture-based vector field visualization is vector field marquetry. Vector field marquetry uses a synthesized image representing direction as a conditioner for pixel replacement over a collection of vector field direction-magnitude portraits. The resulting synthesized image displays easily recognizable local and global features, vector direction, and magnitude.

A related technique enabled by correspondence-based methods is the sparse representation of a vector field by a topological skeleton constructed from isodirection lines. Each vector in a vector field along an isodirection line points in the same direction. Isodirection lines subdivide the domain into regions of similar vectors, converge at critical points, and represent global characteristics of the vector field.

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6061-30, Poster Session

Subjective trajectory characterization: acquisition, matching, and retrieval

M. Y. Zhang, L. Olsen, J. E. Boyd, Univ. of Calgary

We describe a system that automatically tracks moving objects in a scene and subjectively characterizes an object trajectory for storage and retrieval. A multi-target color-histogram particle filter combined with data association is the foundation of our trajectory acquisition algorithm and Procrustes shape analysis is the basis of our subjective trajectory representation. Particle filters are useful for tracking the state of non-linear dynamic systems with clutter and noise. The adaptive color-histogram particle filter uses color measurements to track objects under changes in view and lighting in complex scenes. However, tracking multiple targets requires multiple particle filters, and the automatic initialization and termination of the individual filters presents a challenge. We handle initialization and termination by coupling with simple motion-based object detection, e.g., background subtraction. The system attempts to associate each detected object with a particle filter state. When an object appears that does not associate with a particle filter, the system initializes a new filter. When a particle filter does not have associated objects for an extended time, the system terminates the filter. One can view this as a variation of a multiple-hypothesis tracker that:

- (a) uses particle filters instead of Kalman filters, and
- (b) uses zero scan-back (i.e., resolves the data association at each time step).

To improve computational performance, we use quasi-Monte-Carlo methods to reduce the number of particles required by each filter. The tracking system operates in real-time to produce a stream of XML documents that contain the object trajectories.

To characterize trajectories subjectively, we form a set of shape templates that describes basic maneuvers (e.g., gentle turn right, hard turn left, straight line). Procrustes shape analysis provides a scale- and rotation-invariant mechanism to identify occurrences of these maneuvers within a trajectory. Thus, a temporal sequence of basic maneuvers describes the shape of a trajectory. To add spatial information to our trajectory representation, we partition the two-dimensional space under surveillance into a set of mutually exclusive regions. A temporal sequence of region-to-region transitions gives a spatial representation of the trajectory. The shape and position descriptions combine to form a compact, high-level representation of a trajectory. We provide similarity measures for the shape, position, and combined shape and position representations. Finally, we present experimental results that demonstrate the advantages of this approach for indexing and retrieval in a trajectory database.

6061-32, Poster Session

Archiving of meaningful scenes for personal TV terminals

S. H. Jin, J. H. Cho, Y. M. Ro, Information and Communications Univ. (South Korea); J. Kim, Electronics and Telecommunications Research Institute (South Korea)

In this paper, we propose an archiving method of broadcasts for TV terminals including a set-top box (STB) and a personal video recorder (PVR). Our goal is to effectively cluster and retrieve semantic video scenes obtained by real-time broadcasting content filtering for re-use or transmission. For TV terminals, we generate new video archiving formats which combine broadcasting media resources with the related metadata and auxiliary media data. In addition, we implement an archiving system to decode and retrieve the media resource and the metadata within the format. The

experiment shows that the proposed format makes it possible to retrieve or browse media data or metadata in the TV terminal effectively, and could have compatibility with a portable device.

6061-33, Poster Session

AVIR: a spoken document retrieval system in e-learning environment

I. Gagliardi, M. Padula, P. Pagliarulo, Consiglio Nazionale delle Ricerche (Italy)

The development of automatic methods for Spoken Document Retrieval (SDR) continues to emerge as an important research area for both the speech and information retrieval communities.

In this paper we present AVIR (Audio & Video Information Retrieval), a project of CNR (Italian National Research Council) - ITC to develop a tools to support an information system for distance e-learning.

AVIR has been designed for the storage, indexing, classification and retrieval of audio and video lessons and teaching materials to make them available to students and other interested users. The core of AVIR is a SDR (Spoken Document Retrieval) system which automatically transcribes the spoken documents into texts and indexes them through dictionaries appropriately created (taxonomies, ontologies), so that the users can retrieve the material of interest by means of textual queries.

During the fruition on-line, the user can formulate his queries searching documents by date, professor, title of the lesson or selecting one or more specific words. The results are presented to the users: in case of video lessons the preview of the first frames is shown. Moreover, slides of the lessons and associate papers can be retrieved.

6061-34, Poster Session

Internet-based remote counseling to support stress management: preventing interruptions to regular exercise in elderly people

S. Hashimoto, Univ. of Tsukuba (Japan) and National Institute of Information and Communications Technology (Japan); T. Munakata, Univ. of Tsukuba (Japan); N. Hashimoto, Citizen Watch Co., Ltd. (Japan); J. Okunaka, T. Koga, National Institute of Information and Communications Technology (Japan)

We used an internet based, remotely conducted, face to face, preventive counseling program using video monitors to reduce the source of life-stresses that interrupts regular exercise and evaluated the preventative effects of the program. NTSC Video signals were converted to the IP protocol and facial images were transmitted to a PC display using the exclusive optical network lines of JGN2. Participants were 22 elderly people. IT remote counseling was conducted on two occasions. A survey was conducted before the intervention in August 2003, a post survey in February 2004 and a follow-up in March 2005. Network quality was satisfactory with little data loss and high display quality. Results indicated that self-esteem increased significantly, trait anxiety decreased significantly, cognition of emotional support by people other than family members had a tendency to increase, and source of stress had a tendency to decrease after the intervention. Follow-up results indicated that cognition of emotional support by family increased significantly, and interpersonal dependency decreased significantly compared to before the intervention. These results suggest that IT remote counseling is useful to keep elderly people from feeling anxious and to make them confident to continue exercising regularly. Moreover, it has a stress management effect.

6061-35, Poster Session

Vertex and face permutation order compression for efficient animation support

E. Chang, Electronics and Telecommunications Research Institute (South Korea); D. Kim, B. Min, S. Lee, Hanyang Univ. (South Korea); N. Hur, S. Lee, Electronics and Telecommunications Research Institute (South Korea); E. S. Jang, Hanyang Univ. (South Korea)

In this paper, we have proposed a new vertex and face permutation order compression algorithm to address the efficient animation support with the minimal size of side information. The main contributions of this paper are two: 1) provision of vertex and face permutation order, 2) compression of vertex and face permutation order. Our proposed vertex and face permutation order coding algorithm is based on both the adaptive probability model instead of static probability model and the connected component representation to achieve coding efficiency. As a result, we can allocate one-less-bit codeword to each vertex and face permutation order in every distinguishable unit as encoding process proceeds. And, representing and encoding the given vertex and face permutation order in the unit of the connected component can lead to the reduction of required bit-rate. Test results demonstrate that the proposed algorithm can encode the vertex and face permutation order losslessly while making up to 12% bit-saving compared to the logarithmic representation based on the fixed probability. Furthermore, experimental results demonstrate that further improvement using the connected component concept brings 38% bit-saving compared to the proposed method and 46% bit-saving compared to the logarithmic encoding.

6061-01, Session 1

Requirements for benchmarking personal image retrieval systems

J. Bouguet, C. Dulong, I. V. Kozintsev, Intel Corp.

It is now common to have accumulated tens of thousands of personal pictures. Efficient access to that many pictures can only be done with a robust image retrieval system. This application is of high interest to processor architects. It is highly compute intensive, and could motivate end users to upgrade their personal computers to the next generations of processors.

A key question is how to assess the robustness of a personal image retrieval system. Personal image databases are very different from digital libraries that have been used by many Content Based Image Retrieval Systems. Personal image databases are very different from digital libraries that have been used by many Content Based Image Retrieval Systems. For example a personal image database has a lot of pictures of people, but a small set of different people typically family, relatives, and friends. Pictures are taken in a limited set of places like home, work, school, and vacation destination. The most frequent queries are searched for people, and for places. These attributes, and many others affect how a personal image retrieval system should be benchmarked, and benchmarks need to be different from existing ones based on art images, or medical images for examples.

The attributes of the data set do not change the list of components needed for the benchmarking of such systems as specified in: data sets, query tasks, ground truth, and evaluation measures.

This paper proposes a way to build these components to be representative of personal image databases, and of the corresponding usage models.

6061-02, Session 1

On usage models of content-based image search, filtering, and annotation

D. Telleen-Lawton, C. B. Chang, VIMA Technologies, Inc.; E. Y. Chang, Univ. of California/Santa Barbara

VIMA has observed increasing end-user demand for Content-based Image Retrieval (CBIR) systems since late 2004. This paper's objective is to provide to image retrieval researchers and developers a framework for selecting the best performance measurements for their systems and algorithms based on users' applications and requirements. We describe CBIR search, filtering, and annotation systems, outline their applications and process flow, and provide details of their usage models. We also enumerate some technical challenges of CBIR systems and outline solutions for some of these challenges.

6061-03, Session 2

Human factors in automatic image retrieval system design and evaluation

A. Jaimes, Fuji Xerox Co., Ltd. (Japan)

Image retrieval is a human-centered task: images are created by people and are ultimately accessed and used by people for human-related activities.

In designing image retrieval systems and algorithms, or measuring their performance, it is therefore imperative to consider the conditions that surround both the indexing of image content and the retrieval. This includes examining the different levels of interpretation for retrieval, possible search strategies, and image uses. Furthermore, we must consider different levels of similarity and the role of human factors such as culture, memory, and personal context. This paper takes a human-centered perspective in outlining levels of description, types of users, search strategies, image uses, and human factors that affect the construction and evaluation of automatic content-based retrieval systems, such as human memory, context, and subjectivity.

6061-04, Session 2

Lessons from TRECVID: lexicon design for semantic indexing in media databases

M. R. Naphade, IBM Thomas J. Watson Research Ctr.

No abstract available

6061-21, Session 2

Benchmarking without ground truth

S. Santini, Univ. of California/San Diego

Many evaluation techniques for content based image retrieval are based on the availability of a ground truth, that is on a "correct" categorization of images so that, say, if the query image is of category A, only the returned images in category A will be considered as "hits." Based on such a ground truth, standard information retrieval measures such as precision and recall are given and used to evaluate and compare retrieval algorithms. Coherently, the assemblers of benchmarking data bases go to a certain length to have their images categorized. The assumption of the existence of a ground truth is, in many respect, naive. It is well known that the categorization of the images depends on the a priori (from the point of view of such categorization) subdivision of the semantic field in which the images are placed (a trivial observation: a plant subdivision for a botanist is very different from that for a layperson). Even within a given semantic field, however, categorization by human subjects is subject to uncertainty, and it

makes little statistical sense to consider the categorization given by one person as the unassailable ground truth. (Even worse if, as it often happens, the person who creates the categorization is involved in the design of the system that is being tested!).

In this paper we propose several evaluation techniques that apply to the case in which the ground truth is subject to uncertainty. In this case, obviously, measures such as precision and recall as well will be subject to uncertainty. The paper will explore the relation between the uncertainty in the ground truth and that in the most commonly used evaluation measures, so that the measurements done on a given system can preserve statistical significance. The work will also touch briefly on the influence of such uncertainty on the creation and organization of benchmarking data bases.

6061-06, Session 3

Using heterogeneous annotation and visual information for the benchmarking of image retrieval system

H. Müller, Univ. Hospital of Geneva (Switzerland)

Many image retrieval systems and evaluation methodologies make use of either visual or textual information. Only few combine text and visual features for retrieval and evaluation. If text is used, it often relies upon standardised and complete annotation schema for the entire collection. This, in combination with high-level semantic queries, makes visual/textual combinations almost useless as the information need can often be solved using just text. In reality, many collections have some form of annotation but often heterogeneous and incomplete. Web-based image repositories such as FlickrR even allow collective, as well as multilingual annotation.

This article describes the ImageCLEF evaluation campaign. Unlike some other evaluations, we offer a range of realistic tasks and image collections in which combining text and visual features is likely to obtain the best results. We also offer a medical task which models the situation of heterogeneous annotation by combining four collections with annotations of varying quality, structure, extent and language. Two collections have an annotation per case, which is normal in the medical domain, making it difficult to relate parts of the accompanying text to an image. This is typical of image retrieval from the web in which adjacent text does not always describe an image. ImageCLEF shows the need for realistic and standardised datasets, search tasks and ground truths for image retrieval evaluation.

6061-07, Session 3

On benchmarking content-based image retrieval applications

B. Zhang, Y. Zuo, Tsinghua Univ. (China)

No abstract available

6061-08, Session 3

TRECVID: the utility of a content-based video retrieval evaluation

A. G. Hauptmann, Carnegie Mellon Univ.

TRECVID, an annual retrieval evaluation benchmark organized by NIST, encourages research in information retrieval from digital video. TRECVID benchmarking covers both interactive and manual searching by end users, as well as the benchmarking of some supporting technologies including shot boundary detection, extraction of semantic features, and the automatic segmentation of TV news broadcasts. Evaluations done in the context of the TRECVID benchmarks show that generally, speech transcripts and annotations provide the single most important clue for successful

retrieval. However, automatically finding the individual images is still a tremendous and unsolved challenge. The evaluations repeatedly found that none of the multimedia analysis and retrieval techniques provide a significant benefit over retrieval using only textual information such as from automatic speech recognition transcripts or closed captions. In interactive systems, we do find significant differences among the top systems, indicating that interfaces can make a huge difference for effective video/image search. For interactive tasks efficient interfaces require few key clicks, but display large numbers of images for visual inspection by the user. The text search finds the right context region in the video in general, but to select specific relevant images we need good interfaces to easily browse the storyboard pictures. In general, TRECVID has motivated the video retrieval community to be honest about what we don't know how to do well (sometimes through painful failures), and has focused us to work on the actual task of video retrieval, as opposed to flashy demos based on technological capabilities.

6061-10, Session 4

A color selection tool ensuring legibility of textual information on web pages

S. Zuffi, Consiglio Nazionale delle Ricerche (Italy); G. B. Beretta, Hewlett-Packard Co.; C. Brambilla, Consultant (Italy)

One of the issues in Web page design is the selection of appropriate combinations of background and foreground colors to display textual information. Colors have to be selected in order to guarantee legibility for different devices, viewing conditions and, more important, for all the users, including those with deficient color vision. In this work we present a tool to select background and foreground colors for the display of textual information. The tool is based on the Munsell Book of Colors; it allows the browsing of the atlas and indicates plausible colors based on a set of readability measure that can be selected from a set of criteria. In order to take into account color vision deficiencies, we focused on color selection based on luminance, and performed experiments to evaluate readability of many color combinations selected at different levels of lightness difference by means of a character counting task. As first result, our data suggest that, assigning a lightness difference of about 30 in the color selection tool could be a good strategy to address legibility issues. Our results, even if interesting, require further extensions and comparisons, that we plan to perform in the future.

6061-11, Session 4

A color interface for audio clustering visualization

S. Zuffi, I. Gagliardi, Consiglio Nazionale delle Ricerche (Italy)

The availability of large audio collections calls for ways to efficiently access and explore them by providing an effective overview of their contents at the interface level. We present an innovative strategy for the visualization of the contents of a database of audio records. The database is that of the Archive of Ethnography and Social History of the Lombardy Region (AESS). The website stores information concerning the oral history of the region, and is composed mainly of popular songs and other audio records describing the popular traditions handed down from generation to generation. The AESS website implements various modalities of navigation. These include the location and clustering of similar audios, that is the organization of the audio files stored in the database in groups containing files acoustically similar to each other. An innovative strategy was defined to implement a color coding of audio clusters. We exploited the visual attributes of colors to map the cluster distances in the histogram space into color distances in a perceptually uniform color space. This kind of representation can support the user in the browsing of audio clusters, allowing a rapid visual evaluation of the similarity of cluster contents without the need to listen to the audios.

6061-12, Session 4

Interactive internet delivery of scientific visualization vis structured prerendered imagery

J. Chen, San Francisco State Univ. and Lawrence Berkeley National Lab.; E. W. Bethel, Lawrence Berkeley National Lab.; I. Yoon, San Francisco State Univ.

In this paper, we explore leveraging industry-standard media formats to effectively deliver interactive, 3D scientific visualization to a remote viewer. Our work is motivated by the need for remote visualization of time-varying, 3D data produced by scientific simulations or experiments while taking several practical factors into account, including: maximizing ease of use from the user's perspective, maximizing reuse of image frames, and taking advantage of existing software infrastructure wherever possible. Visualization or graphics applications first generate images at some number of view orientations for 3D scenes and temporal locations for time-varying scenes. We then encode the resulting imagery into one of two industry-standard formats: QuickTime VR Object Movies or a combination of HTML and JavaScript code implementing the client-side navigator. Since the only inputs consist of image data, a viewpoint and time stamps, our approach is generally applicable to all visualization and graphics rendering applications capable of generating image files in an ordered fashion. Our design is a form of latency-tolerant remote visualization infrastructure where processing time for visualization, rendering and content delivery is effectively decoupled from interactive exploration. Our approach trades off increased interactivity, reduced load and effective reuse of coherent frames between multiple users at the expense of unconstrained exploration.

6061-13, Session 5

Clustering and semantically filtering web images to create a large-scale image ontology

S. Zinger, C. Millet, M. Benoit, G. Grefenstette, P. Hède, P. Moëllic, Commissariat à l'Energie Atomique (France)

In our effort to contribute to the closing of the "semantic gap" between images and their semantic description, we are building a large-scale ontology of images of objects. This visual catalog will contain a large number of images of objects, structured in a hierarchical catalog, allowing image processing researchers to derive signatures for wide classes of objects. We are building this ontology using images found on the web. We describe in this article our initial approach for finding coherent sets of object images. We first perform two semantic filtering steps: the first involves deciding which words correspond to objects and using these words to access databases which index text found associated with an image (e.g. Google Image search) to find a set of candidate images; the second semantic filtering step involves using face recognition technology to remove images of people from the candidate set (we have found that often requests for objects return images of people). After these two steps, we have a cleaner set of candidate images for each object. We then index and cluster the remaining images using our system VIKA (VIsual KAtaloguer) to find coherent sets of objects.

6061-14, Session 5

Ontology and image semantics in multimodal imaging: submission and retrieval

Y. Bei, M. Belmamoune, F. J. Verbeek, Leiden Univ. (Netherlands)

In the last decade, research activities in the life sciences are responsible for production of a tremendous amount of digital data.

Considerable part of this data is in the form of images resulting from scientific experiments and, which are often stored in different repositories without any standard approach that could facilitate scientific retrieval, analysis or exchange among them. Without accurate annotation images are not straightforwardly suitable for exchange. Knowledge about what is depicted in the image as well as specific image content is needed for understanding and thus, sharing. We introduce metadata annotation to store image content in both pixel and semantic level. Our approach focuses on structured annotation to unlock the knowledge in microscopy images. Ontology is used as a standard controlled and related vocabulary in our annotation. Different ontologies enrich annotation in different aspects.

Unified ontology based annotation, will help scientists and computers understanding knowledge as present in images more precisely. It will also assure interoperability by allowing structured exchange of information among different repositories. Ontologies provide essential glue for elaborate image retrieval and assure propagation of image content by accurate linking to other resources.

6061-16, Session 6

Combining color models for skin detection

F. Aldershoff, T. Gevers, H. M. Stokman, Univ. van Amsterdam (Netherlands)

The choice of a colour space is of great importance for many computer vision algorithms (e.g. edge detection and object recognition). The choice of this colour space is nontrivial, since it will induce the equivalence classes in the algorithms performing the tasks. The choice is further complicated by the vast range of available colour spaces (e.g. RGB, rgb, CIE L*a*b*, HSV, etc.), each with specific qualities. Moreover the optimal colour space might be a mix of some standard colour spaces. The problem is how to automatically select the weighting to integrate the colour spaces in order to produce the best result for a particular task.

In this paper we propose a method to learn these weights, while exploiting the non-perfect correlation between colour spaces of features through the principle of diversification. As a result an optimal trade-off is achieved between repeatability and distinctiveness. The resulting weighting scheme will ensure maximal feature discrimination.

The method is experimentally verified for three feature detection tasks: Skin colour detection, edge detection and corner detection. In all three tasks the method achieved an optimal trade-off between (colour) invariance (repeatability) and discriminative power (distinctiveness).

6061-17, Session 6

Using context and similarity for face and location identification

M. Davis, Univ. of California/Berkeley; M. A. Smith, France Telecom R&D (France); J. F. Canny, Univ. of California/Berkeley; F. W. M. Stentiford, Univ. College London (United Kingdom)

This paper describes a new approach to the automatic detection of human faces and location in mobile images. The growing infrastructure of internet enabled location services and the ubiquity of position sensing cameraphones present both a challenge and opportunity for multimedia researchers. In addition to their growing global ubiquity, cameraphones offer a unique opportunity to pursue new approaches to media analysis and management: namely to combine the analysis of automatically gathered contextual metadata with media content analysis to radically improve image content recognition and retrieval.

Current approaches to content-based image analysis are not sufficient to enable retrieval of cameraphone photos by high-level semantic concepts, such as who is in the photo or what the photo is actually depicting. In this paper, new methods for determining image similarity are combined with analysis of automatically acquired contextual metadata to produce location information. For faces, context-aware, collaborative filtering, machine-learning techniques that leverage automatically sensed and inferred contextual metadata together with computer vision analysis of image content to make accurate predictions about the human subjects depicted in cameraphone photos. Our database consists of over 1200 images that were collected on cameraphones and annotated to provide context features such as outdoor/indoor setting and time of capture. Most of the images were taken in natural settings with limited frontal pose.

For location, a model of Cognitive Visual Attention (CVA) matches large numbers of pairs of pixel groups (forks) taken from two patterns under comparison. We achieve a significant reduction from a 70% error rate from color histogram and CVA image analysis methods for determining the location of photo content, to a 45% error rate using contextual metadata alone, to a 33% error rate achieved by combining contextual metadata with CVA image analysis. For faces, we apply Sparse-Factor Analysis (SFA) to both the contextual metadata gathered in the database and the results of PCA (Principal Components Analysis) of the photo content to achieve a 60% face recognition accuracy of people depicted in our cameraphone photos, which is 40% better than media analysis alone. The margins in precision/recall among the different methods are quite large. Context+Vision does better than any individual predictor. Its initial precision is about 60% and is fairly flat across the recall range, as seen in the figure below. This paper has shown that the combination of attributes derived from both contextual metadata and image processing produces a measure that can indicate the faces in a photo and the location at which photos were taken, much better than image analysis or context alone.

6061-18, Session 6

Skin segmentation using multiple thresholding

F. Gasparini, R. Schettini, Univ. degli Studi di Milano-Bicocca (Italy)

The segmentation of skin regions in color images is a preliminary step in several applications. Many different methods are available in the literature. The simplest methods build what is called an "explicit skin cluster" classifier which expressly defines the boundaries of the skin cluster in certain color spaces. The main difficulty in achieving high skin recognition rates, and producing the smallest possible number of false positive pixels, is that of defining accurate cluster boundaries through simple, often heuristically chosen, decision rules. We apply a genetic algorithm to determine the boundaries of the skin clusters in multiple color spaces. To quantify the performance of these skin detection methods, we use recall and precision scores. A good classifier should provide both high recall and high precision, but generally, as recall increases, precision decreases. Consequently, we adopt a weighted mean of precision and recall as the fitness function of the genetic algorithm. The weighting coefficients can be chosen to favor either high recall or high precision, or to satisfy a reasonable tradeoff between the two, depending on application demands. To train the genetic algorithm and test the performance of the classifiers applying the suggested boundaries, we use the large and heterogeneous Compaq database.

6061-19, Session 7

Integration of multimedia contents and e-learning resources in a digital library

M. Pascual, N. Ferran, J. Minguillón Alfonso, Univ. Oberta de Catalunya (Spain)

Distance education in virtual e-learning environments permits an intensive use of new technologies, especially in the field of design, creation and management of multimedia contents. The use of multimedia resources, either as learning tools in virtual environments or as basic pieces of multimedia repositories, allows us an improvement in the process of teaching and learning contents of audiovisual nature. In this sense, teaching contents with a clear multimedia structure, such as several subjects in Studies of Audiovisual Communication, for example, but also Multimedia or Humanities Studies, requires learning tools with two desired characteristics: first, each course follows an activity oriented structure using a temporal framework, partially fixed but flexible, and second, content personalization capabilities are needed to create adaptive courses depending on user preferences and background, but also to minimize course obsolescence by means of semi-automated content update. Therefore, content reusability within a course is an important issue related to course quality and management, one of the main goals of this ongoing project.

This paper describes the integration between documents according to standards for multimedia content distribution such as MPEG-7, and other learning resources designed using e-learning standards such as LOM, for example. This is performed within the context of a virtual e-learning environment and a digital library, which uses the Dublin Core standard for metadata or MARC format among other standards. The need for metadata integration across multimedia, e-learning and library standards becomes a key factor for ensuring a proper content management and retrieval by teachers, researchers and students, the users of the digital library. These standards are not orthogonal, so an overlap minimization and the appropriate extensions must be performed to ensure a proper content tagging, mainly to fulfill the main project goal, basically that all the resources in the digital library can be browsed and searched as a large repository of multimedia contents which uses structured metadata for the syntactic and semantic description of all the resources, which can be used in different scenarios.

Metadata provide controlled and structured descriptions of learning resources through searchable access points such as title, author, date, location, description and subject, but can also provide interpretative information on the potential education application of resources or include described information about the relationships with other resources. The learning resources form a hierarchical structure when are combined to create courses using learning objects as the basic pieces. These courses have a flexible structure that allows teachers to adapt their content on-the-fly, depending on any particular teaching requirement.

On the one hand, we define the appropriate mappings between multimedia, e-learning and library standards in a two-stage approach: first, a set of common metadata is identified in all three standards for supporting basic browsing and searching capabilities and, second, the appropriate extensions using ontologies are created to minimize metadata overlap and inconsistencies. The use of XML based languages such as Resource Description Framework (RDF) and Web Ontology Language (OWL) is also addressed. On the other hand, the specific information needed to describe e-learning usage of such multimedia contents, related to pedagogical aspects, needs also to be specified.

Finally, all the elements in the digital library are under an intellectual property rights management policy, which determines the possible contexts and scenarios of use. The digital library tracks all searching and browsing actions with two main goals: first, to improve such

capabilities by means of collaborative filtering and annotation, and second, to ensure that all contents that are part of a course and the users of such course (both teachers and students) have the appropriate rights to access them.

6061-20, Session 7

Selecting the kernel type for a web-based adaptive image retrieval systems (AIRS)

A. Doloc-Mihu, V. V. Raghavan, Univ. of Louisiana at Lafayette

The goal of this paper is to investigate the selection of the kernel for a Web-based AIRS. Using the Kernel Perceptron learning method, several kernels having polynomial and Gaussian Radial Basis Function (RBF) like forms (6 polynomials and 6 RBFs) are applied to general images represented by color histograms in RGB and HSV color spaces. Experimental results on these collections show that performance varies significantly between different kernel types and that choosing an appropriate kernel is important.

6061-22, Session 7

Medical validation and CBIR of spine x-ray images over the Internet

S. K. Antani, J. Cheng, J. L. Long, L. R. Long, G. R. Thoma, National Library of Medicine

As found in the literature, most Internet-based prototype Content-Based Image Retrieval (CBIR) systems focus on stock photo collections and do not address challenges of large specialized image collections and topics such as medical information retrieval by image content. Even fewer have medically validated data to evaluate retrieval quality in terms of precision and relevance. To date, our research has reported over 75% relevant spine X-ray image retrieval tested on 888 validated vertebral shapes from 207 images using our prototype CBIR system operating within our local network. As a next step, we have designed and developed an Internet-based medical validation tool and a CBIR retrieval tool in MATLAB and JAVA that can remotely connect to our database. The retrieval tool supports hybrid text and image queries and also provides partial shape annotation for pathology-specific querying. These tools are initially developed for domain experts, such as radiologists and educators, to identify design issues for improved workflow. This article describes the tools and design considerations in their development.

6061-23, Session 7

The integration of cartographic information into a content management system

M. M. Furnari, C. I. D. Noviello, Consiglio Nazionale delle Ricerche (Italy)

A corporate information system needs to be as accessible as library content, which implies to organize the content in a logical structure, categorizing it, and using the categories to add metadata to the information.

Content Management System (CMS) are an emerging kind software component that manages content, usually making a large use of the web technologies, whose main goals are to allow easy creation, publishing and retrieval of content to fit business needs.

The focus of this paper is to describe how we integrated "map" metaphor into a CMS. Where maps are symbolic information and rely on the use of a graphic sign language. A characteristic feature of maps is that their design has traditionally been constrained by the need to create one model of reality for a variety of purposes. The map's primary role as a communication medium involves the application of processes such as selection, classification, displacement, symbolization and graphic exaggeration. A model of

the infrastructure is presented and the current prototype of the model is briefly discussed together the currently deployed environment for the cultural heritage information dissemination.

6061-36, Session 7

FaceLab: a tool for performance evaluation of face recognition strategies

L. Cafilisch, Comerson s.r.l. (Italy); A. Colombo, C. Cusano, R. Schettini, F. Tisato, Univ. degli Studi di Milano-Bicocca (Italy)

This paper presents FaceLab, an innovative, open environment created to evaluate the performance of face recognition strategies. It simplifies, through an easy-to-use graphical interface, the basic steps involved in testing procedures such as data organization and preprocessing, definition and management of training and test sets, definition and execution of recognition strategies and automatic computation of performance measures. The user can extend the environment to include new algorithms, allowing the definition of innovative recognition strategies. The performance of these strategies can be automatically evaluated and compared by the tool, which computes several performance measures for both identity verification and identification scenarios.

6061-24, Session 8

Enhanced video display and navigation for networked streaming video and networked video playlists

S. G. Deshpande, Sharp Labs. of America, Inc.

In this paper we present an automatic enhanced video display and navigation capability for networked streaming video and networked video playlists. Our proposed method uses Synchronized Multimedia Integration Language (SMIL) as presentation language and Real Time Streaming Protocol (RTSP) as network remote control protocol to automatically generate a "enhanced video strip" display for easy navigation. We propose and describe two approaches - a smart client approach and a smart server approach. We also describe a prototype system implementation of our proposed approach.

6061-25, Session 8

3D display technique for moving pictures from web cameras using screen pixel accessing

T. Hasegawa, T. Namiki, H. Unno, K. Uehira, H. Kasuga, K. Yanaka, Kanagawa Institute of Technology (Japan)

This paper presents a technique to display real-time 3-D images captured by web cameras on the stereoscopic display of a personal computer (PC) using screen pixel access. Images captured by two side-by-side web cameras are sent through the Internet to a PC and displayed in two conventional viewers for moving images. These processes are carried out independently for the two cameras. The image data displayed in the viewer are in the video memory of the PC. Our method uses this video-memory data, i.e., the two web-camera images are read from the video memory, they are composed as a 3-D image, and then it is written in the video memory again. A 3-D image can be seen if the PC being used has a 3-D display. We developed an experimental system to evaluate the feasibility of this technique. The web cameras captured up to 640 x 480 pixels of an image, compressed it with motion JPEG, and then sent it over a LAN. Using an experimental system, we evaluated that the 3-D image had almost the same quality as a conventional TV image by using a broadband network like ADSL.

6061-28, Session 9

Dynamic conversion between XML-based languages for vector graphics

A. Di Iorio, F. Vitali, G. Zonta, Univ. degli Studi di Bologna (Italy)

Vector graphics is increasingly gaining importance within the World Wide Web community, because it allows users to create images that are easily manageable, modifiable and understandable. Two formats play a leading role among the languages for vector graphics: SVG and VML. Achieving a complete interoperability between these two languages means providing users a complete support for vector images across implementations, operating systems and media. Even automatic conversions between raster and vector graphics provide users a lot of benefits and are worth further investigation and support. In this paper we describe VectorConverter, a tool developed at the University of Bologna that allows easy, automatic and reasonably good conversion between two vector graphic formats, SVG and VML, and one raster format, GIF. This tool makes good translations between languages with very different functionalities and expressivity, by applying translation rules, approximation and heuristics. VectorConverter is composed of a few XSLT files to manage the conversion between vector formats, and some PHP scripts that work on raster images. A high-level discussion about implementation details, open issues and future developments of VectorConverter is provided as well.

6061-29, Session 9

Bezier curves approximation of triangularized surfaces using SVG

G. Messina, STMicroelectronics (Italy); E. Ingra, S. Battiato, G. Di Blasi, Univ. di Catania (Italy)

This paper presents a technique to convert surfaces, obtained using a Data Dependent Triangulation (DDT), in Bézier Curves through a Scalable Vector Graphics (SVG) file format. The DDT replaces the input image with a set of triangles according to a specific cost function able to detect the edge details. On the other hand the DDT produces a number of triangles larger than the number of pixels. Although the quality achieved in this way is rather good the size of the resulting files may be very large. To reduce the amount of data the algorithm extracts from the DDT only the boundaries triangles; then the triangles are synthesized as single points using their estimated barycenters. These barycenters are connected together by following the boundaries along the wind rose directions. After the areas are created, the conversion to Bézier Curves is performed by using the resulting path as control points. A simplification of the curves is then applied by removing useless points. Finally the surfaces are sorted using an approximation of the area and saved in SVG format. The proposed technique is compared with other raster to vector conversion methods and software showing good performances in terms of perceptual and measured quality.

Monday-Tuesday 16-17 January 2006

**Part of Proceedings of SPIE Vol. 6062 Spectral Imaging: Eighth International
Symposium on Multispectral Color Science**

6062-01, Session 1

**Hyperspectral imaging of sulfate evaporite
deposits in Western Australia and on Mars**

A. J. Brown, Macquarie Univ. (Australia) and Australian Ctr. for
Astrobiology (Australia); T. J. Cudahy, Commonwealth Scientific &
Industrial Research Organisation (Australia)

The European hyperspectral imaging instrument Observatoire pour
la Minéralogie, l'Eau, la Glace et l'Activité (OMEGA) has been in
operation around Mars since early 2004. OMEGA has constructed
imaging maps covering almost the entire Martian surface. OMEGA
has returned evidence of surficial sulfate deposits at several
locations around the Martian globe. The presence of sulfates on the
Martian surface has important links with past water and possible life
on Mars.

On Earth, sulfates most commonly form in dry lake evaporite basins,
many examples of this type of deposit are in evidence in arid
Western Australia. A number of these dry lakes criss-cross the
ancient (late Archean) Yilgarn Craton. The ultramafic-mafic volcanic
flows in this region make the Yilgarn a good analog for the volcanic
flood basalts of Mars.

In 2004, a hyperspectral imaging survey of the Yilgarn Craton was
carried out using the airborne HyMap instrument. We have analysed
this hyperspectral coverage of the evaporite deposits of the Yilgarn
GGT and found large deposits of gypsum in evidence. Using an
analysis method based on curve fitting of individual spectra in the
dataset, we have compared the results for the Martian North Polar
region with the arid Western Australian evaporite deposits.

6062-02, Session 1

**Multispectral imaging determination of
pigment concentration profiles in meat**

C. Sáenz, B. Hernández, C. Alberdi, S. Alfonso, M. Berroguí, J. M.
Diñeiro, Univ. Pública de Navarra (Spain)

The possibility of using multispectral techniques to determine the
concentration profiles of myoglobin derivatives as a function of the
distance to the meat surface during meat oxygenation is
demonstrated. Reduced myoglobin (Mb) oxygenated oxymyoglobin
(MbO₂) and oxidized Metmyoglobin (MMb) concentration profiles are
determined with a spatial resolution better than of 0.01235 mm/
pixel. Pigment concentrations are calculated using (K/S) ratios at
isobestic points (474, 525, 572 and 610 nm) of the three forms of
myoglobin pigments. This technique greatly improves previous
methods, based on visual determination of pigment layers by their
color, which allowed only estimations of pigment layer position and
width. The multispectral technique avoids observer and illumination
related bias in the pigment layer determination.

6062-03, Session 1

**Visualization of the human face skin
moisturizing-ability by spectroscopic
imaging using two near-infrared bands**

H. Iwasaki, K. Miyazawa, S. Nakauchi, Toyohashi Univ. of
Technology (Japan)

The skin's ability to retain moisture, which is hereafter referred as
skin moisturizing-ability, is one of the important factors in skin
health. Skin defends the biological tissue from the outside
influences, skin sebum and moisture especially play an important
role in that protection. Near-infrared (NIR) spectroscopic imaging has

recently been capable of detecting changes in skin hydration of the
forearms. However, face skin hydration has not been measured, and
the moisture-related sebum has not been paid attention to, even
though the face is important from the cosmetic point of view. This
study, therefore, aims to measure and visualize the spatial
distribution of skin moisturizing-ability of the face by NIR
spectroscopic imaging. The NIR spectral imaging system consists of
two interference filters (1060 and 1450nm) mounted on a filter wheel
and a NIR camera with indium-gallium arsenide array sensor. We
measured face skins with/without moisturizing lotion and the areas
where moisturizing lotion was applied were successfully displayed
by subtracting two absorbance images measured at different
wavelength bands. It was also found that the glabella and nose have
strong moisturizing-ability because of sebaceous glands. This
technique can be applied to the functional assessment of face skin
moisturizer in medicine and cosmetics.

6062-04, Session 2

**Image processing techniques for detection
of buried objects in infrared images**

A. Ceron-Correa, Univ. Militar Nueva Granada (Colombia); O. L.
Lopera, Royal Military Academy (Belgium) and Univ. de Los Andes
(Colombia)

This paper describes the features of infrared thermography and its
application to humanitarian demining in the world and also the
influencing factors on its application in a country like Colombia
which suffers hardly the antipersonnel mines problem. Infrared
image processing methods and results of tests done in different
sites in the country are showed.

The IR cameras are sensitive passive devices; they are capable to
detect infrared radiation of buried objects in specific situations.
These sensors are based in the alteration of heat flux, occasioned by
the presence of strange bodies buried in the soil. This situation
produces differences in the infrared radiation emission from objects
in the location because they hold a different amount of heat than in
its surroundings.

The images are affected for different factors in special when the soil
is composed of stones which can give a great number of false
alarms; a method for estimating this feature named granulometry is
used in this project.

Finally, a method for the detection of the signature of a buried object
is used with successful results. This method uses a combination of
morphology mathematic techniques.

6062-05, Session 2

**Spectral estimation of made-up skin color
under various conditions**

M. Doi, R. Ohtsuki, S. Tominaga, Osaka Electro-Communication
Univ. (Japan)

A method is proposed for estimating the spectral reflectance of
made-up skin color under various conditions including the
undesirable colored skin. The color of dark spot is caused by
increasing the component of melanin. The reddish skin is caused by
the increase of hemoglobin. Our method uses the Kubelka-Munk
theory to calculate the surface spectral reflectance human skin. This
theory calculates the reflectance and transmittance of the light
passing through a turbid medium from the absorption and scattering
of the medium. The spectral reflectance of made-up skin is
estimated by adjusting parameters of the thickness of the makeup
layer. The proposed estimation method is evaluated on an

experiment in detail. First, we measure the spectral reflectance of facial skin under the three conditions of normal skin, undesirable skin, and made-up skin. The undesirable skin includes stain, suntan or ruddy skin. The made-up skin means the skin with foundation on the normal skin, the stain, the suntan and the ruddy skin. Second, we estimate the spectral reflectance of made-up skins from the reflectance of bare skins and optical characteristics of foundations. Good coincidence between the estimated reflectance and the direct measurement shows the feasibility of the proposed method.

6062-06, Session 2

MODIS versus ASTER water classification

C. Alecu, S. Oancea, National Meteorological Administration (Romania); E. Bryant, Dartmouth College

Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) are multi-spectral sensors embarked on the EOS AM-1 (TERRA) satellite platform. Both sensors operate in different spectral bands, but also with different pixel resolutions.

Due to the constraint that high spatial resolution satellite images are low temporal resolution, there exists a need for a reliable method to obtain accurate information from medium resolution data. The overall goal of this paper is to classify MODIS data to get an estimation of water surface area, very useful in the flood management for the decision makers at all levels.

To develop the classification technique, the strategy was to obtain MODIS and ASTER data acquired at the same time over the same location, and use the ASTER data as "ground truth". Two lakes in the Bihor County of Romania were chosen as test area. Water masks were created from ASTER and MODIS data and then superimposed, taking into account that a MODIS pixel contains 400 ASTER pixels. Each MODIS pixel was converted as ratio of water/non-water, based on the ASTER classification. The water surface area, as measured from the MODIS classification, was about 16% more than the ASTER ground truth-value.

6062-07, Session 2

Improving multivariate curve resolution analysis performance when applied to fluorescence hyperspectral biological imaging

H. D. T. Jones, E. Thomas, D. M. Haaland, J. A. Timlin, M. B. Sinclair, Sandia National Labs.

Hyperspectral imaging is becoming a powerful new tool to image biological cell and tissue samples. In a hyperspectral image, hundreds of wavelengths representing whole spectral regions are obtained at each pixel (or voxel for 3-dimensional images). We are using multivariate Curve Resolution (MCR) to analyze the collected image data. MCR is a powerful analysis technique for hyperspectral images since it has the ability to extract pure-component spectra from the spectral images and provide relative quantitative determinations of each component for each pixel in the image. The MCR algorithm performs best when the data are unique, (i.e., orthogonal) in either the spectral or spatial domain. However, this condition is often not met in experimental datasets. In this presentation, I will discuss the use of data preprocessing techniques to select the image pixel spectra to include in the MCR analysis in order to improve the concentration orthogonality of the pixels used in the analysis. The goal is to have the MCR result converge to the most appropriate solution when random numbers are used to initiate the MCR process. The methods to select the most appropriate pixels for MCR analysis will be demonstrated using hyperspectral images of photosynthetic cyanobacteria.

6062-08, Session 3

Estimating reflectance parameters from saturated spectral images

S. Li, Y. Manabe, K. Chihara, Nara Institute of Science and Technology (Japan)

Since commercial image detectors, such as charge-coupled device (CCD) cameras, have a limited dynamic range, it is difficult to obtain images that really are unsaturated, as a result of which the reflectance parameters may be inaccurately estimated. To solve this problem, we describe a method to estimate reflectance parameters from saturated spectral images. We separate reflection data into diffuse and specular components at 5-nm intervals between 380nm and 780nm for each pixel of the spectral images, which are captured at different incident angles. To estimate the specular reflectance parameters from the specular components, we transform the Torrance-Sparrow equation to a linear form. We estimate specular parameters for intensity of the specular reflection and standard deviation of the Gaussian distribution, using the least squares method from unsaturated values of the specular components, assuming Fresnel reflectance is constant. And then, to refine estimation of those specular parameters, we estimate the refractive index of the surface for dielectric materials in terms of the Fresnel equation. We carried out experiments with measured data, and with simulated specular components at different saturation levels, generated according to the Torrance-Sparrow model. Our experimental results reveal that the diffuse and specular reflectance parameters are estimated with high quality.

6062-09, Session 3

Influence of the recovery method in the optimum sensors for spectral imaging of skylight

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We show the similarities and differences between the optimum sensors found for recovering skylight spectra from noisy broadband sensor data with four different spectral estimation methods. We also study the accuracy obtained in the spectral recoveries of skylight with each method. The Maloney-Wandell and Wiener methods, although very different mathematically, present a similar behaviour in the spectral profile of the optimum sensors and the quality of the recoveries. The Imai-Berns method improves a little upon these two methods when the noise present in the system is high. The optimum sensors obtained with the Shi-Healey method are very peculiar, they seem to be equally spaced in the visible and are very narrow-band, which indicates that they could easily be constructed using a Lyquid Crystal Tunable Filter. For the Maloney-Wandell and the Imai-Berns methods the best choice is to use 3 basis vectors when recovering skylight spectra from three-sensor responses. The Shi-Healey method has proved to be the best for the task of recovering skylight spectra from the responses of three sensors, although it is extremely slow when using a large training set.

6062-10, Session 4

Demosaicking methods for multispectral cameras using mosaic focal plane array technology

G. A. Baone, H. Qi, The Univ. of Tennessee

This paper focuses on the introduction of mosaic focal plane array technology to multispectral image acquisition systems. The motivation to use mosaic focal plane arrays for multispectral image acquisition comes from the commercial digital color cameras. The digital color cameras use an array of sensors to sense incoming light

such that only one spectral band is registered per pixel location. This helps in reducing the cost and size of the equipment and at the same time increasing the robustness and improving the registration capability of the equipment. The final (full color) image is formed by estimating the missing spectral bands at each pixel location. This process is called demosaicking. In this paper, we deal with the demosaicking aspect of the multispectral image acquisition systems that use mosaic focal plane arrays. Existing demosaicking techniques have been appropriately extended to the multispectral case. To incorporate external noise and degradations during the acquisition process, we use a Maximum a-Posteriori probability (MAP) based approach that treats the demosaicking problem as a classic case of image restoration. This MAP based approach successfully performs demosaicking by simultaneously removing any existing noise and degradations. Experiments have been performed on a set of seven-band multispectral images and various metrics have been developed to compare different demosaicking techniques.

6062-11, Session 4

Estimation of noise variance of a multispectral image acquisition system

N. Shimano, Kinki Univ. (Japan)

The noise present in a color image acquisition system influences the accuracy of the estimated colorimetric values and the accuracy of the recovered spectral reflectances of objects being imaged through the use of sensor responses. Estimation of the noise levels in the devices is important for the accurate acquisition of colorimetric or spectral information. This work addresses the problem for the determination of noise variances in multispectral image acquisition systems.

In the present paper four different models, i.e., the first two models are based on the recovered spectral reflectances by the Wiener filter and the second two models are based on the statistical analysis of sensor responses, for the determination of the noise variances are briefly reviewed, and they were applied to a multispectral image acquisition system in detail. From the experimental results, it is confirmed that the estimated noise variances by the model which uses recovered spectral reflectances are more accurate than those estimated noise variances by the statistical analysis of sensor responses.

The proposal is very important for the recovery of the surface reflectance spectra of objects being imaged and also useful for the evaluation of a set of sensors.

6062-12, Session 4

Multispectral stand-off imaging with mid-infrared semiconductor lasers

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Multi-spectral laser imaging can be used for target discrimination, classification, and identification based on object spectral signatures. This paper describes a development of semiconductor-laser-based multi-spectral and polarimetric imaging, using near-IR and mid-IR lasers. Key issues and aspects of this technology are discussed, including the fundamental issues of multi-spectral imaging and scattering phenomena, and the system engineering approach for multi-wavelength scaling. The near-IR study employed 7 wavelengths from 0.635-1.55 μm , and demonstrated fundamental aspects of wavelength- and polarization-dependence effects in imaging and scattering. Stokes vector imaging was shown to reveal significant information of the targets. The mid-IR study employed 4 wavelengths from 3.3-9.6 μm , and was applied to diverse targets consisting of natural and man-made materials and household objects. It was shown capable to resolve and distinguish small spectral differences among targets, e. g. colorless objects in the

visible were shown with "colorful" signatures in the mid-IR. For system engineering design, a key feature is the system architecture that employs wavelength-division-multiplexing for accurate and high spectral fidelity, and the scalable CDMA network approach with multiple transmitters and receivers for efficient measurements. The results suggest that multi-spectral laser imaging can be a unique and powerful technology for wide ranging applications.

6062-13, Session 4

Designing flat-bed scanning system for spectral and glossiness recording

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In this paper, we propose a flat-bed scanner system to record spectral and glossiness information for various sheets like objects. In the proposed system, five filters are used to acquire the multi-band images of the object. The spectral reflectance image can be estimated and be recorded from the multi-band images. The glossiness of the object is recorded as two images taken by the different geometries about illuminant which is from 45 degrees, and from $0+\alpha$ degrees respectively when the averaged normal vector of the sheet like object is defined as 0 degree. We performed two types of computer simulation by using the two images to reproduce various appearance of recorded object. As the first simulation, the various appearances of image are reproduced through a weighted linear combination of the two images. As the second simulation, the normal vector distribution of the object is estimated from the image taken by 45 degree illuminant. By using this normal vector distribution, roughness of the object is estimated from the image taken by $0+\alpha$ degree illuminant. The normal vector and estimated roughness are used to reproduce the various appearance of the object under arbitrary illuminant.

6062-15, Session 4

Color measurements with colorimetric and multispectral imaging systems

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This work is focused on the study and comparison of the performance for color measurements of different systems based on optoelectronic imaging sensors. In this context we use both colorimetric, that is, with only three acquisition channels, and multispectral configurations, with more spectral bands, in order to measure the color associated to each pixel of the captured scene. The used configurations consist of a 12-bit depth monochrome CCD camera (QImaging) with a high spatial resolution attached to an objective lens (Nikon), and several broadband filters placed between them. For the colorimetric configurations with a three channel set-up an RGB tunable filter is used, and in the multispectral-based systems a motorized wheel with seven interference filters is placed between the camera and the lens instead. The whole systems have been spatially characterized using a flat-field correction. From the raw digital responses measured with the different configurations we calculated the X, Y and Z tristimulus values using four different methodologies. The first method (colorimetric), which has been studied in previous work, provides the XYZ tristimulus values by means of an absolute spectral and colorimetric characterization of the system, which permits us to obtain the spectral sensitivities associated to the sensor and the colorimetric profile between the RGB space of the device and the CIE-1931 XYZ standard space. The second (colorimetric) permits us to directly transform the RGB digital signals to XYZ values performing a simple mathematical fitting between both sets, such as a minimum least squares regression. The third method (multispectral) uses the same principle

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as the second one but taking into account the seven digital signals associated to the multispectral bands instead of using only the RGB values. The last proposed methodology (multispectral) initially performs the reconstructions of the spectra associated to each pixel using different methods such as the Moore-Penrose pseudo-inverse and finally computes the XYZ tristimulus values from the spectral information provided. The different proposed systems were experimentally tested using the Gretagmacbeth ColorChecker chart and a tele-spectracolorimeter PhotoResearch PR-650 was also used in order to measure the associated true colors of the patches. The results obtained so far show the improvement on the color measurements with the multispectral-based systems, which are more accurate than the ones obtained with the systems with only three acquisition channels. The study also shows the worse performance of the first colorimetric methodology due to the great amount of errors carried along the calculations involved in the spectral and colorimetric characterizations. Finally, the fourth methodology is preferred if spectral information is useful in addition to the colorimetric parameters. The developed systems, whichever configuration is used, may be integrated as an intelligent sensor in automatic manufacturing cells and allows either color measurements using a single register with customizable spatial resolution and offering a fairly higher spatial resolution when compared with standard systems for color measurements.

6062-16, Session 5

High-fidelity video and still-image communication based on spectral information: natural vision system and its applications

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[Background and Purpose]

The reproduction of natural color is one of the key issues in visual communication systems for electronic commerce, telemedicine, and digital museum, in addition to the technologies of high resolution or large screen displays. To breakthrough the limitation of current color imaging systems, which are based on RGB, "Natural Vision (NV)" project has been exploiting the technologies for spectrum-based color reproduction, multispectral imaging, and multiprimary displays, until the project is completed on March 2006 as scheduled. Researchers from two academic institutes (Tokyo Institute of Technology and Chiba University) and industry (NTT Data, Olympus, NTT, etc.) are participated in the NV project, and have addressed the spectrum-based color reproduction technologies for still image (1999-2003) and motion picture (2001-2006). This paper summarizes the results of the seven years activity of NV project, including the multispectral and multiprimary imaging technologies and the experimental investigations on the applications to medicine, digital archives, electronic commerce, and computer graphics.

[Technologies]

In the NV system [1], spectral information is acquired by multispectral image capture to accurately reproduce the colors under arbitrary illuminant, which may be different from the image-capturing environment, as if the object is placed at the front of the observer. In the image display, the reproducible range of color (color gamut) is expanded by multiprimary color displays, in which more than three primary colors are mixed to represent color images.

NV project has developed 16-band multispectral camera for still image capturing, 6-band HDTV camera for motion picture acquisition [2], 6-primary color projection displays and 4-primary color flat panel LCD for wide-gamut color reproduction. For the

interchange between the image input and display systems with arbitrary number of channels, i.e., multispectral and multiprimary systems, the spectrum-based color reproduction system [1] and the natural vision data file format are proposed. The natural color reproduction in the real-time video system is also realized with the use of color conversion device, in which the newly developed multiprimary color conversion algorithm is implemented.

We have shown that the multispectral and multiprimary imaging system also enables to reduce the effect of observer metamerism, while the color difference due to the observer metamerism cannot be ignored in conventional trichromatic systems under colorimetric color reproduction.

[Experimental results and conclusion]

Experiments to investigate the feasibility and the applicability of NV system were carried out in the medical application such as dermatology and pathology, the color image capturing for graphic art printing, digital archives of artworks, cultural heritages [3] and natural scenes, textile and fashion industry applications with multispectral BRDF measurement, and the art expression using wide-gamut computer graphic systems. The effectiveness of the developed system has been confirmed through the experiments with the potential users of spectrum-based color reproduction.

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6062-17, Session 5

Encoding of spectra for multiple observers and multiple illuminants

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In this paper, the encoding of spectra is studied considering a variety of different observers on the one hand and a large set of standardized and non-standardized illuminants on the other. A number of 24 different observers has been defined including the CIE 1931 standard observer and the CIE 1964 supplementary standard observer as well as standard deviators. Others are selected with respect to largest differences from measurements published by Stiles and Burch. In addition, different illuminants are applied. Altogether, 52 illuminants are considered for reproducing color stimuli including such as D50, D55, D65, D75, A, B, C, E, and F1 to F12 as well as measured ones. So, this set contains illuminants with uniform spectral radiating power on the one hand and spiky power distribution on the other.

A number of different encoding methods has been tested by calculating color encoding errors for all combinations of observers, illuminants and a representative set of test spectra assembled from data of Vrhel and Pointer. The encoding methods considered are based on expansions into basis functions derived from original or pre-distorted test spectra, Fourier and sine series as well as expansions into modifications of the latter ones. Maximum as well as average errors are presented.

6062-18, Session 5

Spectral-based color reproduction for print illuminated by image projector

K. Ueda, S. Yamamoto, N. Tsumura, T. Nakaguchi, Y. Miyake, Chiba Univ. (Japan)

We propose a new color matching method between a proof and a target print by using a projection display system based on the spectral color reproduction. In this method, a color of proof is corrected by synthesizing a projection image which is calculated to minimize the color difference between each print. The radiance of the proof and the target print are calculated by using the reflectance of the prints and the radiance from the projector, and we use the method based on the XYZ tristimulus values (colorimetric method) and the spectral values (spectral-based method). We compared the color difference between the colorimetric method and spectral-based method. The average color difference was 4.00 by using the colorimetric method. On the other hand, the average color difference was 2.13 by using the spectral-based method. From these results, we concluded that the spectral-based method is more effective than the colorimetric method to perform the accurate color reproduction in synthesizing the projection color and the proof. We believe that the proposed method was significant to simulate and control the color of proof in the printing industry.

6062-19, Session 5

Spectral-based optimization of screen images for industrial product presentation

L. Härkönen, J. B. Martinkauppi, H. T. Laamanen, M. Hauta-Kasari, Joensuu Yliopisto (Finland); P. Huhtelin, P. Horttanainen, Tulikivi Oyj (Finland)

This paper presents a process used to optimize images for an industrial show room and its results. The selected show room is a quite typical one and therefore its light conditions are not very controllable. The projector used in the room is not a high quality one but its quality is quite standard for this kind of use. Color gamut (i.e. colors that the projector can produce) is good when compared against NTSC and sRGB gamut. The optimization of images is done using metameric reproduction and to do this we measure spectral information of the product (the soap stone tiles provided by the company, Tulikivi), projector and the illumination at the show room. The color temperature of the projector and prevailing room illumination were very different. Because they couldn't be adjusted to the same value this caused additional challenges. However, the spectral characteristic of the red channel of the projector was surprising: the range of possible red values was narrower than the green and blue range. This caused some limitations which needed to be taken into account in calculating the optimal images: optimal images can have either full contrast range with a reddish tint or correct hue with narrower contrast range.

6062-20, Session 5

Spectral gamuts and spectral gamut mapping

M. R. Rosen, Rochester Institute of Technology; M. W. Derhak, Onyx Graphics

All imaging devices have two gamuts: the stimulus gamut and the response gamut. The response gamut of a print engine is typically described in CIE colorimetry units, a system derived to quantify human color response. More fundamental than colorimetric gamuts are spectral gamuts, based on radiance, reflectance or transmittance units. Spectral gamuts depend on the physics of light or on how materials interact with light and do not involve the

human's photoreceptor integration or brain processing. Methods for visualizing a spectral gamut raise challenges as do considerations of how to utilize such a data-set for producing superior color reproductions. Recent work has described a transformation of spectra reduced to 6-dimensions called LabPQR. LabPQR was designed as a hybrid space with three explicit colorimetric axes and three additional spectral reconstruction axes. In this paper spectral gamuts are discussed making use of LabPQR. Also, spectral gamut mapping is considered in light of the colorimetric-spectral duality of the LabPQR space.

6062-21, Session 6

A technique for detecting metameric color areas for investigation of historical materials

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Historical materials tend to be very fragile, and thus, they need to be preserved from further degradations in future. Spectral reflectance includes a variety of objective and device independent information, which is sufficient for analysis of the materials for historical research and advanced investigation purposes. In addition spectral reflectance can be used for forecasting used restoration treatments, natural fading processes, and so on. This study introduces a technique with the use of spectral reflectance to investigate authentic historical materials.

In this paper, spectral reflectance is used to detect metameric areas in the materials. Metamerism is a well known phenomenon; two color stimuli are called metamers if they have the same tristimulus values but different spectral radiant power distributions. In the conservation and restoration of historical materials, evidence of previous restoration treatments provides important information. In such restoration treatments, colorants having metamerism relation to the original colorants could be used. Thus, metameric area could tell us which parts of an object have been possibly repainted. The spectral information of the historical materials is necessary to investigate the metamerism in the materials.

We have developed a spectral imaging system enabling the direct measurement of the spectral reflectance. The system was used for measurements of ten icons stored in University of Joensuu, Finland. All icons has been painted in the middle of the 19th century on wooden plate by using natural pigments. Each icon was placed on the sample holder perpendicular to the spectral camera. The light source was a simulated daylight source, and the icons were illuminated in 45-degree angle to their surface.

The measured spectral reflectance images were used for the investigation of metamerism. The CIE metamerism index shows the degree of metamerism of two objects having different spectra that match in color under a given illuminant. The CIE metamerism index is calculated in terms of the color difference observed between two objects but under another given illuminant. In this study, this concept is expanded to the spectral domain: the metameric areas in each icon image are detected by using a metamerism coefficient introduced in this study. The metamerism coefficient is calculated from color and spectral information between the reference pixel and test pixel in the spectral reflectance image. In the technique, a reference pixel is first set, and then metamers to the reference pixel are searched by pixel-wise procedure.

The performance of the proposed technique is confirmed by using a metamerism test chart, and applied to the ten authentic icons. The technique demonstrates sufficient performance for the test chart, however methods with scientific or chemical analyses such as use of the X-ray diffractometer are required to conclude whether the detected metamers are correct for the icons. As future works,

surface reflection property and color mixture model are necessary to enhance accuracy of the detection because the test chart has a flat surface with homogenous mixture of pigments, while the icons have uneven surfaces with complex structure of color pigments and their mixtures.

6062-22, Session 6

A scanning device for multispectral imaging of paintings

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A scanning device for 32-band multi-spectral imaging of paintings in the 380-800 nm spectral region is presented. The system is based on contact-less and single-point measurement of the spectral reflectance factor. Multi-spectral calculations are obtained by scanning the painted surface under investigation. An adjustment procedure was established and calibration was performed by means of a set of seven matt ceramic color tiles certified by National Physical Laboratory (UK). Colorimetric calculations were carried out in the XYZ colorimetric space, by following the CIE recommendations and choosing the D65 standard illuminant and the 1931 standard observer.

Measurement campaigns were carried out on several paintings in situ and at the INOA Optical Metrology Laboratory located inside the Opificio delle Pietre Dure in Florence. As an example we report herein on the measurements carried out on the Madonna in gloria tra Santi by Andrea Mantegna, at present in the Pinacoteca of the Castello Sforzesco in Milan. Multivariate image analyses (MIA) were performed by considering the multi-spectral images as three-way data set. The stack of detected images were unfolded in a 2D data matrix and analyzed by the conventional Principal Component Analysis (PCA).

6062-23, Session 7

Spectral video intraframe compression and database

J. P. Purmonen, M. Hauta-Kasari, J. Tuomela, Joensuu Yliopisto (Finland); M. Yamaguchi, M. Mitsui, Tokyo Institute of Technology (Japan); H. Fukuda, National Institute of Information and Communications Technology (Japan)

The multiband video camera and display system has developed to increase quality of the video image. The multiband means that there has more than three color channels. The new applications can be created by increasing the number of camera primaries, for example an influence of illumination can be fixed accurately. Furthermore, increasing number of primaries gives a good possibility for image and video processing. However, the growing amount of data causes problems for data transform, store, and process. In this paper, we introduce six band video capturing system and our spectral video database. In the database there is a lot of different type of video clips and the size of spectral video database is more than 300 giga bytes (GB). We also have developed compression scheme for spectral video based on principal component analysis (PCA) and JPEG2000 methods. Here, we concentrate to compress spectral video sequence frame by frame.

6062-24, Session 7

Real-time, multispectral, color acquisition and display using commodity hardware components

D. L. Lau, A. M. Tan, Univ. of Kentucky

The focus of this paper is on the broad extension of multi-spectral color to both scientist and consumer by creating camera/projector arrays composed of commodity hardware. In contrast to expensive, high-maintenance systems which rely on the physical registration of device spaces, we rely on the virtual alignment of viewing spaces in software where real-time alignment is achieved using the processing capacity of the graphical processing units of consumer PC video cards. Specifically, this paper focuses on the inclusion of real-time, composite pattern, structured light illumination (SLI) as a means of recording the 3D shape of objects, which will then be used for the registration of single-color images taken from multiple view points simultaneously. As such, the described system is able to achieve a cost per unit that scales linearly with the number of color primaries.

6062-25, Poster Session

Construction of multichannel camera gamuts

S. Helling, RWTH Aachen (Germany)

Device gamuts are commonly defined for output devices, such as monitors or printers. In this paper, a definition of gamuts of input devices will be examined, considering multispectral cameras as example. A method appropriate to calculate them as a function of the camera model and the spectral reconstruction algorithm will be proposed.

The method will be applied to multispectral camera models with a variable number of channels. The characteristics of the resulting gamuts will be shown and examined as a function of the number of channels. Implications on the minimum number of channels needed will be derived.

The method proposed here to characterize input devices can be used in addition to common quality criteria such as color distances like CIEDE00, spectral errors, etc. The advantage of the proposed method is the independence of any given spectral data set. This makes it a quality criterion universal for linear (multispectral) cameras and reconstruction algorithms.

6062-27, Poster Session

Importance of the texture features in a query from spectral image databases

O. Kohonen, M. Hauta-Kasari, Univ. of Joensuu (Finland)

A new, semantically meaningful technique for querying the images from a spectral image database is proposed. The technique is based on the use of both color- and texture features. The color features are calculated from spectral images by using the Self-Organizing Map (SOM) when methods of Gray Level Co-occurrence Matrix (GLCM) and Local Binary Pattern (LBP) are used for constructing the texture features.

The importance of texture features in a querying is seen in experimental results, which are given by using a real spectral image database. Also the differences between the results gained by the use of co-occurrence matrix and LBP are introduced.

It is shown that the texture features are quite a powerful addition to the earlier proposed searching techniques. In our tests the LBP-method seemed to work better than the co-occurrence matrix. However, there are still some things which have to be considered when combining the texture features together with the color features. The weighting of the different kind of features is one of those things as well as the case-specificity of the query images.

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6063-01, Session 1

Fast computation of free-form deformations in 3D images using FPGAs

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Free-form deformations, which use B-splines to model a three-dimensional curved space, are commonly used to model local deformation fields in elastic image registration algorithms. Fast computation of 3D deformation fields is critical to bringing the application of automated elastic image registration algorithms to routine clinical practice. However, it lies beyond the computational power of current microprocessors, therefore requiring implementations using either massively parallel computers or application-specific hardware accelerators. The use of massively parallel computers in a clinical setting is not practical or cost-effective, therefore making the use of hardware accelerators necessary. We present a hardware pipeline that allows accelerating the computation of 3D deformation fields to speeds up to two orders of magnitude faster than software implementations on current workstations and about 30 times faster than other previously reported architectures. The pipeline implements a version of the free-form deformation calculation algorithm, which is optimized to minimize the number of arithmetic operations required to calculate the transformation of a given set of neighboring voxels, thereby achieving an efficient and compact implementation in hardware which allows its use as part of a larger system. The B-spline control points are stored in internal, on-chip memory, thereby allowing fast, parallel accesses.

6063-02, Session 1

Toward real-time stereoscopic depth reconstruction in laparoscopic surgery

B. J. McCullagh, F. P. Shevlin, The Univ. of Dublin, Trinity College (Ireland)

In order to achieve near real-time frame rates, stereoscopic depth reconstruction applications have to use local methods, such as sum of absolute difference, rather than global methods, such as graph cuts. In this paper we propose some novel methods which will speed up correlation based methods so that more complex algorithms and disparity map refinement can be applied without reducing the frame rate.

Encoding a series of images as an MPEG-2 video sequence produces motion vectors relating 16x16 pixel regions of each frame with the previous frame. Encoding a stereo pair as an MPEG sequence provides a series of estimates which can narrow the search space for correlation type algorithms, decreasing the computation time. Extracting the motion vectors from the left or right sequence reveals areas of the scene that have remained unchanged, and can therefore retain the same disparity value. This is especially useful for applications where robotic arms are moving against an almost static background (laparoscopic surgery etc).

Programmable GPUs have attracted much attention recently and the implementation of some local methods and comparison of execution speed between CPU and GPU are discussed along with the decrease in computation time achieved using motion vectors.

6063-03, Session 1

Real-time wavelet denoising with edge enhancement for medical x-ray imaging

G. Luo, D. Osypiw, Buckinghamshire Chilterns Univ. College (United Kingdom)

X-ray image visualized in real-time plays an important role in clinical applications. The real-time system design requires that images with the highest perceptual quality be acquired while minimizing the x-ray dose to the patient, which can result in severe noise that must be reduced. The approach based on the wavelet transform has been widely used for noise reduction. However, by removing noise, high frequency components belonging to edges that hold important structural information of an image are also removed, which leads to blurring the features. This paper presents a new method of x-ray image denoising based on fast lifting wavelet thresholding for general noise reduction and spatial filtering for further denoising by using a derivative model to preserve edges. General denoising is achieved by estimating the level of the contaminating noise and employing an adaptive thresholding scheme with variance analysis. The soft thresholding scheme is to remove the overall noise including that attached to edges. A new edge identification method of using approximation of spatial gradient at each pixel location is developed together with a spatial filter to smooth noise in the homogeneous areas but preserve important structures. Fine noise reduction is only applied to the non-edge parts, such that edges are preserved and enhanced. Experimental results demonstrate that the method performs well both visually and in terms of quantitative performance measures for clinical x-ray images contaminated by natural and artificial noise. The proposed algorithm with fast computation and low complexity provides a potential solution for real-time applications.

6063-05, Session 2

Real-time high-level video understanding using data warehouse

B. Lienard, X. Desurmont, B. Barrie, J. Delaigle, Multitel A.S.B.L. (Belgium)

High-level Video content analysis such as video-surveillance is often limited by computational aspects of automatic image understanding, i.e. it requires huge computing resources for reasoning processes like categorization and huge amount of data to represent knowledge of objects, scenarios and other models.

This article explains how to design and develop a "near real-time adaptive image datamart", used, in a first time as mass storage, and in a second time as a decisional support system for vision algorithms. Using RDF specification to store data coming from vision algorithms, we can optimize the datawarehouse mechanism and add some processes able to adapt the current model and pre-process data to speed-up queries. In this way, when new data are sent to the datamart for long term storage, using object-oriented interfaces to simplified queries and given distributed computing feature, it is processed and in memory data-model is updated. After some processing possible interpretations of these data is returned back to the caller.

To demonstrate this new approach, we present typical scenarios applied to this architecture such as people tracking and events detection in a multi-camera network and we will show how this system becomes a high-semantic data container for external data-mining.

6063-06, Session 2

Video surveillance using distance maps

T. E. Schouten, H. C. Kuppens, Radboud Univ. Nijmegen (Netherlands); E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands) and Katholieke Univ./Nijmegen (Netherlands)

A distance transformation generates a distance map image in which the value of each pixel is its distance to a given set (O) of pixels. Different kind of surveillance parameters can be derived from the

distance maps. For example, lack of maneuvering space for moving objects can be noticed and, hence, risks on collisions can be minimized. However, such applications are only useful when real-time video processing can be utilized.

Exact ED maps cannot be obtained using local distances alone. Therefore, we have developed a Fast Exact ED (FEED) transformation where each pixel in O feeds its EDs to all pixels, which in turn take the minimum of all received EDs. Using several speed-up methods FEED proved to be the fastest exact Euclidean distance mapping currently available. For a sequence of frames where only some of the objects move, ED maps can be obtained even faster by saving suitable information from frame to frame.

Further methods have been developed for fast detection of fixed and moving objects and for determining the distance of each moving object to the other objects. For each controllable moving object its distance map to the other moving objects and to the fixed objects is determined.

6063-07, Session 2

Vehicle traffic video data real-time processing

M. Andrae, W. K. Cheng, Massachusetts Institute of Technology
Modified Particle Image Velocimetry (PIV) algorithms offer a computationally efficient method of extracting automobile traffic information from video images. In order to apply the PIV algorithms, the original image is reduced to a sparse image based on motion and edge detection. Then the PIV algorithms extract the velocity vector field from consecutive sparse images. These vectors are then segmented to identify individual vehicles. The speed of the algorithms allows this to be accomplished in real-time at normal video framing rate, thus eliminating the need to store or transmit large quantities of data for post-processing. To test the algorithms, data was collected from a busy 4-way urban intersection. The algorithms were able to extract from the images the number of vehicles, the direction of travel, the size of the vehicles, and the path the vehicles traveled over time in real time (at 15 frames per second). The PIV based algorithms were compared to a segmentation-based set of algorithms and were found to be much faster. Image quality was however found to have a significant impact on the algorithm accuracy.

6063-08, Session 2

Vehicle counting system using real-time video processing

P. Crisostomo-Romero, Pontificia Univ. Catolica del Peru (Peru)
Transit studies are of great importance for planning a road network with optimal vehicular flow. A vehicular count is essential. There are many methods to perform it, with their respective advantages and disadvantages in installation, reliability and cost. This article presents a vehicle counting system based on video processing. An advantage of such system is the greater detail that is possible to obtain in the shape, size and speed of vehicles. The presented system uses a video camera placed 6 meters above the street level. Fast image processing algorithms and small image dimensions are used to allow real-time processing. Digital filters, mathematical morphology, segmentation and other techniques are used to identify and count all vehicles in the image sequences. The system was implemented under Linux in a 1.8 GHz Pentium 4 computer. It obtains a successful count with frame rates of 15 frames per second for images of size 240x180 pixels and 24 frames per second for images of size 180x120 pixels, thus being able to count all the vehicles whose speeds do not exceed 150 km/h.

6063-09, Session 3

Real-time auto white balancing using DWT-based multiscale clustering

N. Kehtarnavaz, N. Kim, M. N. Gamadia, The Univ. of Texas at Dallas

Auto white balancing (AWB) involves the process of making white colors to appear as white under different illuminants in digital imaging products such as digital still cameras. This paper presents a computationally efficient auto white balancing algorithm for real-time deployment in imaging products. The algorithm utilizes DWT (discrete wavelet transform) to perform multi-scale clustering (MSC), thus generating a computationally efficient implementation of the original MSC algorithm. The paper also discusses the steps taken to allow running this algorithm in real-time on a digital camera processor. The results of an actual implementation on the Texas Instruments TMS320DM320 processor are provided to illustrate the effectiveness of this algorithm in identifying an illuminant as compared to the widely used gray-world auto white balancing algorithm.

6063-10, Session 3

Real-time antialiasing using adaptive directional filtering

P. Rokita, Politechnika Warszawska (Poland)

In this paper we present an enhanced real-time selective antialiasing solution. We propose to use a directional filtering technique as an antialiasing tool. The best post-processing antialiasing effect will be obtained if we apply the lowpass filter along local orientation of antialiased features. Previously authors proposed a complicated curve fitting method as a solution for the local feature antialiasing. Here we propose a more simple and efficient solution. Instead of using a curve fitting method based on second order intensity derivatives, we can use directly a set of first order derivatives applied on the z-buffer content. For each feature direction detected an appropriate directional Gaussian convolution filter can be applied. This way the lowpass filter is applied along local features selected for antialiasing, filtering out high frequency distortions due to intermodulation. In this approach the highpass convolution filtering applied on the z-buffer has a twofold application: it selects the objects edges that need to be antialiased and it gives a local feature direction allowing for edge reconstruction. The advantage of the approach proposed here is that it preserves texture details. Textures usually are filtered independently using trilinear or anisotropic filtering, which with traditional antialiasing techniques leads to overblurring.

6063-11, Session 3

A fast eye detector using corners, color, and edges

L. Chen, C. Grecos, Loughborough Univ. (United Kingdom)

Eye detection plays a central role in an automatic face detection systems and it is also important for human-computer interaction and face tracking. In this paper, we present a novel, unsupervised scheme for detecting eyes in skin patches based on our previous work on skin patch detection. Working on the normalized RGB color space, we use a combination of corner identification, color and edges as heuristics for eyes detection. The proposed scheme consists of four major steps. In the first step, a Harris corner detector is used to detect some points of interest in the skin patch. The second step is the detection of local gray pixels to build up a gray map. The third step is to build up an edge map of the image. The final step of our scheme is combining the Harris corners detected, edge map and the gray map to filter out useless corners,

and finally locate the eyes. Experimental results show that our scheme is very fast in the AR and Champion databases, while retaining very high detection rates.

6063-12, Session 3

Real-time construction of covariance matrices for arbitrary size image windows

F. M. Porikli, O. Tuzel, Mitsubishi Electric Research Labs.

We present a fast, integral image based algorithm to compute feature covariance matrices within all arbitrary size rectangular regions in an image. This technique significantly improves the computational load of covariance matrix extraction process by taking advantage of the spatial arrangement of points. Covariance is an essential measure of how much the deviation of two or more variables or processes match. In our case, these variables correspond to point features such as coordinate, color, gradient, orientation, and filter responses. Integral images are intermediate image representations used for calculation of region sums. Each point of the integral image is a summation of all the points inside the rectangle bounded by the upper left corner of the image and the point of interest. Using this representation, any rectangular region sum can be computed in constant time. We follow a similar idea for fast calculation of region covariance. We construct integral images for all separate features as well as integral images of the multiplication of any two feature combinations. Using these set of integral images and region corner point coordinates, we directly extract the covariance matrix coefficients. We show that the proposed integral image based method decreases the computational load to quadratic time.

6063-13, Session 4

High-performance VLSI architecture for adaptive scaling

P. P. Dang, STMicroelectronics

Scaling is one of the basic operations in image and video processing. It has been used in many consumer products such as printers, set-top boxes, flat-panel displays and high definition televisions (HDTV). In these applications, scaling algorithms are used to enlarge the images, which produce outputs for printers or display devices. This approach saves substantial amount of CPU time since other kernels in the application do not have to process large size input image.

Scaling algorithms, in general, are based on interpolation operation. Most of the classical scaling algorithms simply apply a single interpolation technique across the whole image. The outputs from this approach suffer from the artifacts of the blurring of edges, the ringing around the edges, loss of texture or details.

In this paper, we introduce an adaptive approach for image scaling. In addition, we present an efficient VLSI architecture to implement the proposed adaptive algorithm in hardware. The proposed algorithm is designed to reduce the artifacts, maintain the sharpness, and produce high-resolution outputs. Experimental results show that it works well for both image and video applications. In this paper, an efficient VLSI architecture was designed to address the real-time constrain for the consumer products.

6063-14, Session 4

Architecture for hardware driven image inspection based on FPGAs

J. Fuertler, J. Brodersen, Austrian Research Ctrs. GmbH - Seibersdorf (Austria); P. Roessler, Technische Univ. Wien (Austria); K. J. Mayer, Austrian Research Ctrs. GmbH - Seibersdorf (Austria); G. Cadek, C. Eckel, H. Nachtnebel, Technische Univ. Wien (Austria)

Requirements for contemporary print inspection systems for industrial applications include, among others, examination of fine details of the print, inspection from various perspectives and with different spectral sensitivity (visible, infrared, ultraviolet), as well as high throughput. Therefore, an optical inspection system for such tasks has to be equipped with several high-speed/high-resolution cameras, each acquiring hundreds of megabytes of data per second. This paper presents an inspection system which meets the given requirements by exploiting data parallelism and algorithmic gate arrays (FPGA) for image processing. The scalable system consists of several processing modules, each representing a pair of a FPGA and a digital signal processor. The main chapters of the paper focus on the functionality implemented in the FPGA. The image processing algorithms include flat-field correction, lens distortion correction, image pyramid generation, neighborhood operations, a programmable arithmetic unit, and a geometry unit. Due to shortage of on-chip memory, we use a multi-port memory concept for buffering streams of image data between off-chip and on-chip memories. Furthermore, performance measurements of the actual processing module and the whole system are presented. The paper concludes with an outlook to future projects.

6063-15, Session 4

Using a field programmable object array (FPOA) to accelerate image processing

S. Riley, P. Chiang, MathStar, Inc.

Digital signal processing has been widely used in the satellite, radar and other surveillance applications. The steadily growing size of the input data array and the sophisticated processing algorithms have continuously added more demand on processing power. The current solutions to these high power computing applications include fixed function ASICs or programmable FPGAs. The ASIC approach can deliver increased computing power but has a high cost, long development time and limited programmability. An FPGA offers the flexibility of modification and upgrades, but individual FPGAs often cannot deliver the required performance. This paper describes a system solution built around a Field Programmable Object Array (FPOA). The FPOA is a reconfigurable architecture that delivers the required high performance without sacrificing programmability. Example FPOA designs for various parts of a satellite image processing engine are described in this presentation. The performance of a complete digital signal processing space satellite application is provided to conclude this paper.

6063-16, Session 4

Novel windowing technique realized in FPGA for radar system

E. Escamilla-Hernández, Instituto Politécnico Nacional (Mexico); V. F. Kravchenko, Instituto Politécnico Nacional (Mexico) and Institute of Radio Engineering and Electronics (Russia); V. I. Ponomaryov, Instituto Politécnico Nacional (Mexico)

To improve the weak target detection ability in radar applications a pulse compression is usually used that in the case linear FM modulation can improve the SNR. One drawback in here is that it can add the range side-lobes in reflectivity measurements. Using weighting window processing in time domain it is possible to decrease significantly the side-lobe level (SLL) and resolve small or low power targets those are masked by powerful ones. There are usually used classical windows such as Hamming, Hanning, etc. in window processing. Additionally to classical ones in this paper we also use a novel class of windows based on atomic functions (AF) theory. For comparison of simulation and experimental results we applied the standard parameters, such as coefficient of amplification, maximum level of side-lobe, width of main lobe, etc.

To implement the compression-windowing model on hardware level it has been employed FPGA. This work aims at demonstrating a reasonably flexible implementation of FM-linear signal, pulse compression and windowing employing FPGA's. Classical and novel AF window technique has been investigated to reduce the SLL taking into account the noise influence and increasing the detection ability of the small or weak targets in the imaging radar.

Paper presents the experimental hardware results of windowing in pulse compression radar resolving several targets for rectangular, Hamming, Kaiser-Bessel, Up(x), Fup1(x), sigma(x), fup4,2(x)B2(x), Fup4(x)D3(x), Fup4(x)D3.5(x), Fup6,2(x)G2,2(x), Fup6(x)G3(x), Fup6,2(x)G3(x) functions windows. The windows created by use the atomic functions offer sufficiently better decreasing of the SLL in case of noise presence and when we move away of the main lobe in comparison with classical windows.

6063-17, Session 4

Real-time hardware for a new 3D display

M. Akil, B. Kaufmann, École Supérieure d'Ingénieurs en Électronique et Électrotechnique (France)

We are working on the study and the design of a new 3D display system based upon auto stereoscopy. To control and make the 3D device working, we need to generate appropriate images. These images will be generated from 3D data sent by a computer to the 3D image processing chain. This processing chain is composed by: 3D geometry, rasterization and voxels processing. In order to reach a speed suitable for real-time display (up to 30x3D frames per second projected to 200 different directions, which means 6,000 projected images per second), the use of a dedicated hardware is necessary. In this article, we focus our presentation on the voxels processing. For this step, we propose a new coding algorithm. We propose a dedicated hardware to implement efficiently this coding algorithm, because this is critical part of our 3D processing chain. The implementation uses chained lists to store depths and patterns. The voxels inside patterns are coded as a chained list to fasten the coding. We obtain a real time processing which is able to store data at 10MBx30 images per second. In this article we describe a dedicated architecture of the processing chain of our new 3D display. We also simulated and validated the coding hardware and the overall architecture chain by using system C and Visual Elite software tool.

6063-18, Session 4

A rapid prototyping methodology to implement and optimize image processing algorithms for FPGAs

M. Akil, P. Niang, T. Grandpierre, École Supérieure d'Ingénieurs en Électronique et Électrotechnique (France)

In this paper we present a seamless flow of transformations that leads to the generation of a complete VHDL design corresponding to the optimized implementation of image processing algorithms specified by Factorized and Conditioned Data Dependence (FCDD) graph model. The aim of our design flow based upon AAA/SynDEx extension is to implement a real-time application onto specific integrated circuits. This extension uses a Factorized (to specify Loop) and Conditioned (to specify if then else structure) Data dependence graph model, from the algorithm specification down to the architecture implementation, through optimization expressed in terms of defactorization (unrolling) transformations. This paper presents the transformation flow used by our methodology to automate the hardware implementation process of image processing algorithms onto reconfigurable circuits. We illustrate the proposed design flow for the hardware implementation on the Spartan XC2S100 Xilinx board of the image processing filters, edge detection operators (operators based on spatial convolution, Canny and Deriche algorithms), and DCT (cosine transform) and DCT-1 .

6063-19, Poster Session

An efficient illuminance-reflectance nonlinear video stream enhancement model

L. Tao, V. K. Asari, Old Dominion Univ.

An efficient real-time video stream enhancement algorithm based on illuminance-reflectance model is proposed for improving the visual quality of digital video streams captured under insufficient and/or non-uniform lighting conditions. The paper presents computational methods for estimation of scene illuminance and reflectance, adaptive dynamic range compression of illuminance, and adaptive enhancement for mid-tone frequency components. Adaptive illuminance enhancement is a global intensity transformation based on a Windowed Inverse Sigmoid (WIS) nonlinear transfer function, the curve shape of WIS is determined by its window range which is self-tuned by the histogram statistics of the input image. This process largely increases the luminance of darker pixels and compresses the dynamic range of the image at the same time. Due to the degradation of mid-tone frequency features caused by illuminance dynamic range compression, a power-function based adaptive mid-tone frequency enhancement is utilized as a compensation by tuning the frequency components of the image (in frequency domain) based on the magnitude of each pixel in spatial domain with respect to its neighboring pixel values, and this process is adaptively controlled by the global statistics of the image. This algorithm is an effective technique for image enhancement with simple computational procedures, which makes real-time enhancement for homeland security application successfully realized. It also demonstrates its robust and high quality performance while enhancing video streams.

6063-21, Poster Session

A novel two-pass hexagonal search algorithm for motion estimation

Y. Wu, The Univ. of Reading (United Kingdom)

This paper presents a novel two-pass algorithm constituted by Linear Hashtable Motion Estimation Algorithm (LHMEA) and Hexagonal Search (HEXBS) for block base motion compensation. On the basis of research from previous algorithms, especially an on-the-edge motion estimation algorithm called hexagonal search (HEXBS), we propose the LHMEA and the Two-Pass Algorithm (TPA). We introduce hashtable into video compression. In this paper we employ LHMEA for the first-pass search in all the Macroblocks (MB) in the picture. Motion Vectors (MV) are then generated from the first-pass and are used as predictors for second-pass HEXBS motion estimation, which only searches a small number of MBs. The evaluation of the algorithm considers the three important metrics being time, compression rate and PSNR. The performance of the algorithm is evaluated by using standard video sequences and the results are compared to current algorithms. Experimental results show that the proposed algorithm can offer the same compression rate as the Full Search. LHMEA with TPA has significant improvement on HEXBS and shows a direction for improving other fast motion estimation algorithms, for example Diamond Search.

6063-22, Poster Session

Real-time image processing based on robust linear combinations of order statistics

F. J. Gallegos-Funes, J. L. Varela-Benitez, V. I. Ponomaryov, Instituto Politécnico Nacional (Mexico)

In this paper we present the capability and real-time processing features of a new type of L-filter for the removal of impulsive and multiplicative noise in real-time image processing applications. The

proposed filter uses the robust RM-estimator in the filtering scheme of L-filter according with the RM-KNN filtering algorithms. Extensive simulation results in known reference images, and some medical and SAR images have demonstrated that the proposed filter consistently outperforms other filters by balancing the tradeoff between noise suppression and detail preservation. The criteria used to compare the performance or various filters were the PSNR, MAE, and processing time. The real-time implementation of proposed algorithm was realized on the DSP TMS320C6701. The processing time of proposed filter includes the time of data acquisition, processing and store data. We found that the processing time values of proposed filter depend of the image to process and do not practically vary for different complex noise level; these values depend also of the calculation of influence functions, parameters of the proposed filter, and different distribution functions used to calculate the coefficients of the new type of L-filter.

6063-23, Poster Session

A new concept of real-time security camera monitoring with privacy protection by masking moving objects

K. Yabuta, H. Kitazawa, T. Tanaka, Tokyo Univ. of Agriculture and Technology (Japan)

We present a novel framework for real-time encoding of images obtained by a security monitoring camera with protecting the privacy of moving objects in recorded images. We are motivated by the fact that although security monitoring cameras can deter crimes, they may infringe the privacy of those who and objects which are monitored by the cameras.

Two methods are proposed to make moving objects unrecognizable. One is the scrambling and the other is erasing in which moving objects are replaced by the corresponding background images. In order to reconstruct the original image, the moving object images are kept in a JPEG bitstream by using watermarking with encryption by the advanced encryption standard (AES). Therefore, a normal user using a JPEG viewer can only see masked images, where the moving objects are unrecognizable or completely invisible. Only a special viewer with a keyword can reconstruct the recorded images with the original objects. In the case where there are multiple moving objects, only a desired object can be decoded by using the moving object tracking information, while the other objects are kept unrecognizable.

Real-time processing was achieved by using distributed computing. The frame rate was nearly 10 frames/sec.

6063-24, Poster Session

Online monitoring for wood pieces on a moving conveyor belt

W. Wang, Chongqing Univ. of Posts and Telecommunications (China)

To make automation in different industrial applications, vision based system development is a kind of computer systems for auto-detection and monitoring of online input material and output products. In combustion industry or wood production industry, one kind of burning materials is waste wood pieces. This paper presents a Windows based system for image analysis and computer vision of wood piece materials. The system was designed for auto-detection of wood piece materials on a moving conveyor belt, and developed on Microsoft Windows on PC computer. To make the system work efficiently in the plant, we designed and developed a flexible Windows platform which mainly consists of image acquisition, image processing, wood piece delineation and analysis, and interface between different computers in use. Hundreds of functions for image analysis and statistics are included in the system, especially in the

wood piece delineation part. A number of newly-developed algorithms can delineate wood pieces with high accuracy and high speed, and in the wood piece analysis part, each wood piece can be characterized by 50-60 parameters that can also be used for constructing wood piece models directly in a Windows platform environment. The system makes online measurement easy. An online database is built in the system, making old measurement data easily checkable.

6063-25, Poster Session

A hardware-accelerated approach to computing multiple image similarity measures from joint histogram

C. R. Castro-Pareja, Intel Corp.; R. Shekhar, Univ. of Maryland/ Baltimore

A hardware-accelerated approach to computing multiple image similarity measures from joint histogram

Image similarity-based image registration is an iterative process that, depending on the number of degrees of freedom in the underlying transformation, may require hundreds to tens of thousands of image similarity computations to converge on a solution. Computation time often limits the use of such algorithms in real-life applications. We have previously shown that hardware acceleration can significantly reduce the time required to register two images. However, the hardware architectures we presented previously were limited to mutual information calculation, which is one of several commonly used image similarity measures. In this presentation, we will show how our architecture can be adapted for the calculation of other image similarity measures such as cross-correlation and rms difference in approximately the same time and using the same hardware resources as those for the mutual information case. As in the case of mutual information calculation, the joint histogram is calculated as a first step. Both cross-correlation and rms difference can be calculated with a single pass through the joint histogram, which normally takes only a small fraction (~1%) of the time required to calculate the joint histogram itself.

6063-26, Poster Session

Real-time human detection by shape and motion

H. Ran, Wuhan Univ. of Technology (China)

In this article, we concentrate on visible-spectrum vision systems for human figure detection that could be successfully implemented in cars for driver support in urban scenes or for autonomous driving. We present here a new classification based on the kind of approaches used in the first place to detect a candidate for a pedestrian, and secondly to recognise a person among the collected candidates and elimination of false positives by its motion. A first distinction among different methods is whether they distinguish two steps in the process (a true detection step and a recognition step) or do not. We first search the entire image for a pedestrian, most often relying on a shape based and multi-scale analysis for the upper body contour. The authors here report a high effectiveness in unpredictable environments, where background segmentation is complicated by uncontrollable variations of the scene. Preliminary experiments on this dataset of 6 videos showed detection rates ranging from 75%-90% with one false alarm per frame on an average. The implementation is quite robust to noise and occlusions.

6063-31, Poster Session

Uranus: an environment for rapid prototyping of real-time video processing based on FPGA

M. A. Nuño-Maganda, V. H. Rosales-Hernández, L. N. Castillo-Jimenez, G. Sosa-Ramírez, M. O. Arias-Estrada, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)

In this work a tool called URANUS for video processing algorithms prototyping is proposed. URANUS takes as input a set of image processing processes, coded in C or Handel-C Languages, and generates the equivalent set of processes mapped into a specific FPGA device. URANUS makes possible the data interchange between PC and FPGA by PCI, Ethernet, USB, Serial or Parallel Ports. The configuration parameters of each FPGA platforms are defined in URANUS. However, the interaction between PC and FPGA is transparent for the users, since the user only chains a set of a desired image processing algorithms. The implemented processes can have many types of input and output information. A high level of abstraction is used to generalize the algorithm implementation for making easy the Software to Hardware migration. A set of Hardware and Software libraries were developed, and final users can add their own processes following some guidelines. URANUS generates reports analysing the source code to migrate it to a specific hardware platform, such as execution time, time consumed in each function and number of operations. The platforms actually supported by URANUS are: Alphadata ADM-XPL and Celoxica RC200. An example of target tracking application is documented in this work.

6063-32, Poster Session

Determination of traffic intensity from camera images using image processing and pattern recognition techniques

M. Mehrubeoglu, Texas A&M Univ./Corpus Christi; L. McLauchlan, Texas A&M Univ./Kingsville

This paper investigates traffic intensity from webcam images. Images are downloaded from live traffic webcams from various highways or intersections at various intervals. Traffic intensity is investigated at different times of the day (currently daylight hours only) under various weather conditions.

Images are transformed into binary images using an adaptive threshold value based on the mean intensity of the region of interest (ROI) in each image. Areas outside ROI that are not part of the road and vehicles on the road are masked and excluded from processing to reduce processing time. Horizontal edges could be obtained from vehicles that corresponded to the intensity transitions across different parts of the vehicles and the road. Horizontal directional patterns were extracted using a 3X3 Prewitt's window. Extracted patterns (horizontal edges that were of predetermined length and width) were recognized using template matching. Once a single pattern was identified, a scaled area based on perspective vision around the location of the found pattern, was excluded from search for the next pattern to avoid detecting multiple patterns from the same vehicle.

Each matched pattern was considered to correspond to a vehicle. Traffic intensity was estimated from the number of vehicles identified by the algorithm.

Monday-Tuesday 16-17 January 2006

Part of Proceedings of SPIE Vol. 6064 Image Processing: Algorithms and Systems, Neural Networks and Machine Learning
6064A-01, Session 1

Affine invariant surface evolutions for 3D image segmentation

Y. Rathi, Georgia Institute of Technology; P. Olver, G. Sapiro, Univ. of Minnesota; A. R. Tannenbaum, Georgia Institute of Technology

In this paper we present an algorithm for 3D medical image segmentation based on an affine invariant flow. The algorithm is simple to implement and semi-automatic. The technique is based on active contours evolving in time according to intrinsic geometric measures of the image. The surface flow is obtained by minimizing a global energy with respect to an affine invariant metric. Affine invariant edge detectors for 3-dimensional objects are also computed which have the same qualitative behavior as the Euclidean edge detectors. Results on artificial and real MRI images show that the algorithm performs well, both in terms of accuracy and robustness to noise.

6064A-02, Session 1

Iterative Markovian estimation of mass functions in Dempster Shafer evidence theory: application to multisensor image segmentation

L. Bentabet, M. Jiang, Bishop's Univ. (Canada)

Mass functions estimation is a key issue in evidence theory-based segmentation of multisensor images. In this paper, we generalize the statistical mixture modeling and the Bayesian inference approach in order to quantify the confidence level in the context of Dempster-Shafer theory. We demonstrate that our model assigns confidence levels in a relevant manner. Contextual information is integrated using a Markovian field that is adapted to handle compound hypotheses. The multiple sensors are assumed to be corrupted by different noise models. In this case, we show the interest of using a flexible Dirichlet distribution to model the data. The effectiveness of our method is demonstrated on synthetic and radar and SPOT images.

6064A-03, Session 1

Progressive halftoning by Perona-Malik error diffusion and stochastic flipping

J. J. Shen, Univ. of Minnesota

Halftoning has been a significant topic in image processing due to many emerging applications, various diversified approaches, and challenging theoretical analysis. Inspired by the wealthy literature on halftoning, as well as the recent PDE (partial differential equations) approach in image processing, the current work proposes a novel progressive halftoning algorithm by emulating the celebrated anisotropic diffusion model of Perona and Malik (IEEE Trans. Pattern Anal. Machine Intell., 12:629-639, 1990), and a properly designed stochastic strategy for binary flipping. The halftone outputs from the proposed model are typical samples of some random fields, which share many virtues of existent deterministic halftone algorithms, as well as show many interesting features like the blue noise behavior. The new model is independent of traditional windows, tiles, or paths, and allows direct parallel implementation.

6064A-04, Session 1

Edge-based stochastic active contours for medical imaging

J. J. Trainsel, A. R. Tannenbaum, Georgia Institute of Technology

Active contour methods have proven to be a useful tool in medical image segmentation. Edge based methods while very popular have several problems including sensitivity to noise; indeed noise and secondary edges may act as local minima about which the evolving contour may get stuck. To overcome this issue, researchers have attempted to formulate models which integrate region-based terms and probabilistic models of the image. In this note, we propose a stochastic version of the geometric active contour for the segmentation of noisy medical imagery based on recent work on Stochastic Partial Differential Equations. The idea is to explicitly adding a stochastic perturbation to the evolution equation. The model has some nice advantages including the fact that one does not need to incorporate any prior knowledge of the image in order to segment the relevant structures. We indicate how to implement the introduction of a given stochastic perturbation in the level set framework, and described several noise models. Experimental results are provided on both real medical images and synthetic images and seem to demonstrate that adding a stochastic term improves the standard edge-based active contour methods by overcoming the problem of a contour being stuck at a local minimum.

6064A-05, Session 1

Multiple wavelet coherence analysis

S. C. Olhede, G. Metikas, Imperial College London (United Kingdom)

We propose a method for analysis of localised relationships between multiple images, that naturally treats the local phase structure and orientation of any variation in the observed images. The method is based on several nonseparable wavelet decompositions of the images. The set of mother wavelets is constructed by finding optimally concentrated orthogonal wavelet functions, and each isotropic wavelet is extended to a triplet of functions. The full set of wavelet transforms of two images can be used to extract local oscillatory components of the images present at a given spatial and scale point, and subsequently used to determine the local attenuation and phase shift between the two images. The determination of the local phase and orientation involves calculating the continuous wavelet transform of the images, then forming the scalogram matrix, and calculating the wavelet coherence.

Robust estimates of noisy images can be constructed by averaging over wavelet coefficients, extending Thomson's method to isotropic localised two-dimensional analysis, and we demonstrate the reduced variability in the estimators by this approach.

6064A-06, Session 1

New class of interpolation methods based on discretized lie group transforms

A. Zaratsyan, J. Patera, Univ. de Montréal (Canada); H. Zhu, York Univ. (Canada)

We propose a new class of interpolation methods for digital images using variants of the discrete group transform (DGT) recently developed by our group. The DGT is a transform of functions given on a finite region of the plane on a rank-2 simple Lie group as their expansions into series of special functions, called the C-functions (in recognition of the fact that the functions generalize cosine to any finite dimensions). The C-functions are orthogonal and readily discretized on lattices of appropriate symmetry and any density. The

traditional two-dimensional discrete cosine transform (DCT) is the simplest particular case of our transforms. Image processing using the DGT has shown successes in the military and medical applications.

The inferiority of the DCT interpolation is qualitatively understood as interpolation in only two orthogonal directions, the variants of the DGT defined on the other three rank-2 groups can invoke higher quality interpolations: 4 directions for square lattice (two orthogonal and two diagonal directions), 3 or 6 directions for triangular lattice. Therefore, interpolation through the DGT may substantially improve the quality of the interpolated image.

Here, the DGT is conceptually introduced and the potential of the DGT in interpolation is demonstrated, using square lattices for simplicity. Quantitative and qualitative comparisons of the interpolation using variants of the DGTs and some standard methods are presented. Both theoretical, as well as some real-world examples are used in the comparisons. The robustness of performance in the presence of noise is also investigated and their computational complexities are discussed.

6064A-07, Session 1

Optimization procedures for the estimation of phase portrait parameters in orientation fields

F. J. Ayres, R. M. Rangayyan, Univ. of Calgary (Canada)

Oriented patterns in an image often convey important information regarding the scene or the objects contained. Given an image presenting oriented texture, the orientation field of the image is the map that depicts the orientation angle of the texture at each pixel. Rao and Jain developed a method to describe oriented patterns in an image based on the association between the orientation field of a textured image and the phase portrait generated by a pair of linear first-order differential equations.

The optimization of the model parameters is a nonlinear, nonconvex optimization problem, and practical experience shows that irrelevant local minima can lead to convergence to inappropriate results. We investigated the performance of three optimization algorithms for the estimation of the best phase portrait parameters, for a given orientation field. The investigated algorithms were: nonlinear least-squares, linear least-squares, and simulated annealing. The algorithms are evaluated in terms of the error between the estimated parameters and the parameters known by design, in the presence of noise in the orientation field and imprecision in the initialization of the parameters. The computational effort required by each algorithm is also assessed.

6064A-08, Session 1

Optimized gradient filters for hexagonal matrices

T. Shima, S. Saito, Tokyo Institute of Technology (Japan); M. Nakajima, Tokyo Institute of Technology (Japan) and National Institute of Informatics (Japan)

In many cases, digital images are represented by square matrices. For instance, digital cameras, displays, and many systems for vision or image processing use square matrices to represent an image. Square matrices are not, however, the only placement method of pixels. Another placement can be found in, for example, the receptors of the human retina, where a hexagonal placement is observed.

In the case of square matrices, the distance between diagonal adjacent pixels is not equal to the one between off-diagonal adjacent pixels. Ando introduced consistent gradient filters to cope with this problem. These filters are derived to minimize inconsistency of gradient filters. In contrast, distances between any adjacent pixels

are the same for hexagonal matrices. The principal advantage of using hexagonal matrices is its isotropy from the perspective of pixel arrangement.

In this paper, we derive consistent gradient filters for hexagonal matrices following Ando's method to derive consistent gradient filters for square matrices. The resultant hexagonal consistent gradient filters are compared with square consistent ones. The results indicate that hexagonal consistent gradient filters are superior to square ones in consistency, in proportion of consistency to output power, and in localization.

6064A-09, Session 2

Super-fast Fourier transform

S. S. Agaian, O. Caglayan, The Univ. of Texas at San Antonio

The discrete Fourier transform (DFT) is the most widely used application in the signal and image processing, and the communication systems. The theory of trigonometric series can be dated back to the beginning of 18th century. In 1747, Euler represented the movements of the planets in the form of a trigonometric series, which actually contain what is now called the Fourier series. In 1807, Fourier discovered that a wide class of signals could be generated by summing scaled sine and cosine functions. Still in 21st century, discrete Fourier transform is one of the most widely applied tools in science and technology. The direct calculation of the DFT and the IDFT is computationally intensive and requires complex multiplications and complex additions. Such computational complexity has been quite costly in terms of reduced signal processing speed, increased power consumption, and higher expense. Therefore, it is natural to ask how we can reduce the arithmetical complexity of DFT. One important tool in modern digital signal processing applications that helps to reduce the high computational cost is the Fast Fourier Transform (FFT). In this paper, a new fast Fourier transform algorithm with linear multiplicative complexity is introduced for real or complex input signals. The proposed algorithm not only reduces the number of multiplications in the computation significantly, but also reduces the total number of operations (arithmetic complexity, which is the number of multiplications and additions) compared to the existing methods.

6064A-11, Session 2

A high-speed rotation method for binary document images based on coordinate operation of run data

Y. Shima, H. Ohya, Meisei Univ. (Japan)

The rotation of an image is one of the fundamental functions in image processing and is applied to document image processing in the office. A method of image rotation based on digital image data has been developed. This paper assumes the binary digital data, and proposes a method which is different from the traditional one based on pixel data. This method can execute a high-speed rotation of binary image based on coordinate data for the start and the end of the run. The image rotation at an arbitrary angle can be realized by the real number operation on the run data, which is suited to the personal processor. It is a practically useful method since the processing is fast and less memory capacity is required. In this paper, a discussion is made first on the format of the run data, the number of runs and the data complexity for the binary data. Then the newly devised rotation for the binary image is described. The rotation method is used to perform successively the skew coordinate transformations in the vertical and horizontal directions, to determine the rotated images. Finally, the processing time was examined to demonstrate experimentally the usefulness of the proposed method.

6064A-12, Session 2

A hardware implementation of the discrete Pascal transform for image processing

T. J. Goodman, M. F. Aburdene, Bucknell Univ.

The discrete Pascal transform is a polynomial transform with applications in pattern recognition, digital filtering, and digital image processing. It already has been shown that the Pascal transform matrix can be decomposed into a product of binary matrices. Such a factorization leads to a fast and efficient hardware implementation without the use of multipliers, which consume large amounts of hardware. We recently developed a field-programmable gate array (FPGA) implementation to compute the Pascal transform. Our goal was to demonstrate the computational efficiency of the transform while keeping hardware requirements at a minimum. Images are uploaded into memory from a remote computer prior to processing, and the transform coefficients can be offloaded from the FPGA board for analysis. Design techniques like as-soon-as-possible scheduling and adder sharing allowed us to develop a fast and efficient system. An eight-point, one-dimensional transform completes in 13 clock cycles and requires only four adders. An 8x8 two-dimensional transform completes in 240 cycles and requires only a top-level controller in addition to the one-dimensional transform hardware. Finally, through minor modifications to the controller, the transform operations can be pipelined to achieve 100% utilization of the four adders, allowing one eight-point transform to complete every seven clock cycles.

6064A-13, Session 3

Using clustering for document reconstruction

A. Ukovich, A. Zacchigna, G. Ramponi, G. Schoier, Univ. Degli Studi di Trieste (Italy)

The reconstruction of shredded or torn documents is a problem which may arise in the forensics and investigative science fields. Image processing techniques give the opportunity for a computer-aided reassembly. The visual content of the pieces is automatically extracted from the digitized remnants and it is represented by numerical features.

The problem of the reconstruction is NP-hard. Hence, approximate algorithms must be adopted for its solution. In order to keep down the computational complexity, we propose an approach based on a clustering strategy. The pieces originally belonging to the same page are first grouped together; the following search for the matching remnant is conducted within smaller subsets instead of within the whole set of remnants.

Three aspects must be taken into consideration for the clustering to be effective: the selection of suitable numerical features, the choice of the number of clusters, and the clustering algorithm used. We use low-level features related to the font format, the page layout, and the ink-background colours. The set of the most discriminating features may vary according to the specific dataset considered. The estimated number of clusters is related to the shredder used (number of remnants/page) and to the amount of blank remnants/page.

6064A-14, Session 3

Automatic detection and tracking of reappearing targets in forward-looking infrared imagery

A. Bal, M. S. Alam, Univ. of South Alabama

Target detection and tracking algorithms deal with the recognition of a variety of targets obtained from a multitude of sensor types such as forward-looking infrared (FLIR), synthetic aperture radar and laser

radar. There are many factors that must be accommodated by the detection and tracking algorithm such as target aspect variations caused by rotation of target or sensor operation (zoom, pan, tilt etc.), different weather conditions, cluttered background, and sensor noise. In addition, temporary disappearance and then reappearance in the field-of-view may be encountered during the tracking processes. To accommodate the above mentioned problems, it is important to develop a robust target model to overcome the problem of distinguishing similar target or non-target objects that already existed in the scene. Since the target history is known before target exiting the current frame, training based techniques have been developed using combination of two techniques; tuned basis functions (TBF) and correlation based template matching (TM) technique. The TBFs obtained for the target class are used to detect possible candidate target images. The detected candidate target images are then introduced into the second algorithm, called clutter rejection module, to determine the target reentering frame and location of the target. The performance of the proposed TBF-TM based reappearing target detection and tracking algorithm has been tested using real-world forward looking infrared video sequences.

6064A-16, Session 3

Robust human motion detection via fuzzy set based image understanding

Q. Li, J. You, The Hong Kong Polytechnic Univ. (Hong Kong China)

This paper presents image understanding approach to monitor human movement and identify the abnormal circumstance by robust motion detection for the care of the elderly in a home-based environment. In contrast to the conventional approaches which apply either a single feature extraction or a fixed object model for motion detection and tracking, we introduce a multiple feature extraction and a fuzzy set based image understanding scheme for robust motion detection. The proposed algorithms include 1) multiple image feature extraction including the fuzzy compactness based detection of interesting points and fuzzy blobs, 2) adaptive image segmentation via multiple features, 3) Hierarchical motion detection, 4) a flexible model of human motion adapted in both rigid and non-rigid conditions, and 5) Fuzzy decision making via multiple features.

6064A-17, Session 3

k-max: segmentation based on selection of max-tree deep nodes

A. G. Silva, S. C. Felipussi, G. L. F. Cassol, Univ. do Estado de Santa Catarina (Brazil); R. de Alencar Lotufo, Univ. Estadual de Campinas (Brazil)

This work proposes the segmentation of grayscale image from of its hierarchical region based representation. The Max-tree structure has demonstrated to be useful for this purpose, offering a semantic vision of the image, therefore, reducing the number of elements to process in relation to the pixel based representation. In this way, a particular searching in this tree can be used to determine regions of interest with lesser computational effort. A generic application of detection of peaks is proposed through searching nodes to k-up steps from leaves in the Max-tree (this operator will be called k-max), being each node corresponds to a connected component. The results are compared with the optimal thresholding and the H-maxima technique.

6064A-18, Session 4

Shape-adaptive DCT for denoising and image reconstruction

A. Foi, K. Dabov, V. Katkovnik, K. O. Egiazarian, Tampere Univ. of Technology (Finland)

The shape-adaptive DCT (SA-DCT) can be computed on a support of arbitrary shape, but retains a computational complexity comparable to that of the usual separable block DCT. Despite the near-optimal decorrelation and energy compaction properties, application of the SA-DCT has been rather limited, targeted nearly exclusively to video compression. It has been recently proposed by the authors to employ the SA-DCT for still image denoising. We use the SA-DCT in conjunction with the directional LPA-ICI technique, which defines the shape of the transform's support in a pointwise adaptive manner. The thresholded or modified SA-DCT coefficients are used to reconstruct a local estimate of the signal within the adaptive-shape support. Since supports corresponding to different points are in general overlapping, the local estimates are averaged together using adaptive weights that depend on the region's statistics. In this paper we further develop this novel approach and extend it to more general restoration problems, with particular emphasis on image deconvolution. Simulation experiments show a state-of-the-art quality of the final estimate, both in terms of objective criteria and visual appearance. Thanks to the adaptive support, reconstructed edges are clean, and no unpleasant ringing artifacts are introduced by the fitted transform.

6064A-19, Session 4

Anisotropic filtering with nonlinear structure tensors

C. A. Castaño Moraga, J. Ruiz-Alzola, Univ. de Las Palmas de Gran Canaria (Spain)

The main goal of anisotropic filtering schemes is to reduce noise at the same time that data structure is neither delocalized nor blurred. This idea, which seems very simple at a first glance, requires a lot of care when trying to put it into practice. Literature shows different approaches based on linear filters, PDEs or more sophisticated methods. Nevertheless, all of them are inspired on a common idea: to penalize smoothing along the direction of maximum signal variation while it is favored in the orthogonal one, which is the one of minimum signal variation. For instance, take the example of anisotropic approaches of linear filters. For these filters either the filter coefficients are estimated taking into account the directions of signal variation or the kernel shape is dynamically adapted to the local image features. In this paper, we propose an image processing algorithm which uses both choices.

To dynamically adapt the neighborhood to the image features, we propose the use of nonlinear structure tensor. This tensor was recently proposed in the literature and it is a generalization of the classical local structure tensor, where isotropic gaussian smoothing is substituted by a nonlinear diffusion process. In this way, a superior performance to determine signal orientation is obtained at the same time that the typical problems of gaussian smoothing, such as structure delocalization and blurring effect, are almost negligible. Thus, as structure delocalization is less blurred we will be able to better adapt the neighborhoods than using only the linear structure tensor. Size and shape of the neighborhood are estimated using the information provided by the eigenvectors and eigenvalues of this nonlinear structure tensor, which determine an ellipse associated to the quadratic form defined by the positive semidefinite structure tensor. In presence of boundaries or a predominant direction of signal variation, this ellipse is elongated along the orthogonal direction, that is, the one of minimum signal variation. In this way, samples inside the ellipse can be used to perform the estimation and we avoid to mix information from different areas of the image. On the other hand, under no predominant signal variation

the ellipse becomes rounder, so an isotropic estimation is achieved. This idea is quite general and it can be applied to any kind of linear filters, such as Wiener or constrained LMMSE, among others, setting the basis of an anisotropic filtering framework. Hence, to determine the filter coefficients we use an anisotropic gaussian kernel, also driven by the nonlinear structure tensor which weighs more the samples found along the direction of minimum signal variation.

Some encouraging results are also presented in this paper in order to show the performance of this approach from a qualitative point of view. A detailed analysis of the results reveals the superior performance of the proposed algorithm in comparison to other adaptive or anisotropic linear filtering schemes, since problems like noise reduction along boundaries or corner delocalization are reduced. In addition, we have set a good framework to be able to determine if the advantages of the nonlinear structure tensor have a positive influence on the filtered image. To do that, we compare the estimated images using the nonlinear structure tensor and the linear counterpart, showing significative differences which allow us to obtain remarkable conclusions. However, some work is still left on the submitted version of the manuscript, since a quantitative analysis of the results is required.

6064A-20, Session 4

A modified wavelet transformation based method of linear object extraction

T. Chen, Univ. of South Carolina

Edges can be characterized through the evolution of a wavelet transformation at different scale levels. A two-dimensional wavelet transformation of a given image is proportional to the gradient of a corresponding smoothed image. Each component of a normal two-dimensional wavelet transformation is in fact a one-dimensional wavelet transformation in one variable followed by a smoothing processing in the other variable. The modified wavelet transformation of the given image gets rid of the smoothing processing since the magnitude of the wavelet transformation in the center of a linear object may be increased by the big magnitudes of the wavelet transformation along the edges if the smoothing processing is adopted, which makes it hard to isolate the centerline of the linear object. The modified wavelet transformation gives high magnitudes along the edges and low magnitudes in the center of the linear objects in the wavelet-transformed image. In the image showing the magnitude of the wavelet transformation, there are high ridges along the edges of the linear objects and low grey level valleys bounded by the ridges. A suitable threshold can be used to extract the low grey level part of the image, such that the centerlines of the linear objects are included.

6064A-21, Session 4

2D approaches to 3D watermarking: state of the art and perspectives

M. P. Mitrea, S. A. Duta, F. J. Preteux, Institut National des Télécommunications (France)

When dealing with property right protection, watermarking becomes a useful solution, which can afford at the same time reliable owner identification and successful media pirate tracking down, while keeping the same commercial value for the considered piece of media (image, video, audio, 3D).

Watermarking can find a theoretical model within the communication theory framework, namely the noisy channel model. Image, video and audio signals have already taken advantage of such a theoretical model, with outstanding result. However, the 3D object watermarking has somehow been left behind. In order to bridge this gap, some studies tried to derive some virtual images (2D data) from the 3D objects. The present paper starts by establishing the overall performances and limitations of such approaches in terms of

transparency, robustness, and data payload. The reason for which the trade off among these three constraints has not yet been reached is determined and discussed. In order to solve this problem, an original 2D/3D watermarking method is further presented. The mark is embedded by an informed embedding approach. The object representation is a set of NURBS (Non Uniform Rational B Spline) surfaces. Firm results concerning robustness (with respect to both 2D and 3D specific attacks) and transparency are obtained, while increasing data payload (up to 20 bits embedded into a quite simple 3D object).

6064A-22, Session 4

Region-based perceptual grouping: a cooperative approach based on Dempster-Shafer theory

N. Zlatoff, B. Tellez, A. M. Baskurt, Univ. Claude Bernard Lyon 1 (France)

As segmentation step does not allow to recover semantic objects, perceptual grouping is often used to overcome segmentation's lacks. This refers to the ability of human visual system to impose structure and regularity over signal-based data. Gestalt psychologists have exhibited some properties which seem to be at work for perceptual grouping and some implementations have been proposed by computer vision. However, few of these works model the use of several properties in order to trigger a grouping, even if it can lead to an increase in robustness. We propose a cooperative approach for perceptual grouping by combining the influence of several Gestalt properties for each hypothesis. We make use of Dempster-Shafer formalism, as it can prevent conflicting hypotheses from jamming the grouping process.

6064A-23, Session 5

Study of muscular deformation based on surface slope estimation

M. Carli, M. Goffredo, M. Schmid, A. Neri, Univ. degli Studi di Roma Tre (Italy)

In this contribution, a novel technique to estimate the skin elasticity factor by using image processing techniques is presented. In human motion analysis, the evaluation of soft tissue deformations, both for clinical and for training purposes, is a relevant task. In non pathological conditions, muscles change shape and size due to contraction, and produce both skin tissue deformations and body shape alterations. In case of skin or muscular pathologies, the skin deformation is not natural, presenting non elastic areas: modelling body limbs with non rigid structures appears a striking solution to highlight this phenomenon.

In this paper reflectance models to estimate soft-tissue surface slope are exploited. Skin and muscular deformations are evaluated by analyzing video sequences: the soft tissue modeling is accomplished by using triangular meshes automatically adapting to the body segment. Starting from previous works of the authors the novel approach uses a non linear operator to locally highlight the spatial differences of luminance due to the contraction gesture. A colour map is then associated to the local expansion or contraction of each triangle. The proposed method has been successfully tested on several videos recorded during isometric contractions of biceps brachial.

6064A-24, Session 5

An automated diagnosis approach based on histopathological images

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In traditional cancer diagnosis, pathologists examine biopsies to make diagnostic assessments largely based on cell morphology and tissue distribution. However, this is subjective and often leads to considerable variability. On the other hand, computational diagnostic tools enable objective judgments by making use of quantitative measures. This paper presents a systematic survey of the computational steps in automated cancer diagnosis based on histopathology. These computational steps are: 1.) image preprocessing to determine the focal areas, 2.) feature extraction to quantify the properties of these focal areas, and 3.) classifying the focal areas as malignant or not or identifying their malignancy levels.

In Step 1, the focal area determination is usually preceded by noise reduction to improve its success. In the case of cellular-level diagnosis, this step also comprises nucleus/cell segmentation. Step 2 defines appropriate representations of the focal areas that provide distinctive objective measures. In Step 3, automated diagnostic systems that operate on quantitative measures are designed. After the design, this step also estimates the accuracy of the system. In this paper, we detail these computational steps, address their challenges, and discuss the remedies to overcome the challenges, emphasizing the importance of constituting benchmark data sets. Such benchmark data sets allow comparing the different features and system designs and prevent misleading accuracy estimation of the systems. Therefore, this allows determining the subsets of distinguishing features, devise new algorithms, and improve the success of automated cancer diagnosis.

Today, cancer constitutes a major health problem. Approximately one out of every two men and one out of every three women get cancer at some point during their lifetime. Furthermore, the risk of getting cancer has been further increasing due to the change in the habits of people in our century such as the increase in tobacco use, deterioration of dietary habits, and lack of activity. Fortunately, the recent advances in medicine have significantly increased the possibility of curing cancer. However, the chance of curing cancer primarily relies on its early diagnosis and the selection of its treatment depends on its malignancy level. Therefore, it is critical for us to detect cancer, distinguish cancerous structures from the benign and healthy ones and identify its malignancy level.

Traditionally, pathologists use histopathological images of biopsy samples removed from patients, examine them under a microscope, and make judgments based on their personal experience. While examining such images, a pathologist typically assesses the deviations in the cell structures and/or the change in the distribution of the cells across the tissue under examination. However, this judgment is subjective, and often leads to considerable variability. To circumvent this problem and improve the reliability of cancer diagnosis, it is important to develop computational tools for automated cancer diagnosis that operate on quantitative measures. Such automated cancer diagnosis facilitates objective mathematical judgment complementary to that of a pathologist, providing a second opinion for patients.

Over the last two decades, a tremendous amount of research work has been conducted for automated cancer diagnosis. This is partly because automated cancer diagnosis holds great promise for large-scale use in the advanced cancer treatment and partly because automated cancer diagnosis is not a straightforward task, with a number of challenges to be overcome. The first challenge is the noise elimination in the task of determining the focal areas in the image. The noise arises from staining the biopsy samples; uneven distribution of stain usually cause problems in processing the stained material. In the case of focusing on the properties of nuclei/

cells in the image, the second challenge is the nucleus/cell segmentation. This is challenging because of the complex nature of the image scenes (e.g., touching and overlapping cells) and the noise (e.g., stain artifacts). The third challenge is the feature selection to represent a cell/tissue in the task of cellular or tissue-level property quantification. The features should provide distinguishing quantitative measures to automatically diagnose the cancer. The last important challenge is the system evaluation in the task of diagnosis. Due to the limited amount of available data, there might be a considerable amount of bias if the system evaluation is not conducted properly.

6064A-25, Session 5

Variational segmentation of x-ray image with overlapped objects

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Image segmentation is a classical and challenging problem in image processing and computer vision. Most of the segmentation algorithms, however, do not consider overlapped objects. Due to the special characteristics of X-ray imaging, the overlapping of objects is very commonly seen in X-ray images and needs to be carefully dealt with. In this paper, we propose a novel energy functional to solve this problem. The Euler-Lagrange equation is derived and the segmentation is converted to a front propagating problem that can be efficiently solved by level set methods. We noticed that the proposed energy functional has no unique extremum and the solution relies on the initialization. Thus, an initialization method is proposed to get satisfying results. The experiment on real data validated our proposed method.

6064A-26, Session 5

Image segmentation for automated dental identification

E. Haj Said, D. E. M. Nassar, H. H. Ammar, West Virginia Univ.

Dental features are one of few biometric identifiers that qualify for postmortem identification; therefore, creation of an Automated Dental Identification System (ADIS) with goals and objectives similar to the Automated Fingerprint Identification System (AFIS) has received increased attention. As a part of ADIS, teeth segmentation from dental radiographs films is an essential step in the identification process. In this paper, we introduce a fully automated approach for teeth segmentation with goal to extract at least one tooth from the dental radiograph film. The approach is based on performing series of convolution filtering operations using point spread function (PSF) and grouping the pixels based on their connectivity and geometrical properties in order to label each individual tooth.

We evaluate our approach based on theoretical and empirical basis. Testing results of segmenting 500 dental radiographs film show that the optimality and the failure rate of our approach are 30.4 % and 1.141% respectively, where the optimality and failure rate percentages capture instances of extreme performance of the segmentation approach. The results show that our approach exhibits the lowest failure rate and the highest optimality among all full automated approaches proposed in the literature.

6064A-27, Session 6

Deblending of the UV photometry in GALEX deep surveys using optical priors in the visible wavelengths

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Since 2004 the GALEX mission of NASA, is collecting a large set of astronomical UV imaging data in far (~1500A) and near (~2300A) UV wavelengths. The GALEX images have a typical PSF with an FWHM~5arcsec, higher than the optical PSF which reaches currently sub arcsec quality. This difference in resolution introduces ambiguities, miss match and wrong UV flux attribution to the optical counterparts, especially in GALEX deep fields with long exposure time (>~10000sec). To overcome this problem, we present a new algorithm which allows to measure the UV photometry, through a bayesian approach working in the Poisson noise regime, and using as priors the position and morphological parameters of the optical sources and the GALEX's PSF. This method maximizes the likelihood and generates a set of non-linear equations which are solved using an EM algorithm. For feasibility reasons, since GALEX covers a large field of view (Diam~1.2 deg) with approximately 30000 objects, a segmentation procedure has been defined to manage the analysis in a tractable form. The optical field is thresholded to define a large set of ROIs which are managed with a line adjacency graph (LAG) algorithm. This allows to generate a set of tractable subfields with no interdependency to be analyzed independently in series or concurrently in parallel. In the present paper, we will describe in detail the method and the performances of the UV flux reconstruction algorithm using the optical priors as well as the methodology to handle the original GALEX image and produce the UV source extractions.

6064A-28, Session 6

Comparative study of logarithmic enhancement algorithms with performance measure

E. J. Wharton, Tufts Univ.; S. S. Agaian, The Univ. of Texas at San Antonio; K. A. Panetta, Tufts Univ.

Performance measures of image enhancement are traditionally subjective and don't quantify the improvement made by the algorithm. Even today, enhancement performance is judged by human observation for many applications. Traditional enhancement measures suffer from the fact that they rely on linear measures of contrast and entropy. This can give preference to images with a large amount of contrast but little useful information because it only considers the total amount of information possible in the image. This could be improved if the measure was biased towards how the human eye sees the image. These shortcomings led to the investigation of the AMEE measure based on entropy.

The AMEE based on entropy uses the Michelson contrast, which is better suited for real images than the Weber contrast, which is used by our EME measure. This is because it assumes a periodic pattern as opposed to a small test target at the center of a large uniform background. In this paper, we demonstrate the logarithmic AMEE measure and show how utilizing logarithmic based addition, subtraction, and multiplication provides better results than previously used measures. Finally, we will present a comprehensive study of several enhancement algorithms from all three domains using our measure.

6064A-29, Session 6

MMW video sequence denoising and enhancement in concealed weapons detection applications

X. Wei, H. Chen, The Univ. of Texas at Arlington; P. K. Varshney, Syracuse Univ.

In this paper, we have developed an adaptive algorithm to improve the quality of MMW video sequence by separating the video into foreground region and background region, and handle them differently. We separate the foreground from background area by using an adaptive Kalman filtering. The background is then denoised by both spatial and temporal algorithms. The foreground is denoised by the block-based motion compensational averaging, and enhanced by wavelet-based multi-scale edge representation. Finally further adaptive contrast enhancement is applied to the reconstructed foreground. The experimental results show that the results of our algorithm can achieve smoother background, more reduced noise, more enhanced foreground and higher contrast of the region of interest.

6064A-30, Session 6

Image denoising with block-matching and 3D filtering

K. Dabov, A. Foi, V. Katkovnik, K. O. Egiazarian, Tampere Univ. of Technology (Finland)

We present a novel approach to still image denoising based on two widely adopted techniques: sliding-window transform processing and block-matching. The latter is predominantly used in video coding to find blocks which follow the motion of objects between consecutive frames. We process blocks within the image in a sliding-window manner and utilize the block-matching concept by searching for variable number of nearby blocks similar to the currently processed one. The matched blocks are stacked together to form a 3D array and due to the similarity between them, the data in the array exhibits high level of correlation. We exploit this correlation by applying a 3D decorrelating unitary transform and attenuate the noise by shrinkage of the transform coefficients. The subsequent inverse transform yields local estimates of the matched blocks. After processing all blocks, the final estimate is a weighed average of all overlapping local ones. We provide experimental results which show that the proposed method delivers highly competitive performance to the state-of-art denoising techniques both in terms of objective criteria and visual quality.

6064A-31, Session 6

An algorithm for the enhancement of images of large dynamic range

F. Hassan, J. E. Carletta, Univ. of Akron

This paper introduces an algorithm for the enhancement of images of large dynamic range. The algorithm addresses a fundamental problem in digital imaging: the mismatch between the dynamic range of the images as captured by sensors and the dynamic range of the devices on which the images are displayed. This mismatch results in poor quality imaging when images have regions of different illumination; it is difficult to choose a single dynamic range for displaying these images that shows the information in all regions. The proposed algorithm provides not only dynamic range compression, but also separate brightness and contrast control. The algorithm does dynamic range compression by applying a log transformation to the pixel intensity. The transform makes it easier to separate out the illumination and reflectance components of the intensity. We accomplish the separation by applying the biorthogonal 9/7 discrete wavelet transform, which is the basis of the JPEG2000 image compression standard. Illumination information

is concentrated in the approximation subband, while reflectance is concentrated in the details subbands. The algorithm controls brightness by scaling the approximation subband, and contrast by scaling the details subbands. After application of the algorithm, the image can be either reconstructed, or compressed using JPEG2000.

6064A-32, Session 6

Nonlinear image enhancement to improve face detection in complex lighting environment

L. Tao, M. Seow, V. K. Asari, Old Dominion Univ.

A robust and efficient image enhancement technique has been developed to improve the visual quality of digital images that exhibit dark shadows due to the limited dynamic ranges of imaging and display devices which are incapable of handling high dynamic range scenes. The proposed technique processes images in two separate steps: dynamic range compression and local contrast enhancement. Dynamic range compression is a neighborhood dependent intensity transformation implemented by a nonlinear transfer function defined as the positive side of a hyperbolic tangent function. The slope of the nonlinear function is tuned based on the statistical characteristics of the input image. A neighborhood dependent local contrast enhancement method is then used to compensate the image contrast degraded from the first step by nonlinearly increasing the local intensity variation, which is transformed using a power function with an exponent based on the ratio of the original intensity and the enhanced luminance. Color rendition of the enhanced images is consistent with those of the input image by a linear color re-mapping, which is based on the assumption of consistent ratio between the original and enhanced V component in the HSV color space.

Experimental results on the proposed image enhancement technique demonstrates strong capability to improve the performance of convolutional face finder compared to histogram equalization and multiscale retinex with color restoration without compromising the false alarm rate.

6064A-33, Poster Session

Noise image enhancement on Hölder function spaces

M. Lee, National Taiwan Ocean Univ. (Taiwan)

In this project, we introduce a novel method for restoring noisy images that requires no noisy model. The proposed method is inspired by a wavelet-based switching smoothness description of Hölder function spaces. We start with a one-dimension signal, expand the signal on a wavelet basis in Hölder function spaces, and demonstrate how to locally switch the smoothness of a signal. Later, combining the wavelet localization property with adjusting the images Hölder smoothness, a tool is derived for image enhancement that improves the image quality. We also discuss simulation comparisons with the conventional deconvolution method, which emphasizes the simplicity of the proposed method. Despite the simplicity of our method, significant improvement is reported in the experiment results in terms of image fidelity measure and visual effect.

6064A-34, Poster Session

Ad hoc segmentation pipeline for microarray image analysis

S. Battiato, G. Di Blasi, G. M. Farinella, G. Gallo, G. C. Guarnera, Univ. di Catania (Italy)

DNA microarray is a fundamental biotechnology for genes expression profiling and biomedical studies. Image analysis has

found application in microarray technology because it is able to extrapolate new and not trivial knowledge that is partially hidden in the images. In microarray experiments, two 16-bit TIFF images are obtained by using microarray scanners. The two images are processed to extrapolate data and quality measures by the following steps: gridding, segmentation, intensity extraction and quality measures. Segmentation is a crucial step: it has a potentially large impact on subsequent analysis (e.g. clustering). In this paper we describe MISP (Microarray Image Segmentation Pipeline), a new segmentation pipeline for Microarray Image Analysis. MISP uses a recent segmentation algorithm based on statistical analysis. The Spot masks produced by MISP are used to derive spots information and quality measures. A software prototype system has been developed; it includes visualization, segmentation, information and quality measure extraction. Experiments show the effectiveness of the proposed pipeline both in terms of visual accuracy and measured quality values. Comparisons with existing solutions (e.g. Scanalyze software) confirm the improvement with respect to previously published solutions.

6064A-35, Poster Session

Color transient improvement via range detection

G. S. Shin, M. G. Kang, Yonsei Univ. (South Korea)

In broadcast system, the image information is transmitted in the form of luminance and color difference signals. The color difference signals usually undergo blurs by the several reasons and result in smooth transition. It is important for the CTI algorithm not to produce color mismatch in the smooth transition as well as to make sharp transition. In this paper, the new CTI algorithm which only needs to determine the transition range is proposed. Since the corrected signal does not rely on the high-frequency values, it does not reveal over- and undershoot near edges. To prevent the color mismatch, transition range is found on only one color difference channel. Experimental results show that our algorithm corrects blurred color edges well and is robust to the input images.

6064A-36, Poster Session

For fast classification and segmentation of high-resolution images of multiple and complicated colonies

W. Wang, Chongqing Univ. of Posts and Telecommunications (China)

When colony counting by using an automated image analysis system, it reduces whole cost by approximately 75%. The previous systems, by using an ordinary CCD camera (e.g. b/w camera with resolution up to 768x576), cannot detect the small and tiny colonies (say, the size is less than 0.4 mm). When using the high resolution digital camera, e.g. the image resolution is 2560x1920x24bits (up to 4000x4000x24bits), the information volume is at least 21 times than that from a b/w CCD camera. If we still use the previous process structure or sequence, its low speed cannot meet the automation requirements. This paper presents a methodology for high resolution image classification and segmentation. The size and information volume of the images, taken by a high resolution digital camera, will be tens to hundreds times as the ones taken by an ordinary CCD camera. In order to speed up the image segmentation process of the large images, we classify the images first by using a low resolution image, then, segment them by a fast segmentation algorithm. The algorithm is studied mainly based on multi-resolution technique and the fusion of edge detection result and similarity segmentation result. By use this methodology, the whole image segmentation process time is reduced by tens' times than traditional segmentation methods. And the accuracy of the image segmentation is not decreased.

6064A-37, Poster Session

Spatially adaptive multiresolution multispectral image fusion based on Bayesian approach

J. H. Park, M. G. Kang, Yonsei Univ. (South Korea)

In this paper, we propose two image fusion algorithms based on Bayesian framework for resolution enhancement of remotely sensed multi-spectral images. For both of the algorithms, we acquire a linear MMSE estimator which depends on the first two moments of the joint probability density function (PDF) of the two data. The estimation is performed in a local region which is considered to be stationary. The critical part of the fusion which dominates the performance of algorithms is the estimation process of the first two moments which are used as parameters for fusion. Both of the algorithms consider the local non-stationary nature of images by employing spatially adaptive windows. In the first algorithm, we simplify the process by assuming that the pixels are uncorrelated to each other. To consider the non-linear and spatially non-stationary characteristics of images, we use a spatially adaptive weight function in the parameter estimation. The second algorithm considers the correlation between the pixels in the neighborhood. Through these procedures, the proposed algorithms prevent spectral distortion as much as possible and sharpen the multi-spectral images simultaneously. Experimental results visually illustrate the benefit of the proposed methods when compared to traditional image fusion methods.

6064A-38, Poster Session

Segmentation of microspheres in ultrahigh density microsphere-based assays

A. Mathur, D. M. Kelso, Northwestern Univ.

We have developed a method to identify and localize luminescent microspheres in dense images of microsphere-based assays. Application of this algorithm to the images of densely packed microspheres would aid in increasing the number of assays per unit target sample volume by several orders of magnitude. We immobilize or sediment microspheres on microscope slides and read luminescence from these randomly arrayed microspheres with a digital imaging microscope equipped with a cooled CCD camera. Our segmentation algorithm, which is based on marker-controlled watershed transformation, is then implemented to segment the microsphere clusters in the luminescent images acquired at different wavelengths. This segmentation algorithm is fully automated and require no manual intervention or training sets for optimizing the parameters and is much more accurate than previously proposed algorithms. Using this algorithm, we have accurately segmented more than 97% of the microspheres in dense images.

6064A-39, Poster Session

Discrete Gould transform and its applications

M. F. Aburdene, H. M. Le, Bucknell Univ.

We present a new discrete transform, the Gould transform (DGT) and its applications. The transform has many interesting mathematical properties and potential applications. For example, the forward and inverse transform matrices are both lower triangular, with constant diagonals and sub-diagonals and both can be factored into the product of binary matrices.

We applied the transform to edge detection and cryptography. The forward transform can be used to detect edges in digital images. If G is the forward transform matrix and y is the image, then the two dimensional DGT, GyGT can be used directly to detect edges. Ways to improve the technique is to use the "combination of forward and

backward difference”, GT(Gy) to better identify the edges. For images that tend to have vertical and horizontal edges, we can further improve the technique by shifting rows (or columns), and then use the technique to detect edges, essentially applying the transform in the diagonal directions. The DGT might have some potential applications in the field of cryptography.

6064A-40, Poster Session

The application of image filters combined with the nonlinear regression analysis on optical autofocusing

M. Lee, W. Hsu, National Kaohsiung Normal Univ. (Taiwan); T. Lin, National Taiwan Univ. (Taiwan)

This paper presents an optical auto-focusing system that is implemented by integrating a real-time auto-focusing algorithm, an image capturing and processing module and a stepper motor. Several image filters are tested and compared through the system for their effects on suppressing noise to accelerate the auto-focusing procedure. Besides, a nonlinear regression method is applied in the data analysis for the system to quickly move the stepper motor to the focus. The concise and effective algorithm can be applied on digital cameras for auto-focusing with noise reduction.

6064A-41, Poster Session

Crease enhancement and the segmentation of topographic images

H. C. Morris, San José State Univ.

A topographic image can be viewed as a field of ridges and valleys, the gray level representing the altitude; a low gray level is regarded as corresponding to a low altitude, and higher gray levels to higher altitudes. In this paper we present techniques, based on nonlinear diffusion methods, that facilitate the de-noising and segmentation such topographic images. The methods we develop are particularly useful for the analysis of images that display a complex crack structure such as those of planetary surfaces or crystals. There are many works devoted to the extraction of ridge-valley structure. Gaussian de-noising is not appropriate as it destroys the highly oriented textures that we seek to analyze. An alternative is to use anisotropic diffusion filters. However, an undesirable effect of diffusion filters is that ridge-valley junctions are destroyed and non-linear structures are deformed. In this paper we implement a crease-enhancement diffusion based on the image structure tensor. Our method makes possible to close interrupted linear structures and enhances reliable linear structures. This paper provides a basic review of the mathematics behind crease-enhancing diffusion. It is also shown that the method can also implement a form of grayscale morphology.

6064A-43, Poster Session

A multiscale approach to contour detection and texture suppression

G. Papari, Rijksuniv. Groningen (Netherlands); P. Campisi, Univ. degli Studi Roma Tre (Italy); N. Petkov, Rijksuniv. Groningen (Netherlands); A. Neri, Univ. degli Studi Roma Tre (Italy)

In this paper we propose a multiscale biologically motivated technique for contour detection and texture suppression. Standard edge detectors reacts to all the local luminance changes, irrespective whether they are due to the contours of the objects represented in the scene, rather than to natural texture like grass, foliage, water, etc. Moreover, edges due to texture are often stronger than edges due to true contours. This implies that further process is needed to discriminate true contours from texture edges. In this contribution we exploit the fact that, in a multiresolution analysis, at

coarser scales, only the edges due to object contours are relevant and that texture disappears. This is used in combination with surrounding inhibition, a biologically motivated technique for texture suppression, in order to build a contour detector which is insensitive to texture. Experimental results have also pointed out that our approach is robust to additive noise.

6064A-44, Poster Session

A heuristic approach for the extraction of region and boundary of mammalian cells in bio-electric images

L. Tao, V. K. Asari, Old Dominion Univ.

A robust segmentation and tracking technique for the extraction of region and boundary of mammalian cells in bio-electric images is presented in this paper. The proposed algorithm consists of three steps. The first step is an image enhancement process composed of low-pass filtering and local contrast enhancement. The low-pass filter employs a circular disk operator to suppress the noise. A linear ‘high-boosting’ based algorithm is proposed to enhance the luminance of cell objects with respect to the background. The ‘degree factor’ * introduced for adjusting the contrast degree is the exponential base of the ‘inverse mean’ of the difference of the original and the low-passed image. The second step employs recursive global adaptive thresholding method based on the statistical information of the contrast enhanced image to separate cells from the background. Due to the efficient image enhancement produced in the previous step, global adaptive thresholding is sufficient to provide satisfactory image thresholding results with all cell objects successfully segmented and minimum connections created among adjacent cells. The final step in the segmentation process is composed of boundary tracking and morphological measurement for cell detection. A new robust boundary tracking algorithm using only one searching window with considering boundary tracking route history is proposed to provide rapid and accurate object boundary tracking results. This boundary tracking strategy determines the location of the next boundary pixel by examining the location of the previous boundary pixel and neighboring pixels of the current pixel. This one-window tracking strategy can be summarized and simplified by considering only three cases which will cover all the possibilities without discriminating left-side or right-side searching. This boundary tracking method proves robust performance for any size and complex shaped objects. The tracked boundaries are automatically labeled individually corresponding to the sequence of tracking while they are being searched. Morphological measurements of object perimeter P and area S are obtained after labeling. Mammalian cell decision is implemented based on the areas and the values of form factors of the objects. For the non-cell objects whose areas fall into the range of other cells, the value of object form factor will be considered for comparing to a standard circle.

6064A-45, Poster Session

Lip segmentation and tracking for facial palsy

M. Park, J. Seo, K. S. Park, Seoul National Univ. (South Korea)

We developed the asymmetry analyzing system for facial palsy patient’s rehabilitation progress study. Using PC standard imaging device, captured 640*480 RGB image is converted into HSV space. A Lip-shape mask is extracted by thresholding. By taking 5 regions consisted in one region on lip and four regions on face skin, reasonable thresholds are determined by Fuzzy C-Means clustering. The extreme points on the lip shape mask are extracted to get the seeds for tracking.

Segmented seed points are tracking by Iterative Lucas-Kanade tracking method in pyramids at 30 fps and recording simultaneously.

To reduce the disk writing load on computer, we use asynchronous mode file writing, which is going to transfer to and review by clinician. Tracking shows quite reliable results, but sometimes the tracked points are following along the lip line because of the similar contrasts. Therefore, the first strategy to improve the reliability of tracking is using the high contrast points, such as left and right maximal point of lip shape. The second is clustering some points near the maximal points and eliminating outlying tracking points. The third is rechecking the lip shape using lip segmentation when the operator confirms that subject's maximal lip moving. Left and right tracking points are compared in forms of trajectory plot.

6064A-46, Poster Session

A multithreshold algorithm based on intensity distribution

D. Chen, M. Sarhadi, Brunel Univ. (United Kingdom)

In current automatic threshold algorithms, the global feature statistic information is used to obtain the threshold to segment or to convert images into binary formats in vision inspection. The main shortcoming of all above algorithms is that they are often designed to process ideal images in laboratory conditions and are not suitable for real world images resulting from industrial environments with uneven illumination distributions.

A new automatic threshold algorithm based on multi-thresholds is presented against uneven illumination distribution for the fibre material surface analysis. The proposed multi-threshold algorithm first automatically classifies an image into several geometrical regions that depends on the intensity distribution of the image. Secondly in each region of the image, Otsu's threshold algorithm is applied to obtain the local threshold value. Then the local threshold value is used to segment the local region into the binary format. Finally each local region with its binary format is consisted of the total binary format of the image.

Experimental results obtained for images from fibre material in the presence of uneven illumination distribution, show reduced noise levels and enhanced fibre surface properties. The paper presents resulting images and provides key data.

6064A-47, Poster Session

An efficient multiresolution GA approach to dental image alignment

D. E. M. Nassar, M. Ogirala, D. A. Adjero, H. H. Ammar, West Virginia Univ.

Automating the process of postmortem identification of individuals using dental records is receiving increased attention in forensic science. Dental image comparison requires proper alignment of teeth before extracting the features used for matching. In this paper we presented an efficient multi-resolution genetic algorithm (MR-GA) approach to the problem of teeth alignment. We use location and orientation attributes of edge points as alignment features and we to seek an affine mapping that aligns a subject tooth to a reference tooth. To search a solution point in the 6D space corresponding to the affine parameters, we instrument GA search progressively across multi-resolution versions of the query and reference images. We use Hausdorff distance to evaluate the fitness of the chromosomes associated with the possible solution points. To efficiently search the parameters space we use some space bounds and thus exclude potentially unreasonable alignment parameters.

We tested our MR-GA approach using 52 teeth-pair images and found that our algorithm converges to reasonable solutions in more than 85% of the test cases. The main source of error in the remainder of the cases is the excessive misalignment between the reference and the query images, which is hard to correct within reasonable search time.

6064A-48, Poster Session

Phase unwrapping by means of finite differences

L. I. Olivos-Pérez, E. de la Rosa Miranda, L. R. Berriel-Valdos, R. Ramos-López, Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico)

Many problems in metrology and optical tomography have to recover information from phase. In most of the cases, phase, that is associate to a physical magnitude, is continuous and generally, varies smoothly and is wrapping. Therefore, we can say that the problem in these cases is reduced to find a continuous phase. Considering this, many solutions to this kind of problems have been proposed, from the use of local planes to the implementation of most robust algorithms. However, these methods are also very slow. That is why the unwrapping problem is an open subject research in optics. We propose a phase unwrapping method based on finite differences that is fast and robust. In addition, it is easy to program.

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Part of Proceedings of SPIE Vol. 6064 Image Processing: Algorithms and Systems, Neural Networks and Machine Learning

6064B-65, Poster Session

Key-text spotting in documentary videos using Adaboost

M. Lalonde, L. Gagnon, CRIM (Canada)

Important progress regarding text detection in video has been achieved over the last ten years, driven, in particular, by the development of tools for automatic content-based video indexing. This paper presents a method for spotting text in videos based on a cascade of classifiers trained with Adaboost. A video is first segmented into shots, which are then reduced to a set of keyframes. Each keyframe is then analyzed for its text content (subtitles, captions, text that is 'naturally' present in the video such as commercial or street signs, etc.). Text spotting is performed by scanning the image with a variable-size window (to account for scale) inside which simple features (mean/variance of grayscale values and x/y derivatives) are extracted in various subareas. Training builds classifiers using the most discriminant spatial combinations of features for text detection. The text-spotting module output is a decision map of the size of the input keyframe showing regions of interest that may contain text suitable for recognition by an OCR system. Test results on documentary films provided by the National Film Board of Canada are given.

6064B-67, Poster Session

Research on classifying performance of SVMs with basic kernel in HCCR

L. Sun, YanTai Univ. (China)

It still is a difficult task for handwritten chinese character recognition (HCCR) to put into practical use. An efficient classifier occupies very important position for increasing offline HCCR rate. SVMs offer a theoretically well-founded approach to automated learning of pattern classifiers for mining labeled data sets. As we know, the performance of SVM largely depends on the kernel function. In this paper, we investigated the performance of SVMs with various common kernels such as linear kernel, polynomial kernel, sigmoid kernel, Gaussian kernel, multi-quadratic kernel, etc. in HCCR. We found that when the feature dimension of character is 64 or lower than 64, Gaussian and multi-quadratic kernel is better than others. When the feature dimension is around 256, the behavior of linear kernel, polynomial kernel, Gaussian and multi-quadratic kernel is pretty much the same thing.

6064B-68, Poster Session

Face recognition based on HMM in compressed domain

H. Wang, G. Feng, Sun Yat-sen Univ. (China)

In this paper we present an approach for face recognition based on Hidden Markov Model (HMM) on compressed domain. We model each individual as an HMM which consists of several face images. A set of DCT coefficients as observation vectors which are obtained from original images by a slipped window are clustered by K-means method using to be the feature of face images. These classified features are applied to train HMMs, equaling to get the parameters of HMMs. Based on the constructed HMMs, face recognition from unknown images are carried out by adjusting experiment parameters (size of window and set of DCT coefficients). ORL face database of 40 individuals with 10 images per individual and Yale face database of 15 individuals with 11 images per individual are used to evaluate the performance of the proposed HMM-based method. For both

ORL and Yale face databases, experiments for different number of images per individual are extracted for training, and the rest ones are for recognition. Different number of images for training corresponds to different experiment parameters. Compared to the other methods relevant to HMM methods reported so far on the two face databases, results of this approach give a better recognition rate, with reduced computational complexity.

6064B-69, Poster Session

Application of ANN and DT on medium resolution ASTER image to model gully network in Southern Italy

A. Ghaffari, P. M. Mather, G. Priestnall, M. L. Clarke, The Univ. of Nottingham (United Kingdom)

This paper describes an approach of utilising ASTER imagery, surface modelling and land cover information to detect gully erosion networks with maximum obtainable accuracy. Comparing and contrasting two different methods, ANN, and Decision Trees (DT) are applied at final stages of research. However, a Grey Level Co-Occurrence Matrix texture analysis method (GLCM) has been applied for ASTER bands as one of the input layers. GLCM outputs have just used to combine with geomorphological input layers such as flow accumulation, slope angle and aspect, which have been derived from an ASTER-based Digital Elevation Model (DEM). The ASTER-based DEM with 15-meter resolution has been prepared from L1A.

ANN and DT have been used to classify of input layers for 5 sample areas, to the gullies area and none- gully area. Subsequently, The final result shows that DT could classify the image with the highest accuracy (85% overall accuracy) in compare with the ANN. WEKA has used for the analysis as a Machine Learning software. It is possible to improve the accuracy of gully detection using other input layers and classification methods, which could apply during next stages.

6064B-49, Session 7

Nonlinear shape prior from Kernel space for geometric active contours

S. Dambreville, Y. Rathi, A. R. Tannenbaum, Georgia Institute of Technology

The Geometric Active Contour (GAC) framework, which utilizes image information, has proven to be quite valuable for performing segmentation. However, the use of image information alone often leads to poor segmentation results in the presence of noise, clutter or occlusion. The introduction of shapes priors in the contour evolution proved to be an effective way to circumvent this issue. Recently, an algorithm was proposed, in which linear PCA (principal component analysis) was performed on training sets of data and the shape statistics thus obtained were used in the segmentation process. This approach was shown to convincingly capture small variations in the shape of an object.

However, linear PCA assumes that the distribution underlying the variation in shapes is Gaussian. This assumption can be over-simplifying when shapes undergo complex variations. In the present work, we propose to use Kernel PCA to introduce shape prior in the GAC framework. Several experiments were performed using different training-sets of shapes. Starting with any initial contour, we show that the contour evolves to adopt a shape that is faithful to the elements of the training set. The proposed method compares very advantageously to linear PCA.

6064B-50, Session 7

Kernel subspace matched target detectors

H. Kwon, N. M. Nasrabadi, Army Research Lab.

In this paper, we compare several detection algorithms that are based on spectral matched (subspace) filters.

Nonlinear kernel versions of these spectral matched (subspace) detectors are also discussed and their performance is compared with the linear versions. These kernel-based detectors exploit the nonlinear correlations between the spectral bands that are ignored by the conventional detectors.

Several well-known matched detectors, such as matched subspace detector, orthogonal subspace detector, spectral matched filter and adaptive subspace detector (adaptive cosine estimator) are extended to their corresponding kernel versions by using the idea of kernel-based learning theory. In kernel-based detection algorithms the data is implicitly mapped into a high dimensional kernel feature space by a nonlinear mapping which is associated with a kernel function. The detection algorithm is then derived in the feature space which is kernelized in terms of the kernel functions in order to avoid explicit computation in the high dimensional feature space.

Experimental results based on simulated toy-examples and real hyperspectral imagery show that the kernel versions of these detectors outperform the conventional linear detectors.

6064B-51, Session 7

Statistical shape analysis using kernel PCA

Y. Rathi, S. Dambreville, A. R. Tannenbaum, Georgia Institute of Technology

Mercer kernels are widely used for a wide range of image and signal processing tasks like de-noising, clustering, discriminant analysis etc. These algorithms construct their solutions in terms of the expansions in a high-dimensional feature space F . However, many applications like kernel PCA can be used more effectively if a pre-image of the projection in the feature space is available. In this paper, we propose a novel method to reconstruct a unique approximate pre-image of a feature vector and apply it for statistical shape analysis. The proposed reconstruction algorithm can find the pre-image for any invertible kernel. We provide some experimental results to demonstrate the advantages of kernel PCA over linear PCA for shape learning, which include, but are not limited to, ability to learn and distinguish multiple geometries of shapes and robustness to occlusions. We also show the different modes of variation of the learned shapes in the feature space.

6064B-52, Session 8

Segmentation and enhancement of digital copies using a new fuzzy clustering method

M. N. Ahmed, B. E. Cooper, Lexmark International, Inc.

We introduce a new system to segment and label document images into text, halftoned images, and background using a modified fuzzy c-means (FCM) algorithm.

Previously, we introduced a penalty function to the FCM algorithm for the neighborhood term, based on the distance between the neighboring feature vectors and the current cluster center. Inspired by Markov Random Field (MRF) image modeling, the new algorithm is formulated by modifying the objective function of the standard FCM algorithm to allow the labeling of a pixel to be influenced by the labels in its immediate neighborhood. The new cost function conforms with MRF neighborhood modeling through the use of cliques. The objective function is minimized when the center pixel has a high membership value in a certain class at the same time that its related cliques possess low membership values in the other classes.

Each pixel is assigned a feature vector, extracted from edge information and gray level distribution. The feature pattern is then assigned to a specific region using the modified fuzzy c-means approach. In the process of minimizing the new objective function, the neighborhood effect acts as a regularizer and biases the solution towards piecewise-homogeneous labelings. Such a regularization is useful in segmenting scans corrupted by scanner noise.

6064B-54, Session 9

2D/3D facial feature extraction

B. Sankur, L. Akarun, H. Cinar, A. Ali Salah, Bogaziçi Univ. (Turkey)

With the availability of better sensors, 3D information has become an important source for face recognition, yet face registration and normalization both depend on good localization of fiducial points. In this paper, we compare different methods for landmarking near-frontal faces automatically. Following a coarse-to-fine approach, three novel methods have been introduced to analyze facial features. The first method uses a mixture of factor analyzers to learn Gabor filter outputs. The second method employs a combination of principal component analysis (PCA) and independent component analysis (ICA) features to analyze a Gabor feature set. The last method uses a subset of DCT coefficients for template-based matching. For the latter two methods we use SVM classifiers with polynomial kernel functions. We contrast 2D texture and 3D depth information, and find that the more successful localization methods use 2D gray level images. The 3D information is still beneficial to the 2D system in eliminating the background, thus reducing the time complexity to one third, and in eliminating false alarms.

6064B-56, Session 10

Noniterative neural network learning of an N-dimension curve representing the dynamic history of a time varying pattern

C. J. Hu, Southern Illinois Univ.

When an image pattern is varying continuously in time, the arrow tip of an N -Dim analog vector representing the image will trace an N -Dim curve in the N -space. Like the 2-D and 3-D curves, this N -D curve can also be approximated by some broken N -D straight lines joining the extreme points or "maximum curvature points" on the curve. Each extreme point on the N -D curve represents an extreme "static" pattern of the "dynamic" time-varying pattern. Because of the unique convex learning property possessed by the one-layered, noniterative neural network (OLNN), if one uses an OLNN to learn just the extreme patterns alone, any unlearned test pattern falling close to the N D curve can also be recognized immediately by the OLNN.

Therefore it is a very efficient learning-recognition system that will not only learn and recognize the static patterns of the object classes, it will also learn and recognize the dynamic pattern variations of each class.

This paper will report the general theoretical analysis and design approaches of this dynamic pattern recognition system.

6064B-57, Session 10

Manifold of color perception: color constancy using a nonlinear line attractor

V. K. Asari, M. Seow, Old Dominion Univ.

In this paper, we propose the concept of manifold of color perception based on an observation that the perceived color in a set of similar color images defines a manifold in the high dimensional space. Such a manifold representation can be learned from a few images of similar color characteristics. This learned manifold can then be used as a basis for color correction of the images having

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different color perception to the previously learned color. To learn the manifold for color perception, we propose a novel learning algorithm based on a recurrent neural network. Unlike the conventional recurrent neural network model in which the memory is stored in an attractive fixed point at discrete locations in the state space, the dynamics of the proposed learning algorithm represents memory as a line of attraction. The region of convergence to the line of attraction is defined by the statistical characteristics of the training data. We demonstrate experimentally how we can use the proposed manifold to color-balance the common lighting variations in the environment.

6064B-58, Session 10

A novel neural net application for image compression

H. S. Soliman, M. Omari, New Mexico Institute of Mining and Technology

Adaptive vector quantization (AVQ) is one of the most important modern techniques used in the domain of lossy image compression because of its low training/operating complexity and high image quality and compression ratio. It clusters similar subimage vectors into the same class with a center of mass representative (centroid) that is stored into an indexed codebook. In the image compression process, each input subimage will be encoded into its corresponding centroid's index of size " \log_2 [codebook's size]". Hence, the larger the codebook (i.e. richer) the better the image quality, yet the lower the compression ratio. Fortunately, doubling the size of the codebook requires only a single bit addition to every index, due to the logarithmic mapping (\log_2) of centroids encoding.

In order to compromise between the critical factors of compression ratio and quality, we introduce two mechanisms: local and universal codebook. In the former, each image will have its own codebook (space overhead for better quality), with the latter having one large codebook for similar domain images (space saving with lower quality). The construction of the universal codebook is a complex issue (it takes days to fully train few images). Moreover, the inability to automatically detect the image group might result in misclassification and consequently, degrade the image quality.

Because of the aforementioned problems of the universal codebook, we introduced the local codebook approach. Each input image is used to train its own private codebook that is able to capture the entire image details. Yet, it is counted against the compression ratio since the codebook is concatenated to the image indices file to form the final compressed image. However, the reconstructed image will be of much better quality compared to that of the universal codebook approach. In addition, the local codebook size is considerably smaller than the image itself, which compensates for the inclusion of the codebook inside the compressed file.

Based on the AVQ theory, we designed our new Direct Classification (DC) neural net engine for image compression/decompression. It is based on the philosophy of the winner-take-all feature of the Kohonen model, as well as the elasticity/stability feature with only a "single epoch" training cycle of the ART1 model. In the DC model, the training and compression sub-phases are interleaved. The training sub-phase starts by dividing the total subimage vector domain into classes of subimages. The compression sub-phase consists of assigning the corresponding centroid index as the input subimage compression index. In the decompression phase, each index in the compressed file is looked up in the codebook and replaced with its corresponding centroid.

Generating a local codebook per each image seems, at the first glance, a very inefficient approach since it serves a single image, and it is integrated in the compressed file, decreasing the compression ratio. Yet, we discovered experimentally that in case of simple non-complicated images (documents), the codebook is small reducing the space overhead, yet the recovered image quality is improved. We are currently investigating the novelty of our approach in the satellite image domain.

6064B-59, Session 10

Toward content-based object recognition with image primitives

G. Wang, J. M. Kinser, George Mason Univ.

Content-based object recognition is very useful in many applications, such as medical image processing and diagnosis, target identification with satellite remote sensing. For content-based object recognition, the representation of image segments is critical. Although there are already some approaches to represent image shapes, many of them have limitations because of their insensitivity to the deviations of object appearance. In this paper, an approach is proposed by constructing an image primitive database and representing image with a basis set extracted from the database. The cortical modeling is used here to extract the basis set by isolating the inherent shapes within each image from an image database and defines shapes from this basis set. In our approach, image segments are clustered based on similarity in perimeter and size instead of centroid based metrics by employing the fractional power filter, and the clusters are represented in descriptive vectors as signatures and form basis for shape representation. This approach has advantages in sensitivity to the idiosyncratic nature of the distribution of shapes and efficiency. For validation, we selected a large number of images from web sites randomly. The experiments indicate that describing shapes from this basis set is robust to alterations of the shape such as small occlusions, limited skew, and limited range.

6064B-60, Session 10

Translation invariance in a network of oscillatory units

A. R. Rao, G. A. Cecchi, C. Peck, J. Kozloski, IBM Corp.

One of the important features of the human visual system is that it is able to recognize objects in a scale and translational invariant manner. However, achieving this desirable behavior through biologically realistic networks is a challenge.

It has been recognized (von der Malsburg [1]) that neurons are oscillatory dynamical units, and

that the synchronization of neuronal firing patterns could be used to solve the binding problem. Networks consisting of such oscillatory units have been applied to solve the signal deconvolution or blind source separation problems. However, the use of the same network to achieve properties that the visual system exhibits, such as scale and translational invariance have not been fully explored.

Some approaches investigated in the literature (Wallis [2]) involve the use of non-oscillatory elements that are arranged in a hierarchy of layers. The objects presented are allowed to move, and the network utilizes a trace learning rule, where a time averaged value of an output value is used to perform Hebbian learning with respect to the input value. This is a modification of the standard Hebbian learning rule, which typically uses instantaneous values of the input and output.

In this paper we present a network of oscillatory amplitude-phase units connected in two layers. The types of connections include feedforward, feedback and lateral. The network consists of amplitude-phase units that can synchronize their dynamics. We have previously shown (paper submitted to NIPS 2005) that such a network can segment the components of each input object that most contribute to its classification. Learning is unsupervised and based on a Hebbian update, and the architecture is very simple.

We extend the ability of the network to address the problem of translational invariance. We show that by a specific treatment of the phase values of the output layer, limited translational invariance is achieved. The scheme used in training is as follows. The network is presented with an input, which then moves. During the motion the

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amplitude and phase of the upper layer units is not reset, but continues with the past value before the introduction of the object in the new position. Only the input layer is changed instantaneously to reflect the moving object. This is a promising result as it uses the same framework of oscillatory units, and introduces motion to achieve translational invariance.

There appears to be some biological grounding for this type of computation, as there are microsaccades during which no phase resetting occurs. It is only when a completely new saccade is undertaken, while looking at a different visual field, that phase resetting occurs.

References:

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by neural oscillators. International Joint Conference on Neural Networks, Part II, pp. 603-607.

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6064B-61, Session 10

Efficient learning and recognition using segmented analytical data of an edge-detected 2D image

C. J. Hu, Southern Illinois Univ.

As we published last year in this conference, we have developed a very efficient image pre-processing scheme for use in any image analyzing system or any neural network pattern recognition system. This scheme calls for a compact mathematical analysis on the binary curves obtained from any original image by a particular scheme, e.g., the Canny edge-detection scheme, which are generally all the binary edge points of the original colored picture. Our preprocessing scheme has a unique property that it can analyze these edge points and synthesize them into jointed branches of analytical curves represented by extremely compact analog data file. Then we can use this compact data file to re-construct, in real time, all the edge boundaries of the objects included in the original image. The error in the re-construction is seen to be very small in all 12 experiments we did last year.

This paper reports a noniterative neural network system that will accept this compact data file directly. Then it will automatically analyze the image geometry with possible environmental noises eliminated and with live variation ranges of each pattern taken into account. Finally, it will automatically identify the image according to its overall topological, or syntactic, properties which are generally independent of any geometrical shape, geometrical size, different viewing angles, and different viewing heights.

6064B-62, Session 11

Support vector machine as digital image watermark detector

P. H. H. Then, Swinburne Univ. of Technology (Malaysia); Y. C. Wang, Univ. Malaysia Sarawak (Malaysia)

We perceive the digital watermark detection as classification problem in image processing. We classify watermarked images as positive class whilst unwatermarked images as negative class. Support Vector Machine (SVM) is used as classifier of the watermarked and unwatermarked digital images. We use two watermarking schemes i.e. Cox's spread spectrum and Single Value Decomposition (SVD) to embed watermark into digital images. The payload of the watermark used for both algorithms is consistent at certain number of bits. SVM is trained with both the watermarked and unwatermarked images. Receiver Operating Characteristics (ROC) graphs are plotted to assess the statistical detection behavior

of both the correlation detector and SVM classifier. We found that straight forward application of SVM leads to generalization problem. We suggest remedies to preprocess the training data in order to achieve substantially better performance from SVM classifier than those resulting from the straightforward application of SVM. Both watermarked and unwatermarked images are attacked under Stirmark and are then tested with the correlation detectors and SVM classifier. A comparison of the ROC of the correlation detectors and SVM classifier is performed to assess the accuracy of SVM classifier relative to correlation detectors. We found that SVM classifier has higher robustness to Stirmark attacks.

6064B-63, Session 11

Neural networks approach to high vertical resolution atmospheric temperature profile retrieval from spaceborne high spectral resolution infrared sounder measurements

D. Jiang, C. Dong, Hunan Meteorological Bureau (China)

Temperature profiles with 1km vertical resolution at 100 pressure layers, from surface up to 0.005 hPa, were retrieved on different spectral bands and on different types of terrain in the middle latitude area by using a three-layered feed-forward neural networks with back-propagation algorithm. Results show that temperature profiles with accuracy of less than 1K in 1 km thick tropospheric layers can be achieved by using AIRS data and neural networks method. And the Qinghai-Tibet Plateau has a measurably impact on the retrieval accuracy which is corresponding to the spectral bands used in performing retrievals. A promising approach to the elimination of this effect is to apply additional predictors which are non-satellite observed (e.g. surface altitude).

6064B-64, Session 11

Probabilistic multiresolution human classification

H. Ran, Wuhan Univ. of Technology (China); J. Tu, Hubei Univ. of Technology (China)

Recently there has been some interest in using infrared cameras for human detection because of the sharply decreasing prices of easy to use infrared cameras. The training data used in our work for developing the probabilistic template consists of 1000 128x48 rectangular images all of which are known to contain humans in different poses and orientation but having the same height. Multi-resolution decomposing is performed on the templates as described above. This is done so that the model does not learn the intensity variations among the background pixels and intensity variations among the foreground pixels. Each template at every level is then translated so that the centroid of the non-zero pixels matches the geometrical center of the image. After this normalization step, for each pixel of the template, the probability $p(x,y)$ of it being pedestrian is calculated based on the how frequently it appears as 1 in the training data. Once we have this probability map, the mean and standard deviation of the combined probability is calculated for 1000 training samples. Also the mean and standard deviation is calculated for 1000 128x48 windows that do not contain pedestrians. The videos had quite a lot of variations in the scenes, sizes of people, amount of occlusions and clutter in the backgrounds as is clearly evident. Preliminary experiments shows the robustness.

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6065-01, Session 1

Keynote: title needed

M. V. de Hoop, Purdue Univ.

No abstract available

6065-02, Session 2

Modeling hierarchical structure of images with stochastic grammars

W. Wang, T. Wong, I. Pollak, C. A. Bouman, M. P. Harper, Purdue Univ.

We construct a novel hierarchical stochastic model for images. The model is based on the concept of stochastic context-free grammars (SCFGs) which have previously been used for modeling one-dimensional objects such as sentences. We extend SCFGs to multiple dimensions, to enable modeling of multidimensional random fields. We develop efficient estimation algorithms for this model and illustrate through several image classification and segmentation examples.

6065-03, Session 2

Multiresolution analysis of digital images using the continuous extension of discrete group transforms

M. Germain, J. Patera, A. Zaratsyan, Univ. de Montréal (Canada)

A new technique is presented for multiresolution analysis of digital images. In 2D, it has four variants, two of them are applicable on square lattices like the Discrete Cosine Transform (DCT) which is the simpler. The other two variants would be used similarly on triangular lattices. The property of the Continuous Extension of these Discrete Group Transforms (CEDGT) is used to analyse data for each level of decomposition.

The multiresolution step is obtained by increasing the data grid for each level of decomposition, and by using an adapted low filter to reduce some irregularities due to noise effect. Compared to some stationary wavelet transforms, the image analysis gives better results with a multiresolution CEDGT transform. In fact, a wavelet transform is capable of providing a local representation at multiple scales, but some local details disappear due to the using of the low pass filter and the reduction of the spatial resolution for a high level of decomposition.

The smooth interpolation, used by the multiresolution CEDGT, gives interesting results for coarse-to-fine segmentation algorithm and others analysis processes. This technique is applied in segmentation of polarimetric SAR images and the characterization of man-made objects.

6065-04, Session 2

Modeling multiscale differential pixel statistics with applications

D. Odom, P. Milanfar, Univ. of California/Santa Cruz

Assumptions about the statistical properties of pixel differences between neighboring pixels in an image are often used in image processing tasks. It has been asserted that pixel differences are described well with a Generalized Gaussian distribution. Assuming a Laplace distribution between neighboring pixels (e.g. the Total Variation framework) has also been shown to yield good results. However, neither assumption has been investigated in a statistical

framework. In this paper, the quality of these assumptions was investigated by means of chi-squared goodness of fit tests.

A mixture distribution consisting of a Laplace and a Gaussian distribution is proposed as an alternative description of pixel difference statistics. This mixture distribution is seen to provide the best fit to real image data among the distributions tested. A denoising application is presented that utilizes the mixture distribution in the form of a prior. The observed improvement in denoising performance confirms that the mixture model is statistically a better description of real image data.

6065-05, Session 2

Graph-based 3D object classification

S. Baloch, A. H. Krim, North Carolina State Univ.

No abstract available

6065-06, Session 2

Compression via optimal basis selection in large tree-structured dictionaries

Y. Huang, Purdue Univ.

No abstract available

6065-07, Session 3

Compressed sensing in noisy imaging environments

J. Haupt, R. Castro, R. D. Nowak, Univ. of Wisconsin/Madison

Compressive sampling (CS), or "Compressed Sensing", has recently generated a tremendous amount of excitement in the image processing community. CS involves taking a relatively small number of non-traditional samples in the form of projections of the signal onto random basis elements or random vectors (random projections). Recent results show that such observations can contain most of the salient information in the signal. It follows that if a signal is compressible in some basis, then a very accurate reconstruction can be obtained from these random projections. We have shown that compressible signals can be accurately recovered, at the usual nonparametric rates, from random projections that are contaminated with zero-mean additive noise. In many cases this reconstruction is much more accurate than is possible using an equivalent number of conventional point samples, illustrating the utility of projection sampling. For certain classes of sparse or compressible signals, the subspace in which the signal lies may be completely unknown a priori. CS provides universality in such setups because of its ability to both locate and estimate the relevant signal components. In this work we will motivate the use of CS for imaging, present theory predicting reconstruction error rates, and illustrate the utility and universality of CS in electronic imaging with several examples.

6065-08, Session 3

Stable signal recovery from incomplete and inaccurate observations

J. K. Romberg, California Institute of Technology

Recently, a series of exciting results have shown that it is possible to reconstruct a sparse signal exactly from a very limited number of linear measurements. If our underlying signal f can be written as a superposition of M elements from a known basis, it is possible to recover f from a projection onto a generic subspace of dimension about $M \log N$.

We will show that the recovery is robust. That is, if the measurements are perturbed, the reconstruction is still stable. We will discuss the implications of this results for applications such as signal compression and tomographic imaging.

6065-09, Session 3

A compressed sensing camera: new theory and an implementation using digital micromirrors

D. Takhar, M. B. Wakin, M. Duarte, D. Baron, K. F. Kelly, R. G. Baraniuk, Rice Univ.

Current imaging devices rely on CCD or CMOS technology for the optical sensing element. While the scale and cost of this technology have been continually decreasing, the complexity and power requirements have not scaled similarly. On the other hand, digital micromirror devices have proven to be a commercially viable MEMS technology for the video/projector display market. Inspired by the success of this technology, we propose to combine a microcontrolled mirror with a single optical sensor so that it can additionally acquire images, rather than merely adapt current camera technology to serve as an optical sensor. In this project, we have developed a prototype image/video camera based on this concept and realized it through the use of Compressed Sensing for signal reconstruction. Our design has additional desirable properties including scalable output bit stream, variable image resolutions and video frame rates, and an automatically encrypted bit stream at no extra computational or energy cost.

6065-10, Session 4

A fast algorithm for 3D reconstruction from unoriented projections and cryo-electron microscopy of viruses

J. Lee, Y. Zheng, P. C. Doerschuk, Purdue Univ.

In a cryo electron microscopy experiment, the data is noisy 2-D projection images of the 3-D electron scattering intensity where the orientation of the projections is not known. In previous work we have developed a solution for this problem based on a maximum likelihood estimator that is computed by an expectation maximization algorithm. In the expectation maximization algorithm the expensive step is the expectation which requires numerical evaluation of 3- or 5-dimensional integrations of a square matrix of dimension equal to the number of Fourier series coefficients used to describe the 3-D reconstruction. By taking advantage of the rotational properties of spherical harmonics, we can reduce the integrations of a matrix to integrations of a scalar. The key properties is that a rotated spherical harmonic can be expressed as a linear combination of the other harmonics of the same order and that the weights in the linear combination factor so that each of the three factors is a function of only one of the Euler angles describing the orientation of the projection.

6065-11, Session 4

Spatially adaptive 3D inverse for optical sectioning

D. V. Paliy, V. Katkovnik, K. O. Egiazarian, Tampere Univ. of Technology (Finland)

One can see well only the focused areas of a three-dimensional (3D) object, observing it in a microscope or another optical device, while others are seen as blurred. However, these out-of-focus structures are in the field of view and thus obscure the in-focus areas. We propose a novel approach to reconstruction of the 3D object from 2D blurred and noisy observations. The technique is based on an approximate image formation model which takes into account depth

varying nature of the blur described by a matrix of shift-invariant 2D point-spread functions (PSF) of an optical system. The proposed restoration scheme incorporates matrix regularized inverse and matrix regularized Wiener inverse algorithms in combination with a novel spatially adaptive denoising technique. This technique is based on special statistical rules for selection of the adaptive size and shape neighbourhood used for the local polynomial approximation of the 2D image intensity. The simulation shows efficiency of the developed approach.

6065-12, Session 4

On soft clipping of Zernike moments for deblurring and enhancement of optical point spread functions

N. Becherer, J. Hesser, Univ. Mannheim (Germany)

Blur and noise originating from the physical imaging processes degrade the data. Deblurring however demands for an accurate estimation of the underlying point-spread function (PSF). Zernike polynomials allow a compact representation of PSFs since their low order coefficients represent typical aberrations of optical wave fronts while noise is represented by higher order coefficients.

A quantitative description of the distribution of noise (Gaussian, Poisson) over the Zernike moments of various orders is given which is the basis for the new soft clipping approach for denoising of PSFs. Instead of discarding moments beyond a certain order, those Zernike moments that are more sensitive to noise are dampened according to the measured distribution and the present noise model.

Further, a new scheme to combine experimental and theoretical PSFs in Zernike space is presented. According to our experimental reconstructions, using the new improved PSF the correlation between reconstructed and original volumes is raised by 15% on average cases and up to 85% in the case of thin fibre structures, compared to reconstructions where a non improved PSF was used.

Finally we illustrate our results on real life microscopy volumes of cells where our techniques lead to visually improved results.

6065-13, Session 4

Adaptive sampling for atomic force microscopy with system level motion constraints

H. Cheng, G. T. C. Chiu, Purdue Univ.

In atomic force microscope experiment, a 3-D image of a substrate is obtained. With the total number of samples remains constant, there is a trade-off between the size of the scanned image and the resolution. For the scanning mechanism, the time needed to image an area depends mainly on the number of samples and the size of the image. It is desirable to improve the imaging speed with limited impact to the effective resolution of the portion of the substrate that is of interested. To improve the imaging speed, there are two options: 1) increase the data process rate or 2) reduce the amount of data. Increasing the data process rate is difficult without hardware modifications. Therefore, reducing the amount of data is a more practical and cost effective approach. One key issue for reducing the amount of data is to maintain acceptable image fidelity. To address this issue, we need to classify the sample area into regions based on importance. For high importance regions, a higher resolution is needed. For regions of less importance, a coarse sample density is employed.

In this study, we propose a new adaptive sampling scheme that is leveraged from image compression. By adapting the sampling resolution to the substrate profile, the proposed method can decrease the scanning time by reducing the amount of data while maintaining the desired image fidelity.

6065-14, Session 5

Bayesian image reconstruction from Fourier-domain samples using prior edge information: convergence and parameter sensitivity

T. S. Denney, Jr., S. J. Reeves, Auburn Univ.

Image reconstruction from Fourier-domain measurements is a specialized problem within the general area of image reconstruction using prior information. The structure of the equations in Fourier imaging is challenging, since the observation equation matrix is non-sparse in the spatial domain but diagonal in the Fourier domain. Recently, the Bayesian image reconstruction with prior edges (BIRPE) algorithm has been proposed for image reconstruction from Fourier-domain samples using edge information automatically extracted from a high-resolution prior image. In the BIRPE algorithm, computing the maximum a posteriori (MAP) estimate of the reconstructed image and edge variables involves high-dimensional, non-convex optimization, which can be computationally prohibitive. Consequently, we iteratively update our estimate of the image then update our estimate of the edge variables. In this paper, we propose two techniques for updating the image based on fixed edge variables * one based on iterated conditional modes (ICM) and the other based on Jacobi iteration. ICM is guaranteed to converge, but, depending on the structure of the Fourier-domain samples, can be computationally prohibitive. The Jacobi iteration technique is more computationally efficient but does not always converge. In this paper, we study the convergence properties of the Jacobi iteration technique and its parameter sensitivity.

6065-15, Session 5

Thin digital imaging systems using focal plane coding

A. D. Portnoy, J. P. Guo, N. P. Pitsianis, D. J. Brady, Duke Univ.; M. A. Fiddy, Univ. of North Carolina/Charlotte; M. R. Feldman, R. D. Te Kolste, Digital Optics Corp.

The Compressive Optical MONTAGE Photography Initiative (COMP-I) is an effort under the DARPA MONTAGE program to construct thin digital imaging systems while maintaining image quality metrics. COMP-I uses "focal plane coding" to produce nondegenerate data between subapertures. Subaperture data is integrated to form a single high resolution image.

Multiple apertures generate multiple copies of a scene on the detector plane. Placed in the image plane, the focal plane mask applies a unique code to each of these sub-images. Within each sub-image, each pixel is masked so that light from only certain optical pixels reaches the detector. Thus, each sub-image measures a different linear combination of optical pixels. Image reconstruction is achieved by inversion of the transformation performed by the imaging system. Registered detector pixels in each sub-image represent the magnitude of the projection of the same optical information onto different sampling vectors.

Without a coding element, the imaging system would be limited by the spatial frequency response of the electronic detector pixel. The small mask features allow the imager to broaden this response and reconstruct higher spatial frequencies than a conventional coarsely sampling focal plane.

6065-16, Session 5

3D reconstructions from spherically averaged Fourier transform magnitude and solution x-ray scattering experiments

Y. Hwang, P. C. Doerschuk, Purdue Univ.

Measuring the scattering a beam of x-rays off a solution of identical particles gives data that is the spherically-averaged magnitude of the Fourier transform of the electron number density in the particle. Although the 1-D data provides only limited information for a 3-D reconstruction of the particle, this approach is still attractive because it does not require that the particle be crystallized for x-ray crystallography or frozen for cryo electron microscopy. We describe ongoing work using two mathematical models of the particle, a piecewise constant model and an orthonormal expansion model, and a variety of specialized optimization tools to determine the 3-D reconstruction of the particle from a weighted nonlinear least squares problem.

6065-17, Session 5

Computed spectroscopy using segmented apertures

R. T. Hoxter, F. W. Wheeler, GE Global Research; E. B. Barrett, Lockheed Martin Corp.

A novel technique for optical imaging spectroscopy is introduced. The technique makes use of an adjustable aperture and pan-chromatic light intensity sensors on the imaging plane. The approach is an image reconstruction technique, through which a collection of pan-chromatic images of a scene, each with its own distinct point spread function (PSF), is used to compute a single hyperspectral image (HSI). We have given the name Computed Spectroscopy (CS) to this type of processing.

The paper introduces and analyzes Computed Spectroscopy in the context of segmented-aperture optical imaging systems, in which the PSF is adjusted by modifying the path lengths between the image formation plane and a set of independent optical sub-apertures. Such systems have recently been proposed for Fourier transform imaging spectroscopy (FTIS) applications, and they have long been considered for incoherent synthetic aperture imaging.

Computed Spectroscopy is both a new form of computed imaging and an alternative to FTIS that is applicable to division-of-wavefront interferometers. Additionally, the approach provides interesting theoretical connections between image restoration, incoherent aperture synthesis and interferometric spectroscopy. The paper presents analysis and simulation, and it will discuss the limitations and advantages of the new approach. Future research directions will also be discussed.

6065-18, Session 5

Preconditioned conjugate gradient without linesearch: a comparison with the half-quadratic approach for edge-preserving image restoration

C. Labat, J. Idier, Institute of Research in Communications and Cybernetics of Nantes (France)

Our contribution deals with image restoration. The adopted approach consists in minimizing a penalized least squares (PLS) criterion. Here, we are interested in the search of efficient algorithms to carry out such a task.

The minimization of PLS criteria can be addressed using a half-quadratic approach (HQ). However, the nontrivial inversion of a linear system is needed at each iteration. In practice, it is often proposed

to approximate this inversion using a truncated preconditioned conjugate gradient (PCG) method.

However, we point out that theoretical convergence is not proved for such approximate HQ algorithms, referred here as HQ+PCG. In the proposed contribution, we rely on a different scheme, also based on PCG and HQ ingredients and referred as PCG+HQ1D. General linesearch methods ensuring convergence of PCG type algorithms are difficult to code and to tune.

Therefore, we propose to replace the linesearch step by a truncated scalar HQ algorithm. Convergence is established for any finite number of HQ1D sub-iterations. Compared to the HQ+PCG approach, we show that our scheme is preferable on both the theoretical and practical grounds.

6065-19, Session 6

Computational methods for image restoration, image segmentation, and texture modeling

G. Chung, T. M. Le, L. H. Lieu, N. Tanushev, L. Vese, Univ. of California/Los Angeles

This work is devoted to new computational models for image segmentation, restoration and decomposition. In particular, we partition an image into piecewise-constant regions using energy minimization and curve evolution approaches. Applications to brain imaging and tomography will be presented.

Also, we decompose a natural image into a cartoon or geometric component, and an oscillatory or texture component, in a variational approach. New computational methods to model oscillatory patterns will be presented.

6065-20, Session 7

An adaptive model for restoration of optically distorted video frames

D. Li, Georgia Institute of Technology; M. J. T. Smith, Purdue Univ.; R. M. Mersereau, Georgia Institute of Technology

Atmospheric turbulence is a common problem in astronomy and long distance surveillance applications. It can lead to optical distortions that can significantly degrade the quality of the captured images and video. Quality improvement can be achieved through digital restoration methods that effectively suppress the effects of optical distortion. In this paper, atmospheric optical distortion is modeled as having two components: a dispersive component and a time-varying distortion component. A new restoration algorithm is introduced that compensates for dispersion using a fourth-order statistic and employs a new adaptive warping algorithm to suppress turbulent motion effects. The new algorithm is able to improve quality significantly and is able to handle difficult cases involving panning, zooming, and natural motion.

6065-21, Session 7

Resource-driven content adaptation

Y. Lu, D. S. Ebert, E. J. Delp III, Purdue Univ.

No abstract available

6065-22, Session 7

Algebraic methods for structure from motion

M. Boutin, J. Zhang, D. G. Aliaga, Purdue Univ.

Structure from motion (SFM) is the problem of reconstructing the geometry of a scene from a stream of images with tracked features.

In this paper, we consider a projective camera model and assume that the internal parameters of the camera are known. Our goal is to reconstruct the geometry of the scene up to a rigid motion (i.e. Euclidean reconstruction.) It has been shown that estimating the pose of the camera from the images is an ill-conditioned problem, as variations in the camera orientation and camera position cannot be distinguished.

Unfortunately, the camera pose parameters are an intrinsic part of current formulations of SFM. This leads to numerical instability in the reconstruction of the scene. Using algebraic methods, we obtain a new formulation of SFM which eliminates this cause of instability.

6065-23, Session 7

A maximum entropy kernel density estimator with applications to function interpolation and texture segmentation

N. Balakrishnan, D. Schonfeld, Univ. of Illinois at Chicago

In this paper, we develop a new algorithm to estimate an unknown probability density function given a finite data sample using a tree shaped kernel density estimator. The algorithm formulates an integrated squared error based cost function which minimizes the quadratic divergence between the kernel density and the Parzen density estimate. The cost function reduces to a quadratic programming problem which is minimized within the maximum entropy framework. The maximum entropy principle acts as a regularizer which yields a smooth solution. A smooth density estimate enables better generalization to unseen data and offers distinct advantages in high dimensions and cases where there is limited data. We demonstrate applications of the hierarchical kernel density estimator for function interpolation and texture segmentation problems. When applied to function interpolation, the kernel density estimator improves performance considerably in situations where the posterior conditional density of the dependent variable is multimodal. The kernel density estimator allows flexible non parametric modeling of textures which improves performance in texture segmentation algorithms. We demonstrate performance on a text labeling problem which shows performance of the algorithm in high dimensions. The hierarchical nature of the density estimator also enables multiresolution solutions depending on the complexity of the data. The algorithm is fast and has at most quadratic scaling in the number of kernels.

6065-24, Session 7

Multiple watermarking: a vector space projection approach

O. Altun, G. Sharma, M. Bocko, Univ. of Rochester

We present a new paradigm for the insertion of multiple watermarks in images. Instead of an explicitly defined embedding process, the watermark embedding is achieved implicitly by determining a feasible image meeting multiple desired constraints. The constraints are designed to ensure that the watermarked image signal is visually indistinguishable from the original and produces a positive detection result when subjected to detectors for the individual watermarks even in the presence of signal processing operations, particularly compression. We develop useful mathematical definitions of constraint sets for different visual models, for transform domain compression, and for both spread-spectrum and quantization index modulation (QIM) watermark detection scenarios. Using the constraints with a generalized vector space projections method (VSPM), we determine a watermarked signal. Experimental results demonstrate the flexibility and usefulness of the presented methodology in addressing multiple watermarking scenarios while providing implicit shaping of the watermark power to meet visual requirements.

6065-25, Session 8

Spherical harmonics for shape-based inverse problems, as applied to electrical impedance tomography

S. Babaeizadeh, D. H. Brooks, Northeastern Univ.

Electrical Impedance Tomography (EIT) is a badly posed inverse problem. In a 3-D volume it requires too many parameters to be able to obtain stable estimates with good spatial resolution and accuracy. One approach to such problems that has been presented recently in a number of reports, when the relevant constituent parameters can be modeled as isotropic and piecewise continuous or homogeneous, is to use shape-based solutions. In this work, we report on a method, based on a spherical harmonics expansion, that allows us to parameterize the 3-D geometry using approximation assumptions about the objects which constitute the conductivity inhomogeneities in the interior; for instance, we could assume the general shape of piecewise constant inhomogeneities is known but their conductivities and their exact location and shape are not. Using this assumption, we have developed a 3-stage optimization algorithm that allows us to iteratively estimate the location of the inhomogeneous objects, to find their external boundaries, and to estimate their internal conductivities. The performance of the proposed method is illustrated via simulation in a realistic torso model, as well as via experimental data from a tank phantom.

6065-26, Session 8

3D nonlinear multigrid algorithm for direct reconstruction of chromophore concentrations in diffuse optical tomography

J. C. Ye, Korea Advanced Institute of Science and Technology (South Korea)

It is well-known that the tissue has a relatively low absorption for near infrared (NIR) signals between 700nm and 1000nm, which can penetrate up to several inches. For spectroscopic applications, there has been growing interests in using NIR light to monitor physiologically relevant tissue parameters such as blood oxygen saturation and total hemoglobin concentration level in vivo. The diffuse optical tomography (DOT) even further increases the scope of spectroscopic characterization to an imaging level such that we can reconstruct cross-section images of the physiological parameters based on measurements of the scattered and attenuated near infrared light. There are three different types of implementation for DOT - continuous wave (CW), time domain (TD) and frequency domain (FD) approaches. Among them, the CW implementation is the most simple. However, it is known that the inverse problem associated with CW DOT does not have unique solutions due to the cross-talk between the scattering image and absorption image. Recently, Corlue et al describe a model-based spectral approach for inversion of CW data that reduces the cross-talk. In this method, the absorption and scattering parameters are given by wavelength dependent parametric model such that

$$\begin{matrix} \begin{matrix} \begin{matrix} \mu_a(\lambda) = \sum_i \epsilon_i(\lambda) c_i \end{matrix} \\ \begin{matrix} \mu_s(\lambda) = a \lambda^{-b} \end{matrix} \end{matrix} \end{matrix} \end{matrix}$$

where c_i is the concentration of the i -th chromophore, and $\epsilon_i(\lambda)$ is the extinction coefficients of the i -th chromophore at wavelength λ ; a and b are related to the size, the index of refraction, and the concentration of scatterers in the tissue as well as the index of refraction of the surrounding medium. Using the parametric models and optimized selection of the multiple wavelength, they demonstrated that the cross talk problem has been significantly reduced. Such parametric model has been also used for frequency domain DOT problem to provide more accurate image reconstruction from multiple excitation. While such finite parametric

representation of optical parameters can alleviate the ill-posedness of inverse problems, one of the main technical difficulties associated with multiple wavelength and parametric model is significantly increased computational complexity. Since the relationship between the measurement and the unknown optical parameters is a highly nonlinear, reconstruction poses a very challenging nonlinear inverse problem even in conventional DOT algorithm. In parametric imaging model, we should furthermore obtain separate images of c_i 's, a and b directly from multiple wavelength excitation, which makes the computational burden significantly increasing.

In order to overcome the complexity, we investigate the 3-D multigrid algorithms for direct reconstruction of the chromophore concentration. In addition to its computational advantages, the global nature of the multigrid optimization tends to more robustly achieve the global minimum, resulting in improved reconstruction quality. The method is evaluated with simulated data following individual variation of oxygen saturation, hemoglobin, and scattering parameters. A finite-difference model of the diffusion equation is used, and the algorithm reconstructs images of five parameters: oxyhemoglobin, deoxyhemoglobin, water fraction, scatter amplitude, and scatter power, with no assumptions on the scatter amplitude or power. The results show that the new multigrid technique is computationally much less expensive and provide more improved reconstruction quality.

6065-27, Session 8

Adaptation of fast marching methods to subcellular modeling

A. Chikando, J. M. Kinser, George Mason Univ.

It has long been known that the movement of proteins and other signaling molecules within the cell is controlled by a precise mechanism. However, computational modeling of this mechanism is an ongoing effort. The presented research employs fast marching methods to implement a computer simulation of this cellular transport mechanism. The simulation is then used to illustrate the subcellular trafficking of signaling molecules such as calcium during Excitation - Contraction coupling, and to illustrate proteins conformational and structural rearrangements that occur during translocation to their functional positions within the cell. The developed model adequately simulates diffusive calcium wave subjected to the elements of the calcium release and uptake mechanism during Excitation - Contraction coupling, and illustrates proteins folding and unfolding methodically in order to navigate through the complex cellular cytoskeleton. The accuracy of the simulation is assessed through a detailed exploration of the nascent biophysical properties of proteins, which play a major role in the subcellular transport mechanism. That is, in nature proteins retain their simplest conformation, which is the conformation requiring the least amount of energy. This conformation is a function of the biophysical constituency of their environment. By assessing how well our simulation adheres to these biophysical properties of the protein, we obtain a metric that can be used to measure the accuracy of the simulation.

6065-28, Session 8

Machine learning of human responses to images

M. N. Wernick, Y. Yang, J. G. Brankov, L. Wei, Illinois Institute of Technology; I. M. El-Naqa, Washington Univ. in St. Louis; N. P. Galatsanos, Univ. of Ioannina (Greece)

The human user is an often ignored component of the imaging chain. In medical diagnostic tasks, the human observer is usually the decision-maker. In content-based image retrieval, the human user is the ultimate judge of the relevance of images recalled from a database. We argue that data collected from human observers should be used in conjunction with machine-learning algorithms to

model and optimize performance in tasks that involve humans. In essence, we treat the human observer as a nonlinear system to be identified. Two examples of this idea will be discussed. In the first, a learning machine is trained to predict the accuracy of human observers in a lesion detection task. In the second, a learning machine is trained to predict human users' perception of the similarity of two images for purposes of image retrieval from a database. In both examples, it is shown that a nonlinear learning machine can accurately identify the nonlinear human system that maps images into numerical values, such as detection performance or image similarity.

6065-29, Session 9

Image reconstruction algorithms for a novel PET system with a half-ring insert

D. Pal, J. A. O'Sullivan, H. Wu, M. Janecek, Y. C. Tai, Washington Univ. in St. Louis

We have shown that a higher resolution image can be obtained by incorporating an insert ring with high-resolution detectors around a field-of-view inside a scanner. Coincidences are recorded between pair of detectors in the insert (Type II), the insert and the scanner (Type IS) and the scanner (Type SS). Activity in the space enclosed by the half-ring insert contribute to II, IS and SS types of coincidences. Activity outside the half-ring insert contributes to only IS and SS types of coincidences. This leads to full sampling of the entire imaging FOV, with additional high-resolution sampling within the half-ring.

Individual data sets of the half-ring insert system do not provide full sampling of the FOV. A maximum likelihood based expectation maximization (ML-EM) algorithm can combine the log-likelihood functions of all three data sets to estimate a single activity distribution. The algorithm was tested on data from Monte Carlo simulation as well as experiment. Attenuation correction and regularization were incorporated in the EM iterations to obtain a quantitatively accurate image estimate.

6065-30, Session 9

Improved sampling of parallel projection in cylindrical PET scanners

B. Farsaii, SUNY/Univ. at Buffalo

For a PET scanner with circular array of detectors, the width of line-of-response (LOR) decreases as the distance between the LOR and the center increases. The decrease of width of the LOR leads to problem of non-uniform and under sampling of projections. The consequence of non non-uniform sampling is the distortion of high frequency reconstructed images or loss of fine detail. Correcting this non-uniform sampling problem is known as arc-correction. The purpose of this study is to create the best estimate of non-uniformly sampled projections from uniformly spaced set of LOR. Four polynomial type interpolating algorithms: Lagrange, iterative Neville, natural cubic spline and clamped cubic spline are used to get the best estimate of projections. A set of simulated projections based on GE Advance, CTI EXAT HR+ and CTI ECAT EXACT/953B commercial scanner is generated. To be within the theoretical requirement of three sample points for each FWHM, we have increased the number of sample points from 1 to 6 interpolations per detector. The simulated projections are divided into two groups: the first group consists of a set of functions with no added noise and the second group has added Gaussian noise. Each group consists of two sets: the first set has 10 functions of pulses such that f11 has one pulse, f12 has two pulses and so on. In the second set f21 has one triangular pulse, f22 has two triangular pulses and so on. For each group interpolated data is compared to the original data. In addition, two projections of a 20cm FDG filled disk is used for comparison with simulated data, where the first is the raw projection with no interpolation and the second one is an interpolated projection. It is

shown that clamped and natural cubic spline accuracy was superior to other three algorithms in every case but Lagrange outperforms other algorithms for the speed of execution.

6065-31, Session 9

A Bayesian approach to tomography of multiply scattered beams

Z. H. Levine, National Institute of Standards and Technology

Recently, Levine, Kearsley, and Hagedorn proposed a generalization of generalized Gaussian random Markov field (GGMRF) as developed by Bouman and Sauer. The principal components of the Bouman-Sauer formulation are a quadratic approximation to the log-likelihood assuming a Poisson distribution and a Beer's Law interaction and a prior distribution which penalized deviation of the values in a neighborhood as a user-defined power in the interval [1-2]. The generalization removes the restriction that the transmission function follows Beer's Law, but instead admits any functional form for the transmission-thickness relation, such as those arising in transmission electron microscopy of thick samples.

Judging from the examples, limited-angle tomography is more sensitive to the choice of the transmission function than all-angle tomography.

6065-32, Session 9

Progress in multiple-image radiography

M. N. Wernick, J. G. Brankov, Y. Yang, G. Khelashvili, Illinois Institute of Technology; D. Chapman, Univ. of Saskatchewan (Canada); I. Mondal, B. Marquet, Illinois Institute of Technology; Z. Zhong, Brookhaven National Lab.

Conventional mammography is one of the most widely used diagnostic imaging techniques, but it has serious and well-known shortcomings, which are driving the development of innovative alternatives. Our group has been developing an x-ray imaging approach called multiple-image radiography (MIR), which shows promise as a potential alternative to conventional x-ray imaging (radiography). Like computed tomography (CT), MIR is a computed imaging technique, in which the images are not directly observed, but rather computed algorithmically. Whereas conventional radiography produces just one image, depicting absorption effects, MIR simultaneously produces three images, showing separately the effects of absorption, refraction, and ultra-small-angle x-ray scattering. The latter two effects are caused by refractive-index variations in the object, which yield fine image details not seen in standard radiographs. MIR has the added benefits of dramatically lessening radiation dose, virtually eliminating scatter degradation, and lessening the importance of compressing the breast during imaging. Progress to date on the MIR technique will be reviewed in this talk, which will focus on the basic physics and signal-processing issues involved in this new imaging method.

6065-33, Session 9

A recursive filter for noise reduction in tomographic imaging

J. Thibault, GE Medical Systems; C. A. Bouman, Purdue Univ.; J. Hsieh, GE Medical Systems; K. D. Sauer, Univ. of Notre Dame

CT screening and pediatric imaging, among other applications, prompt the development of more efficient techniques to diminish radiation dose to the patient. While many methods are proposed to limit or modulate patient exposure to x-ray at scan time, the resulting data is excessively noisy, and generates image artifacts unless properly corrected. Statistical iterative reconstruction (IR) techniques have recently been introduced for reconstruction of low-dose CT data, and rely on the accurate modeling of the distribution

of noise in the acquired data. After conversion from detector counts to attenuation measurements, noisy data usually deviates from a physically accurate representation, and limits the ability of IR to generate artifact-free images. This paper introduces a recursive filter for IR that conserves the physical properties of the measured data while pre-processing attenuation measurements. A basic framework for inclusion of detector electronic noise into the statistical modeling for IR is also presented. The results are shown to successfully eliminate streaking artifacts in photon-starved situations.

6065-34, Session 9

A branch-less distance driven projection and backprojection algorithm

S. Basu, General Electric Co.; B. De Man, GE Global Research

We have previously presented a technique called Distance Driven (DD) projection and backprojection that has good computational properties as well as sufficient accuracy to avoid high frequency artifacts in either projection or backprojection. In the original formulation, we used a loop structure to compute the overlap kernel that is central to the behavior of the algorithm. We have observed that on some architectures, the branching nature of the kernel significantly affects performance. In this paper, we present a reformulation of our Distance Driven projector and backprojector that eliminates the branches in the inner loop, and also enables the reuse of hardware accelerated components (e.g., Application Specific Integrated Circuits that implement pixel driven projection and backprojection with linear interpolation), while preserving the artifact-free nature of the original technique.

6065-35, Session 9

Cupping artifacts analysis and correction for a FPD-based cone-beam CT

L. Zhang, H. Gao, Z. Chen, S. Li, Y. Xing, Tsinghua Univ. (China)

Cupping artifact is one of the most serious problems in a middle-low energy X-ray Flat panel detector (FPD)-based cone beam CT system. Both beam hardening effects and scatter could induce cupping artifacts in reconstructions and degrade image quality. In this paper, a two-step cupping-correction method is proposed to eliminate cupping: 1) scatter removal; 2) beam hardening correction. By experimental measurement using Beam Stop Array (BSA), the X-ray scatter distribution of a specific object is estimated in the projection image. After interpolation and subtraction, the primary intensity of the projection image is computed. The scatter distribution can also be obtained using convolution with a low-pass filter as kernel. In this paper, linearization is selected as beam hardening correction method for one-material object. For two-material cylindrical objects, a new approach without iteration involved is present. There are three processes in this approach. Firstly, correct raw projections by the mapping function of the outer material. Secondly, reconstruct the cross-section image from the modified projections. Finally, scale the image by a simple weighting function. After scatter removal and beam hardening correction, the cupping artifacts are well removed, and the contrast of the reconstructed image is remarkably improved.

6065-44, Poster Session

A block-iterative deterministic annealing algorithm for Bayesian tomographic reconstruction

S. Lee, Paichai Univ. (South Korea)

Most common maximum a posteriori approaches in emission tomography involve assumptions on the local spatial characteristics of the underlying source. To explicitly model the existence of anatomical boundaries, the line-process model has been often used. The unobservable binary line processes in this case acts to suspend smoothness constraints at sites where they are turned on. Due to the nonconvexity of its objective function, however, the line-process model requires annealing algorithms for optimization. Deterministic annealing (DA) algorithms are known to provide an efficient means of handling the problems associated with mixed continuous and binary variable objectives. However, they are still computer intensive and require many iterations to converge. In this work, to make the DA algorithm permit reconstruction in a clinically acceptable time, we use a block-iterative (BI) method, which is derived from the ordered subsets principle. The BI-DA algorithm processes the data in blocks within each iteration, thereby accelerating the convergence speed of the standard DA algorithm by a factor proportional to the number of blocks. According to our experimental results, the BI-DA algorithm with 32 blocks yielded acceptable images with only 10 iterations, which corresponded to the reconstruction obtained with 320 iterations of the standard DA algorithm.

6065-46, Poster Session

Deinterlacing in spatial and temporal domain

I. Kim, C. Lee, Yonsei Univ. (South Korea)

A number of deinterlacing algorithms have been proposed, which can be divided into two categories: spatial interpolation and temporal interpolation. Each technique has its own advantages and limitations. In order to take advantages of both approaches, attempts have been made to combine both methods. In particular, spatial interpolation methods along with a temporal deinterlacing method using motion compensation have been showing promising results. In this paper, we investigate the performance of several spatial interpolation methods when they are used with motion-compensated deinterlacing methods.

6065-47, Poster Session

Cosine transform generalized to lie groups $SU(2) \times SU(2)$, $O(5)$ and $SU(2) \times SU(2) \times SU(2)$: application to digital image processing

M. Germain, J. Patera, Univ. de Montréal (Canada)

We propose to apply three of the multiple variants of the 2 and 3-dimensional of the cosine transform. We consider the Lie groups leading to square lattices, namely $SU(2) \times SU(2)$ and $O(5)$ in the 2-dimensional space, and the cubic lattice $SU(2) \times SU(2) \times SU(2)$ in the 3-dimensional space. We aim at evaluating the benefits of some Discrete Group Transform (DGT) techniques, in particular the Continuous Extension of the Discrete Cosine Transform (CEDCT), and at developing new techniques that refine image quality: this refinement is called the high-resolution process. This highest quality is useful to increase the effectiveness of standard features extraction, fusion and classification algorithms.

All algorithms based on the 2 and 3-dimensional DGT have the advantage to give the exact value of the original data at the points of the grid lattice, and interpolate well the data values between the grid

points. The quality of the interpolation is comparable with the most efficient data interpolation which are currently used for purposes of image zooming.

In our first application, we use DGT techniques to refine fully polarimetric radar images, and to increase the effectiveness of standard features extraction algorithms.

In our second application, we apply DGT techniques on medical images extracted from a system and a Magnetic Resonance Imaging (MRI) system.

6065-48, Poster Session

A prioritized and adaptive approach to volumetric seeded region growing using texture descriptors

N. J. Backman, Whitworth College; B. W. Whitney, Northern Kentucky Univ.; J. D. Furst, D. S. Raicu, DePaul Univ.

The performance of segmentation algorithms often depends on numerous parameters such as initial seed and contour placement, threshold selection, and other region-dependent a priori knowledge. While necessary for successful segmentation, appropriate setting of these parameters can be difficult to achieve and requires a user experienced with the algorithm of the application field. In order to overcome these difficulties, we propose a prioritized and adaptive volumetric region growing algorithm which will automatically segment a region of interest while simultaneously developing a stopping criterion. This algorithm utilizes volumetric texture extraction to establish the homogeneity criterion whereas the analysis of the aggregating voxel similarities will, over time, define region boundaries. Using our proposed approach on a volume, derived from Computed Tomography (CT) images of the abdomen, we segmented three organs of interest (liver, kidney and spleen). We find that this algorithm is capable of providing excellent volumetric segmentations while also demanding significantly less user intervention than other techniques as it requires only one interaction from the user, namely the selection of a single seed voxel.

6065-49, Poster Session

A fast MAP-based superresolution algorithm for general motion

M. Tanaka, M. Okutomi, Tokyo Institute of Technology (Japan)

Super-resolution is a technique to reconstruct a high resolution image (HRI) by combining multiple low-resolution images (LRIs). MAP-based super-resolution is one of famous algorithms. A huge calculation amount is an open issue of MAP-based super-resolution. We propose a fast MAP-based super-resolution. The MAP-based super-resolution is formulated as an optimization problem with respect to the HRI. The direct solution of the optimization problem is not feasible, since the number of unknown parameters is typically greater than several thousands. Therefore, the MAP-based super-resolution solves that optimization problem by an iterative method. For the proposed algorithm, basic five images related to the cost function are defined. The cost function is reformulated to a combination of simple image operations among those five images. Then, the proposed algorithm optimizes the cost function with respect to the HRI in the frequency domain, whereas existing MAP algorithms optimize with respect to the HRI in the spatial domain. Calculation amount comparison verifies that the proposed algorithm has much smaller calculation cost than a typical algorithm. Experiments using real images captured by a hand-held camera are also demonstrated. They show that the proposed algorithm greatly hastens the super-resolution process, reconstructing an identical HRI to the typical algorithm.

6065-50, Poster Session

Image deblurring by the combined use of a superresolution technique and inverse filtering

Y. Yamada, K. Nakamae, Osaka Univ. (Japan); H. Fujioka, Fukui Univ. of Technology (Japan)

The secondary electron images by scanning electron microscopy (SEM) are considered to be blurred by the electron beam profile. The electron beam profile is approximated by a Gaussian profile. This implies that the transfer function of SEM is necessarily bandlimited. As one of superresolution techniques that seek to recover information beyond the limit, the extrapolation method by error energy reduction is well known. The method is based on a principle of successive energy reduction. However, when the transfer function is the Gaussian function, it is difficult to extrapolate the spectrum of an object beyond the limit by using the extrapolation method.

In this study, we try to deblur the image by the combined use of an extrapolation method and inverse filtering. The procedure is as follows. At first, the electron beam profile "h" is estimated from the secondary electron profile for step edge included in the observed image "g". Then the image "g" is transformed into the image "G" in the frequency domain by the Fourier transform and is low-pass filtered by truncating its Fourier transform to zero outside the interval $(-e, e)$. The bandlimited image "G_lim" is obtained. For the estimated electron beam profile "h", the same process is carried out. That is, "h" is transformed into "H" in the frequency domain and is low-pass filtered. The bandlimited blurring function "H_lim" is obtained. Next the bandlimited original image "F_lim" is computed by using inverse filtering or by dividing "G_lim" by "H_lim". It is well known that when "H" has zero or very small values, then the noise related ratio "N/H" could easily dominate the estimate "G/H". N is the Fourier transform of the additive noise term. By limiting the analysis to frequencies near the origin, we reduce the probability of encountering zero values. Lastly, by applying the error energy reduction extrapolation method to "F_lim", we can obtain the original, deblurring image. We applied our proposed method to simulated blurred images. The quality of our results is superior to that of images restored with Wiener filtering technique.

6065-36, Session 10

Estimation of color filter array data from JPEG images for improved demosaicing

W. Feng, S. J. Reeves, Auburn Univ.

On-camera demosaicing algorithms are necessarily simple and therefore do not yield the best possible images. However, off-camera demosaicing algorithms face the additional challenge that the data has been compressed and therefore corrupted by quantization noise. We propose a method to estimate the original color filter array (CFA) data from JPEG-compressed images so that more sophisticated (and better) demosaicing schemes can be applied to get higher-quality images. The JPEG image formation process, including simple demosaicing, color space transformation, chrominance channel decimation and DCT, is modeled as a series of matrix operations followed by quantization on the CFA data, which is estimated by least squares. A simple iterative method (steepest descent) is used in implementation to memory concern and fast computation. Our experiments show that the mean square error with respect to the original CFA data is reduced by a factor of 30 to 60 percent using our algorithm, compared to that of unprocessed JPEG and de-blocked JPEG data.

6065-37, Session 10

Separation of irradiance and reflectance from observed color images by logarithmical nonlinear diffusion process

T. Saito, H. Takahashi, T. Komatsu, Kanagawa Univ. (Japan)

The Retinex theory was first proposed by Land and deals with separation of irradiance from reflectance in an image. The problem is an ill-posed problem. Land and others proposed various Retinex separation algorithms. Recently, Kimmel and others proposed a variational framework that unifies the previous Retinex algorithms such as the Poisson-equation-type Retinex algorithms developed by Horn and others, and presented a Retinex separation algorithm with the time-evolution of the linear diffusion process. However, the Kimmel's separation algorithm cannot achieve physically rational separation, if true irradiance varies among color channels. To cope with this problem, we introduce a nonlinear diffusion process into the time-evolution. Moreover, as to its extension to color images, we present two approaches to treat color channels: the independent approach to treat each color channel separately and the collective approach to treat all color channels collectively. The latter approach outperforms the former. Furthermore, we apply our separation algorithm to a chroma key in which before combining a foreground frame and a background frame into an output image a color of each pixel in the foreground frame are spatially adaptively corrected through transformation of the separated irradiance. Experiments demonstrate superiority of our separation algorithm over the Kimmel's separation algorithm.

6065-38, Session 10

Novel scanner characterization method for color measurement and diagnostics applications

B. Lee, Thomson Corporate Research; R. Bala, Xerox Corp.; G. Sharma, Univ. of Rochester

We propose a novel scanner characterization approach for applications requiring color measurement of hardcopy output in printer calibration, characterization, and diagnostic applications. It is assumed that a typical printed medium comprises the three basic colorants C, M, Y. The proposed method is particularly advantageous when additional colorants are used in the print (e.g. black (K)). A family of scanner characterization targets is constructed, each varying in C, M, Y and at a fixed level of K. A corresponding family of 3-D scanner characterizations is derived, one for each level of K. Each characterization maps scanner RGB to CIELAB, using standard characterization techniques. These are then combined into a single 4-D characterization mapping RGBK to CIELAB. A refinement of the technique improves performance significantly by using the scanned values for K (e.g. the scanner's green channel response to printed K). This makes this new approach more robust with respect to variations in printed K over time. Secondly it enables, with a single scanner characterization, accurate color measurement of prints from different printers within the same family. Results show that the 4-D characterization technique can significantly outperform standard 3-D approaches especially in cases where the image being scanned is a patch target made up of unconstrained CMYK combinations.

6065-39, Session 11

Elastic surface registration by parameterization optimization in spectral space

F. G. Vadakkumpadan, Y. Tong, Y. Sun, Purdue Univ.

This paper proposes a novel method to register 3D surfaces. Given two surface meshes, we formulate the registration as a problem of optimizing the parameterization of one mesh for the other. The optimal parameterization of the mesh is achieved in two steps. First, we find an initial solution close to the optimal solution. Second, we elastically modify the parameterization to minimize the cost function. The modification of the parameterization is expressed as a linear combination of a relatively small number of low-frequency eigenvectors of an appropriate mesh Laplacian. The minimization of the cost function uses a standard nonlinear optimization procedure that determines the coefficients of the linear combination. Constraints are added so that the parameterization validity is preserved during the optimization.

The proposed method extends parametric registration of 2D images to the domain of 3D surfaces. This method is generic and capable of elastically registering surfaces with arbitrary geometry. It is also very efficient and can be fully automatic. We believe that this paper for the first time introduces eigenvectors of mesh Laplacians into the problem of surface registration. We have conducted experiments using real meshes that represent human cortical surfaces and the results are promising.

6065-40, Session 11

Mosaicking of astronomical images with MOPEX

D. Makovoz, I. Khan, F. J. Masci, California Institute of Technology

We present MOPEX - a software package for mosaicking of astronomical images.

MOPEX features image registration, background matching, usage of several interpolation techniques, coaddition schemes, and robust and flexible outlier detection based on spatial and temporal filtering.

Image registration is based on matching the positions and fluxes of common point sources in image overlap regions. This information is used to compute a set of image offset corrections by globally minimizing the cumulative point source positional difference. A similar approach was used for background matching in overlapping. The cumulative pixel-by-pixel difference between the overlapping areas of all pairs of images is minimized with respect to the unknown constant offsets of the input images.

The interpolation techniques used by MOPEX are the area overlap, drizzle, grid, and bicubic interpolation. We compare different interpolation techniques for their fidelity and speed. Robust outlier detection techniques allow for effective and reliable removal of the cosmic ray hits contaminating the detector array images. Efficient use of computer memory allows mosaicking of data sets of very deep coverage of thousands of images per pointing, as well as areas of sky covering many square degrees. MOPEX has been developed for the Spitzer Space Telescope.

6065-41, Session 11

Image processing using parallel GPU units

K. A. Bjorke, NVIDIA Corp.

GPGPU or General Processing on GPUs, is a growing field of research that capitalizes on the parallel-processing horsepower found in the GPUs used by millions of computers to speed real-time 3D display. GPUs are powerful multi-threaded parallel floating-point processors, capable of much higher bandwidth and image-processing power than traditional or even multi-core CPU designs. To tap into GPGPU requires a few key insights into how to re-compose imaging algorithms into forms that execute well on GPUs, such as decomposition of complex asymmetric convolutions into multiple passes, how to manage data-dependent changes in filter kernels, and how to manage issues such as the scatter problem.

6065-42, Session 11

Partial shape similarity of contours is needed for object recognition

Z. Pizlo, Purdue Univ.; L. J. Latecki, Temple Univ.

No abstract available

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6066-01, Session 1

A deformable model with topology analysis and adaptive clustering for boundary detection

M. Allili, Bishop's Univ. (Canada); B. Yang, Univ. de Sherbrooke (Canada); L. Bentabet, Bishop's Univ. (Canada)

Object recognition using the shape of objects boundaries and surface reconstruction using slice contours rely on the identification of the complete boundary information of the segmented objects in the scene. Geometric deformable models (GDM) using the level sets method provide a very efficient framework for image segmentation. However, the segmentation results provided by these models are usually dependent on the contour initialization, and in most cases where the strategy is to detect all the scene objects, the results of the segmentation will only provide partial objects boundaries. In this work, we propose a method based on digital topology and adaptive fuzzy clustering to detect the complete boundary information of segmented objects. This information turns out to be very crucial in carrying out a topological analysis of the objects and can be used in their higher level processing as outlined previously. A key issue in object recognition using the shape of the object's boundary and surface reconstruction using slice contours is the ability to identify the complete boundaries of the segmented objects in the scene. Geometric deformable models (GDM) using level sets method provide a very efficient framework for image segmentation. However, the segmentation results provided by these models are usually dependent on the contour initialization, and in most cases where the strategy is to detect all the scene objects, the results of the segmentation will only provide partial objects boundaries. In this work, we propose a method based on a combination of concepts from digital topology and unsupervised clustering that will allow in certain cases to detect the complete boundary information of the segmented objects. This information turns out to be very crucial in carrying out the detection and the topological analysis of objects in the scene and can be used in their higher level processing as outlined previously. A number of experiments are performed on both synthetic and real images to assess the performance of the proposed approach.

6066-02, Session 1

Refining road map using active shape model from aerial images

G. Koutaki, K. Uchimura, Z. Hu, Kumamoto Univ. (Japan)

A digital topographic database is an essential part of a Geographic Information System. Road arcs and topological networks stored in a database of digital maps are used in various applications, such as car navigation, transportation, city planning, etc. While it is necessary to correct the spatial errors of road maps, manual extraction from aerial images is time consuming and tedious work. In order to correct road using existing road maps, we propose to use an active shape models. An active shape model can deform itself preserving a given basic shape template by restricting the deformation to the affine transformation. In addition, in order to deal with more flexible deformation, B-spline approximation is used. Polylines of the existing digital road map are used to set initial contours of active shape model and used to construct shape templates. In order to consider a topological connections for road map, we apply the deformation to not single road but simultaneously several roads one step at a time. By iterating the deformation step, road network is refined. Finally, experimental results will show that proposed method can refine the existing road map correctly by fitting aerial image.

6066-03, Session 1

Quantification of line-mura defect level based on multiple characterizing features

N. K. Park, K. N. Choi, S. I. Yoo, Seoul National Univ. (South Korea)

Recently, with an increasing FPD market, automatic detection of the mura in the manufacturing process has become a critical issue for manufactures interested in increasing their TFT-LCD quality. But segmentation based detection algorithms deviate from human visual perception model. To supplement the detection error produced by deviation, the mura is re-inspected through a visual inspection during manufacturing process. If we could objectively quantify each mura's defect degree, then based on some threshold of defect degree, we could reduce the number of re-inspection. We call this degree line muras defect level. Our approach is an attempt to quantify the ideal defect level of line mura, that for each individual could vary because of subjectivity, based on multiple features crucial in the detection of line mura. In the process, we approximated what we call JND surface that passes through the middle of feature points with mean mura visibility of 0.5. Then Index function, which measures distance from JND surface, is employed to measure the objective defect level of each candidate mura.

6066-04, Session 1

Model-based shape classification using shape-transformation-invariant descriptors

S. C. Lee, Univ. of Oklahoma; Y. Wang, E. T. Lee, Univ. of Oklahoma Health Sciences Ctr.

Shape descriptors can be classified into two categories in relation to shape transformation: shape-transformation-variant descriptors (STVD) and shape-transformation-invariant descriptors (STID). As shown in many previous studies, the shape classification methods derived from the STVD-based similarity measures often require shape normalization/standardization that involves complicated computations and contour or code matching schemes. These methods are in general vulnerable to some, if not all, shape transformations.

In this paper, we introduce a quantitative shape similarity measure and a new model-based shape classification method that use exclusively the STIDs, which include compactness, eccentricity, elongatedness, rectangularity, and sphericity. The measure and the new method eliminate all possible variations caused by shape transformation. Given n model shapes representing n classes of shapes, and a set of test shapes, the purpose of this paper is to first classify each of the test shapes into one of the n classes based on their shape similarities, and then rank the similarities of the test shapes with respect to their model shapes using the proposed STID-based similarity measure. It is found that the shape classifications and similarity measures performed by the proposed method match well with human observations. An example is given to illustrate the method.

6066-05, Session 1

Refinement of axial shape description

A. N. Skourikhine, Los Alamos National Lab.

The representation and characterization of shapes has important consequences for image processing and image content understanding. Numerous approaches have been developed to provide image analysis with efficient methods to represent shapes. We present a region-based approach to extract a refined axial regional shape description in the form of a skeleton, which is based on the use of the constrained Delaunay triangulation (CDT) and the chordal axis transform (CAT). We elaborate on the exploitation of the

approximate edge co-circularity criterion that is used to refine CAT-produced skeletons. The co-circularity criterion enables saliency evaluation of CDT-generated triangle edges lying inside regions (chords), filters out non-salient chords, and its application leads to reconstruction of smoother skeletons. In contrast with the chord strength evaluation of the original skeleton rectification algorithm, where chord strength evaluation does not consider strengths of its neighboring chords, we introduce smoothing operator to evaluate chord strength by processing chord strengths within local neighborhood. The result of region characterization based on the proposed smoothing-based chord evaluation is that skeleton is more authentic to original shape, while at the same time it significantly reduces number of skeleton segments, thus providing more compact shape representation for the further shape analysis.

6066-06, Session 2

Geometry of human vision

Z. Pizlo, Purdue Univ.

No abstract available

6066-07, Session 3

Fitting polygonal regions for matching 3D polyhedra

L. Mukherjee, V. Singh, J. Xu, R. Berezney, SUNY/Univ. at Buffalo
Matching geometric objects is a fundamental problem in computer vision and computational geometry with applications in a number of different areas. We study an important partial matching problem motivated from several applications in nuclear and medical imaging. In such applications, 3D images are represented as sampled slices, i.e. they are only a partial representation of the actual 3D object. However, reconstruction based on such under-samples is inherently flawed, usually as a function of the amount of information lost due to the under-sampling. This severely limits the applicability of classical shape matching techniques, necessitating the development of efficient partial matching techniques. In summary, the problem is that given sets of under-sampled slices of one (or more) unknown 3D objects, possibly generated by slicing planes of arbitrary orientations, whether it is 'possible' that two under-sampled sets are from the same object. Alternatively, can we determine with 'certainty' that the given input samples cannot be from the same object? A simple "No" or "Maybe" answer helps eliminate a good part of possible candidates for a match. Once the culling process is done, a combination of other techniques could be used in conjunction with specialized knowledge to determine likely matches, drastically reducing manual intervention.

6066-09, Session 3

Hierarchical two view line segment matching using wavelet transform

F. Mai, Y. Hung, W. Sze, The Univ. of Hong Kong (Hong Kong China)

This paper presents a novel algorithm for line segment matching over two views. Defining supporters for a line segment to be the edge points lying close to it, a line segment is treated as a list of edge points, and the problem of line segment matching is transformed into that of point matching. Two image pyramids are built by applying wavelet decomposition to the two images. Matching is done from the coarsest level in the image pyramid and upgraded to the finest level gradually. At each level, first the supporters are matched using cross-correlation techniques. Then a voting process is used to obtain matched line segment pairs. This method can match line segments over two uncalibrated views, in which the line segments need not be the images of the same section of a 3D line segment. The hierarchical strategy helps to reduce the

computational complexity. A wavelet approach is adopted to build the hierarchical frame for its built-in multi-scale structure and fast decomposition algorithm. Furthermore, it overcomes the flattening-out problem in the traditional multi-scale Gaussian pyramid technique. Experiments on real image pairs are given to demonstrate the effectiveness and the robustness of our algorithm.

6066-10, Session 3

A vision-based approach to extracting the tilt angle and altitude of a PTZ camera

I. Chen, S. Wang, National Chiao Tung Univ. (Taiwan)

In this paper, we propose a vision-based approach to infer both the tilt angle and the altitude of a PTZ camera. Under the constraint that all observed points are lying on a horizontal plane, the mapping between the 3-D space and the 2-D image plane with respect to the tilt angle and altitude is first deduced. Then, based on the back projection formulae, the tilt angle and altitude of the camera can be easily estimated by viewing simple patterns on a horizontal plane. The pattern could be a circle, a corner with known angle, more than two corners with unknown but equal angles, or more than two line segments with unknown but equal lengths. Moreover, if we are given a few line segments with known lengths, not only the tilt angle but also the altitude of the PTZ camera above the horizontal plane can also be extracted via an optimization procedure. This method does not need a large amount of data and requires low computational load. Experiments over real data demonstrate the efficiency of the proposed method. If compared with the homography and the rotation matrix extracted in conventional calibration approaches, the tilt angle and altitude information extracted by our approach can offer direct geometric sense and would be very useful for the development of surveillance systems.

6066-12, Session 4

Perspex machine V: compilation of C programs

M. P. Spanner, J. A. D. W. Anderson, The Univ. of Reading (United Kingdom)

The perspex machine arose from the unification of the Turing machine with projective geometry. The original, constructive proof used four special, perspective transformations to implement the Turing machine in projective geometry. These four transformations are now generalised and applied in a compiler, implemented in Pop11, that converts a subset of the C programming language into perspexes. This is interesting both from a geometrical and a computational point of view. Geometrically, it is interesting that program source can be converted automatically to a sequence of perspective transformations and conditional jumps, though we find that the product of homogeneous transformations with normalisation can be non-associative.

Computationally, it is interesting that program source can be compiled for a Reduced Instruction Set Computer (RISC), the perspex machine, that is a Single Instruction, Zero Exception (SIZE) computer.

6066-13, Session 4

Automatic and robust classification of independent motions in video sequences

X. An, Zhejiang Univ. (China)

Segmentation of independent motions from video sequences is a challenging problem that can be a prelude to many further applications in computer vision. In this paper, we present an accurate and efficient approach for automatic segmentation of all the independently moving objects in the scene.

The system begins with an initialization module, which provides initial segmentation of the scene, computes 2D motions, etc. Then, we propose a novel object classification method by analyzing motions base on the epipolar geometry constraint. To achieve the best robustness, and minimize the total computation load, we choose to work on multiple key frames simultaneously to obtain global optimal classification. Our approach achieves accurate object classification and avoids the uncertainty in detection of moving objects existed in some traditional methods. We demonstrate high stability, accuracy and performance of our proposed algorithm with a number of experiments on real video sequences.

6066-28, Poster Session

A three-dimensional shape measurement method: structure light space-time stereo

X. Li, Shanghai Univ. (China)

The active triangulation principal used in the structured light system has disadvantage which is located in the limit position, or whose calibration process is difficult. The principle based on light-plane model can solve it as far as possible. Taking account of the distortion coefficient of CCD lens, such as radial distortion, it would increase the whole system precision. Subpixel measurement about stripe boundary is advantageous to accuracy. The method is based on gravity principal, which is fit to stripe measurement of the structured light system. During the coded methodology, the temporal and special stripe boundary is suitable to real-time condition. So the 56 coded stripes are designed, which use the 3 consecutive patterns on time. Compared with the hybrid method of Hall-Holt and Rusinkiewicz, which is 4 patterns with 111 binary stripes and coded efficiency of , there are 3 patterns with 56 binary stripes and coded efficiency of 56/64. In order to acquire the full range image or to acquire more accuracy in the same condition, ICP algorithm is applied in data registration of the structured light system. The advanced ICP based on projection principal is utilized.

6066-29, Poster Session

Multiview image calibration and rectification for and effective 3D display

K. Bae, 3R Inc. (South Korea); H. Kang, E. Kim, Kwangwoon Univ. (South Korea)

In this paper, multiview calibration system for an effective 3D display is proposed. This calibration system can obtain non-calibrated 4-view image from multiview camera calibration system. Also it can be rectify camera's lens distortion, an error of brightness and color, and distortion of geometry. In this paper, the miss-matching of the brightness and the colors are calibrated by extracting the feature point and correspondence point. In addition, the difference of brightness is calibrated by using the differential map of brightness from each camera's image. A spherical lens distortion is corrected by extracting the pattern of the multiview camera images. Finally the camera error and size among the multiview cameras is calibrated by removing the distortion which is removing error components caused by the housing, the location of censor, and the distortion of lenses. Accordingly, this proposed multiview camera calibration system enables to effect mutiview 3D display and acquire realistic 3D image.

6066-30, Poster Session

Perspex machine VI: a graphical user interface to the Perspex machine

C. J. Kershaw, J. A. D. W. Anderson, The Univ. of Reading (United Kingdom)

The perspex machine is a continuous, super-Turing machine which, in previous work, was simulated programatically on a digital computer in the AI language Pop11. Here we present a C++

simulation of the perspex machine, along with a graphical user interface, that can be used to implement, edit, visualise, instrument, and run perspex programs interactively. The interface uses a number of different projections to make 4D perspex-space more accessible to the user.

We also present a new proof of the Walnut Cake Theorem that has much weaker conditions than the previous proof and is, therefore, much more widely applicable. It predicts non-monotonicities in numerical algorithms with sub-quadratic convergence.

6066-31, Poster Session

Perspex machine VII: the universal Perspex machine

J. A. D. W. Anderson, The Univ. of Reading (United Kingdom)

The perspex machine arose from the unification of projective geometry with the Turing machine. It uses a total arithmetic, called transreal arithmetic, that contains real arithmetic and allows division by zero. Transreal arithmetic is redefined here. The new arithmetic has both a positive and a negative infinity which lie at the extremes of the number line, and a number nullity that lies off the number line. We prove that nullity, $0/0$, is a number. Hence a number may have one of four signs: negative, zero, positive, or nullity. It is, therefore, impossible to encode the sign of a number in one bit, as floating-point arithmetic attempts to do, resulting in the difficulty of having both positive and negative zeros and NaNs.

Transrational arithmetic is consistent with Cantor arithmetic. In an extension to real arithmetic, the product of zero, an infinity, or nullity with its reciprocal is nullity, not unity. This avoids the usual contradictions that follow from allowing division by zero. Transreal arithmetic has a fixed algebraic structure and does not admit options as IEEE, floating-point arithmetic does. Most significantly, nullity has a simple semantics that is related to zero. Zero means "no value" and nullity means "no information." We argue that nullity is as useful to a manufactured computer as zero is to a human computer.

The perspex machine is intended to offer one solution to the mind-body problem by showing how the computable aspects of mind and, perhaps, the whole of mind relates to the geometrical aspects of body and, perhaps, the whole of body. We review some of Turing's writings and show that he held the view that his machine has spatial properties. In particular, that it has the property of being a 7D lattice of compact spaces. Thus, we read Turing as believing that his machine relates computation to geometrical bodies.

We simplify the perspex machine by substituting an augmented Euclidean geometry for projective geometry. This leads to a general-linear perspex-machine which is very much easier to program than the original perspex-machine. We then show how to map the whole of perspex space into a unit cube. This allows us to construct a fractal of perspex machines with the cardinality of a real-numbered line or space. This fractal is the universal perspex machine. It can solve, in unit time, the halting problem for itself and for all perspex machines instantiated in real-numbered space, including all Turing machines. We cite an experiment that has been proposed to test the physical reality of the perspex machine's model of time, but we make no claim that the physical universe works this way or that it has the cardinality of the perspex machine. We leave it that the perspex machine provides an upper bound on the computational properties of physical things, including manufactured computers and biological organisms, that have a cardinality no greater than the real-number line.

6066-14, Session 5

Discrete circles: an arithmetical approach with non-constant thickness

C. Fiorio, D. Jamet, J. Toutant, Univ. Montpellier II (France)

Discrete geometry attempts to provide an analogue of Euclidean geometry for discrete spaces. Its main application is computer graphics, since images can be seen as grids of pixels. The primary objective was to draw basic objects: discrete lines and discrete circles.

In the present paper, we introduce a general arithmetical definition of discrete circles inspired by J.-P. Reveillès' discrete geometry, namely the discrete arithmetical geometry. Our main contribution consists in considering non-constant thickness, depending on the local behavior of the corresponding Euclidean circle. We thus show how the present definition includes already known discrete circles, such as E. Andres' discrete analytical circles as well as algorithmical approach (for instance, J. Bresenham's circles). As far as we know, this is the first arithmetical characterization of the latter. Finally, by considering usual norms, norm 1 and infinite norm, we characterize 0-minimal and 1-minimal discrete circles.

6066-15, Session 5

Estimating the analog perimeter of a pre-digitized shape

S. C. Lee, Univ. of Oklahoma; Y. Wang, E. T. Lee, Univ. of Oklahoma Health Sciences Ctr.

Given a general digital shape of high-resolution, its analog perimeter of the pre-digitized shape (APPS) can be adequately estimated using the conventional chain-code based methods. For a digital shape of low resolution, however, these methods may not provide accurate or consistent estimates due to the variations of APPS with shape orientations, which are inversely proportional to the digitization resolutions. Aiming at improving the accuracy and consistency in estimating APPS for low-resolution digital shapes, this paper presents a method to find the median values of digital perimeter curves (DPC) obtained from rotating the shapes.

For digital shapes in low-resolution images, the proposed method not only eliminates the inconsistency or uncertainty in the estimates of APPS due to their variations with shape orientations, but also produces estimates with high accuracy.

Two examples are given to illustrate and evaluate the proposed method. In the first example, four polygons and a circle are digitized using two different (high and low) resolutions. Accuracies of their APPS estimated by the proposed method are 96.70 ~ 99.97% for the low-resolution shapes and 96.48 ~ 100.00% for the high-resolution shapes. In the second example, the proposed method gives a 98.08 ~ 99.98% accuracy in estimating the APPS of a low-resolution arbitrary shape. These results support our expected accuracy.

6066-17, Session 5

Three-dimensional fast exact Euclidean distance (3D-FEED) maps

T. E. Schouten, H. C. Kuppens, Radboud Univ. Nijmegen (Netherlands); E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands)

In image and video analysis, distance maps are frequently used. They provide the (Euclidean) distance (ED) of background pixels to the nearest object pixel. Recently, the Fast Exact Euclidean Distance (FEED) transformation was launched. In this paper, we present the three dimensional (3D) version of FEED. 3D-FEED is compared with four other methods for a wide range of 3D test images. 3D-FEED proved to be twice as fast as the fastest algorithm available.

Moreover, it provides true exact EDs, where other algorithms only approximate the ED. This unique algorithm makes the difference, especially there where time and precision are of importance. More and more, three dimensional (3D) images are used in many applications of computer vision. Various methods that have proven to be useful in two dimensional (2D) image processing, were adapted to 3D images. One of these methods is the distance transformation, which generates an image in which the value of each pixel is its distance to a given set of pixels O in the original binary image.

6066-18, Session 5

Estimating the surface area and volume of a general 3D shape

S. C. Lee, Univ. of Oklahoma; Y. Wang, E. T. Lee, Univ. of Oklahoma Health Sciences Ctr.

A new method for estimating the analog surface area and the volume of a general 3D shape is presented. By using chain-code based boundary estimation formulas, the proposed method eliminates many complicated interpolation and estimation procedures employed by the conventional methods, which makes the proposed method simple both in algorithm and computation. Considering the variation of digital boundary with shape orientations, the estimated perimeters of each slide of the 3D shape are used to measure the lateral area of a 3D surface through a single integration. The same approach is applied to estimating the volume of a 3D shape.

The proposed method is suitable in estimating the surface area and volume of 3D objects presented in volumetric images such as MRI and CT scan. An example is given to illustrate the proposed method. The result shows that the proposed method gives a 94.4 ~ 97.86% accuracy in estimating the surface area and a 97.58 ~ 98.59% accuracy in estimating the volume, which is in agreement with our expectations.

6066-19, Session 6

Dynamic RANSAC

W. Sze, A. W. Tang, Y. Hung, The Univ. of Hong Kong (Hong Kong China)

Putative matches from 2-view matching methods based on similarity measures are not reliable. Hence, fitting a model for a set of putative matches to remove 'outliers' becomes essential. Outliers are point pairs which are not consistent with the geometric models and they are usually mismatches generated by the matching process. In this paper, the classical random sample consensus (RANSAC) approach is considered for robust matching to remove mismatches (outliers) in a list of putative correspondences. We examine the justification for using the minimal size of sample set in a RANSAC trial and propose that the size of the sample set should be varied dynamically depending on the noise and data set. Using larger sample set will not increase the number of iterations dramatically but it can provide a more reliable solution. A new adjusting factor is added into the original RANSAC sampling equation such that the equation can model the noisy world better. In the proposed method, the noise variances, percentage of outliers and number of iterations are all estimated iteratively. Experimental results show that the estimated parameters are close to the ground truth. The modification can also be applied to any sampling consensus methods extended from RANSAC.

6066-20, Session 6

Singular value decomposition based scale invariant image matching

W. Sze, A. W. Tang, Y. Hung, The Univ. of Hong Kong (Hong Kong China)

In this paper, an image matching algorithm combining a SVD matching approach and scale invariant measure is proposed to relate images with large-scale variations. To obtain a better performance on handling redundant points, we modify the SVD matching approach which enforces the condition of minimal distance between the structures of point patterns, while at the same time, ensures the likelihood of the matched points. The algorithm can be subdivided into two stages. First, point correspondences between two images are matched by scale invariant similarity measures. Once the ratios between scales of the matched pairs are calculated, the scale difference between two images can subsequently be determined from the peak of the histogram of the scale ratios. The images are then rescaled according to their scale ratio and the origins of the images are translated to the centroids of the matched points. Following this, proximities between points in the images are computed. Incorporating the scale invariant similarity measures into the proximities, SVD-based matching is performed. Experimental results show that the proposed method gives better and more consistent correspondences even without any outlier detection. Excellent performance is obtained even at a scale factor of more than 3.

6066-21, Session 6

Image matching using algebraic topology

S. Derdar, Univ. de Sherbrooke (Canada); A. Madjid, Bishop's Univ. (Canada); D. Ziou, Univ. de Sherbrooke (Canada)

In this paper, two new approaches for the topological feature matching problem are proposed. The first one consists of estimating a combinatorial map between block structures (pixels, windows) of given binary images which is then analyzed for topological correspondence using the concept of homology of maps. The second approach establishes a matching by using a similarity measure between two sets of boundary representations of the connected components extracted from two given binary images. The similarity measure is applied on all oriented boundary components of given features. A number of experiments are carried out on both synthetic and real images to validate the two approaches.

6066-22, Session 6

Robustness and statistical analysis of object/image metrics

P. F. Stiller, Texas A&M Univ.

In previous papers we examined several fundamental problems related to object recognition for the generalized weak perspective model of image formation and offered a complete solution to those problems for configurations of point features. In this paper we convert those theoretical solutions to working algorithms and examine the robustness of the algorithms in the face of various combinations of errors and noise.

Our approach makes use of progress in shape theory, including the development of object/image equations for shape matching and shape space metrics (especially object/image metrics). This theory exploits advanced mathematical techniques from algebraic and differential geometry to construct generalized shape spaces for various projection and sensor models, and then uses that construction to find natural metrics that express the distance (difference) between two configurations of object features, two configurations of image features, or an object and an image pair. Such metrics are believed to produce the most robust tests for

target identification; at least as far as target geometry is concerned. Moreover, they also provide a basis for efficient hashing schemes to do target identification quickly, and they provide a rigorous foundation for error analysis in ATR. It is that error analysis that is the focus of this paper.

The most important feature of a shape theoretic approach is that all of the matching tests and metrics are independent of the choice of coordinates used to express the feature locations on the object or in the image. In addition, the approach is also independent of the camera/sensor position and any camera/sensor parameters.

6066-23, Session 6

GSIFT: Geometric Scale Invariant Feature Transform for Terrain Data

Y. Xiao, S. K. Lodha, Univ. of California/Santa Cruz

No abstract available.

6066-24, Session 7

Reconstruction of quadratic curves in 3D using two or more perspective views: simulation studies

S. Kumar, N. Sukavanam, R. Balasubramanian, Indian Institute of Technology Roorkee (India)

The shapes of many natural and man-made objects have planar and curvilinear surfaces. The images of such curves usually do not have sufficient distinctive features to apply conventional feature-based reconstruction algorithms. We describe a method of reconstruction of a quadratic curve in 3-D space as an intersection of two cones containing the respective projected curve images. The correspondence between this pair of projections of the curve is assumed to be established in this work. Using least-square curve fitting, the parameters of a curve in 2-D space are found. From this we are reconstructing the 3-D quadratic curve. Relevant mathematical formulations and analytical solutions for obtaining the equation of reconstructed curve are given. The results of the described reconstruction methodology are studied by simulation studies. This reconstruction methodology is of considerable practical importance in modern computer vision systems that are employed for tracking objects moving through space under gravity. One such example is the electronic analysis of ball trajectories at sporting events such as tennis and cricket, such analyses of ball trajectories are used to validate or overturn the decisions that are currently made by referees and umpires in these sports (line calls in tennis and LBW decisions in cricket).

6066-25, Session 7

Visualization of volumetric scattered data by using weighted alpha shapes

J. Paik, K. Lee, Handong Global Univ. (South Korea); O. Gwon, Chonbuk National Univ. (South Korea)

Alpha shapes express the intuitive notion of the shape of the point set, and α is a parameter that controls the level of detail reflected by the polytope. However, alpha-shapes give good results for points of roughly uniform density, it does not give for non-uniform point sets. In reconstructing a surface from scattered data it is rarely the case that the points are uniformly dense everywhere on the surface. In order to be effective in non-uniform point sets, it needs to change the value of alpha (radius of sphere) locally depending on the intensity of a point set. The weighted alpha shapes is defined for a finite set of weighted points. We need to investigate the way to achieve different levels of detail in a single shape by assigning weights to the data points. One of the ways to assign weight can be considered by using Inverse Distance Weighted methods. This paper

describes how to assign the weight for each data points. The quality of interpolant of volumetric scattered data depend on the way of assigning weights. To achieve the reasonable way of assigning weights, we need to consider not only the positional information (Euclidian distance), but also intensity.

6066-26, Session 7

POSS: efficient nonlinear optimization for parameterization methods

F. G. Vadakkumpadan, Y. Tong, Y. Sun, Purdue Univ.

We propose a new, generic method called POSS (Parameterization by Optimization in Spectral Space) to efficiently obtain parameterizations with low distortions for 3D surface meshes. Given a mesh, first we compute a valid initial parameterization using an available method and then express the optimal solution as a linear combination of the initial parameterization and an unknown displacement term. The displacement term is approximated by a linear combination of the eigenvectors with the smallest eigenvalues of a mesh Laplacian. This approximation considerably reduces the number of unknowns while minimizing the deviation from the optimality. Finally, we find a valid parameterization with low distortion using a standard constrained nonlinear optimization procedure. POSS is fast, flexible, generic, and hierarchical. Its advantage has been confirmed by its application to planar parameterizations of surface meshes that represent complex human cortical surfaces. This method has a promising potential to improve the efficiency of all parameterization techniques which involve constrained nonlinear optimization.

6066-27, Session 7

Piecewise compression of large mesh

A. Qin, Zhejiang Univ. (China) and Shanxi Univ. (China); J. Shi, Z. Liu, M. Huang, Zhejiang Univ. (China)

Large and detailed 3D polygon mesh with standard representation results in files of gigantic size. So the need for more compact representations and a parallel implementation is clear. But the compressed gigantic mesh applied in parallel rendering to achieve high performance is still an unexplored area. In this work, we present a mesh compression scheme employed in parallel rendering system.

The scheme includes two parts: Mesh segmentation and segments compression. Firstly, the multilevel mesh simplification idea is adopted to separate the mesh into large patches with less curvature. Then the large patches are farther partitioned with MeTiS[1] to get small patches with a balanced vertex counts. As the multilevel mesh produced by the feature preserved mesh simplification procedure, our segmentation algorithm takes both the segment's flatness and balanced vertex counts into account. Secondly, each patch is compressed separately. The vertices in the patch are classified into two distinguish types, namely boundary vertex and inner vertex, different compression algorithm are applied to them. The boundary vertexes are compressed with a novel compression algorithm PMC proposed in this work. To avoid decoding the whole boundary during every frame rendering, the boundary vertexes are compressed piecewise. The successive boundary edges shared by the same patches can act as an element when it is compressed. During sorting only the encoded boundary in the view-frustum needs to be loaded and decompressed.

Experiments show that the encoded mesh can be partitioned in compression-domain in parallel rendering system. It reduces the communication bandwidth requirement significantly.

Wednesday-Thursday 18-19 January 2006

Part of Proceedings of SPIE Vol. 6067 Document Recognition and Retrieval XIII

6067-01, Session 1

Combining one- and two-dimensional signal recognition approaches to off-line signature verification

S. N. Srihari, SUNY/Univ. at Buffalo

A signature verification method that combines recognition methods of one-dimensional signals, e.g., on-line handwriting, and two-dimensional images, e.g., holistic word recognition, is described. A sequence of data is obtained by tracing the exterior contour of the signature which allows the application of straining matching algorithms. The upper and lower contours of the signature are obtained by ignoring small gaps between signature components. To match two signatures a non-linear normalization method, viz., dynamic time warping, is applied to segment them into small curves. Shape descriptors based on Zernike moments are extracted from each segment. A harmonic distance is used for measuring signature similarity. Performance is better than that of a word-shape based signature verification method. When the two methods are combined performance is significantly better than either method alone. With a database of 1320 genuines and 1320 forgeries the combination method has an accuracy of 90%.

6067-02, Session 1

Spotting words in handwritten Arabic documents

S. N. Srihari, H. Srinivasan, P. Babu, C. Bhole, SUNY/Univ. at Buffalo

The design and performance of a system for spotting handwritten Arabic words in scanned document images is presented. Three main components of the system are a word segmenter, a shape based matcher for words and a search interface. The user types in a query in English within a search window, the system finds the equivalent Arabic word, e.g., by dictionary look-up, locates word images in an indexed (segmented) set of documents. A two-step approach is employed in performing the search: (1) prototype selection: the query is used to obtain a set of handwritten samples of that word from a known set of writers (these are the prototypes), and (2) word matching: the prototypes are used to spot each occurrence of those words in the indexed document database. A ranking is performed on the entire set of test word images— where the ranking criterion is a similarity score between each prototype word and the candidate words based on global word shape features. A database of 20,000 word images contained in 100 scanned handwritten Arabic documents written by 10 different writers was used to study retrieval performance. Using five writers for providing prototypes and the other five for testing, using manually segmented documents, 55% precision is obtained at 50% recall. Performance increases as more writers are used for training.

6067-03, Session 1

HCCR by contour-based elastic mesh fuzzy feature

L. Sun, YanTai Univ. (China)

Offline handwritten Chinese character recognition is one of the difficult problems in pattern recognition area because of its large stroke distortion, writing anomaly, and no stroke ranking information can be gotten. The basic characteristic of Chinese character is that it is composed of four kinds of stroke, i.e. horizontal, vertical, 45 degree direction and 135 degree direction. A Chinese character can be uniquely confirmed by the quantity of the four directional strokes

and its relative position. From the contour of Chinese character, we can get the features mentioned above. In this paper, we proposed first to modify an existed contour extraction algorithm and obtained strict single pixel contour of Chinese character, and then to give a contour-based elastic mesh fuzzy feature extraction method. Comparison experimental results show that the performance of our approaches is encouraging and can be comparable to other algorithms.

6067-04, Session 2

Human language technology research at DARPA

J. Olive, Defense Advanced Research Projects Agency

No abstract available

6067-05, Session 3

Partitioning of the degradation space for OCR training

E. H. Barney Smith, T. L. Andersen, Boise State Univ.

Generally speaking optical character recognition algorithms tend to perform better when presented with homogeneous data. This paper studies a method that is designed to increase the homogeneity of training data, based on an understanding of the types of degradations that occur during the printing and scanning process, and how these degradations affect the homogeneity of the data. While it has been shown that dividing the degradation space by edge spread improves recognition accuracy over dividing the degradation space by threshold or point spread function width alone, the challenge is in deciding how many partitions and at what value of edge spread the divisions should be made. Clustering of different types of character features, fonts, sizes, resolutions and noise levels shows that edge spread is indeed shown to be a strong indicator of the homogeneity of character data clusters.

6067-06, Session 3

Match graph generation for symbolic indirect correlation

D. P. Lopresti, Lehigh Univ.; G. Nagy, A. Joshi, Rensselaer Polytechnic Institute

Symbolic indirect correlation (SIC) is a new approach for bringing lexical context into the recognition of unsegmented signals that represent words or phrases in printed or spoken form. One way of viewing the SIC problem is to find the correspondence, if one exists, between two bipartite graphs, one representing the matching of the two lexical strings and the other representing the matching of the two signal strings. While perfect matching cannot be expected with real-world signals and while some degree of mismatch is allowed for in the second stage of SIC, such errors, if they are too numerous, can present a serious impediment to a successful implementation of the concept. In this paper, we describe a framework for evaluating the effectiveness of SIC match graph generation and examine the relatively simple, controlled cases of synthetic images of text strings typeset, both normally and in highly condensed fashion. We quantify and categorize the errors that arise, as well as present a variety of techniques we have developed to visualize the intermediate results of the SIC process.

6067-07, Session 3

Toward quantifying the amount of style in a dataset

X. Zhang, S. Andra, Rensselaer Polytechnic Institute

Exploiting style consistency in groups of patterns (pattern fields) generated by the same source has been demonstrated to yield higher accuracies in OCR applications. The accuracy gains obtained by a style consistent classifier depend on the amount of style in a dataset in addition to the classifier itself. The computational complexity of style-based classifiers precludes their applicability in situations where datasets have small amounts of style. In this paper, we propose a correlation-based measure to quantify the amount of style in a dataset and demonstrate its use in determining the suitability of a style consistent classifier on both simulation and real datasets.

6067-08, Session 3

Robust feature extraction for character recognition based on binary image

L. Wang, L. Zhang, Y. Xing, Z. Wang, Nuctech Co. Ltd. (China); H. Gao, Tsinghua Univ. (China)

Optical Character Recognition (OCR) is a classical research field and has become one of most successful applications in the area of pattern recognition. Feature extraction is a key step in the process of OCR. This paper presents three algorithms for feature extraction based on binary images: the Lattice with Distance Transform (DTL), Stroke Density (SD) and Co-occurrence Matrix (CM). DTL algorithm improves the robustness of the lattice feature by using distance transform to increase the distance of the foreground and background and thus reduce the influence from the boundary of strokes. SD and CM algorithms extract robust stroke features based on the fact that human recognize characters according to strokes, including length and orientation. SD reflects the quantized stroke information including the length and the orientation. CM reflects the length and orientation of a contour. SD and CM together sufficiently describe strokes. Since these three groups of feature vectors complement each other in expressing characters, we integrate them and adopt a hierarchical algorithm to achieve optimal performance. Our methods are tested on the USPS (United States Postal Service) database and the Vehicle License Plate Number Pictures Database (VLNPD). Experimental results show that the methods gain high recognition rate and cost reasonable average running time. Also, based on similar condition, we compared our results to the box method proposed by Hanmandlu. Our methods demonstrated better performance in efficiency.

6067-09, Session 4

DOCLIB: a software library for document processing

S. R. Jaeger, G. Zhu, D. S. Doermann, Univ. of Maryland/College Park

Most researchers would agree that research in the field of document processing can benefit tremendously from a common software library through which institutions are able to develop and share research-related software and applications across academic, business, and government domains. However, despite several attempts in the past, the research community still lacks a widely-accepted standard software library for document processing. This paper describes a new library called DOCLIB, which tries to overcome the drawbacks of earlier approaches. Many of DOCLIB's features are unique either in themselves or in their combination with others, e.g. the factory concept for support of different image types,

the juxtaposition of image data and metadata, or the add-on mechanism. We cherish the hope that DOCLIB serves the needs of researchers better than previous approaches and will readily be accepted by a larger group of scientists.

6067-10, Session 4

Address block features for image-based automated mail orientation

M. S. Khan, SRI International and Univ. of California; H. B. Aradhye, SRI International

When mixed mail enters a postal facility, it must first be faced and oriented so that the address is readable by mail processors. Existing USPS automated systems face and orient domestic mail by searching for fluorescing stamps on each mail piece. However, misplaced or partially fluorescing postage cause a significant fraction of mail to be rejected. Previously, rejected mail had to be faced and oriented by hand, thus increasing mail processing costs for the USPS. Our earlier work successfully demonstrated the utility of machine vision based extraction of postal delimiters - such as cancellation marks and barcodes - for a camera-based mail facing and orientation. Arguably, of all the localized information sources on the envelope image, the destination address block is the richest in content and most structured in its form and layout. This paper focuses exclusively on the destination address block image and describes new vision-based features that can be extracted and used for mail orientation. Our results on real USPS provided datasets indicate a robust performance. The proposed algorithms will be deployed nationwide on USPS hardware in the near future.

6067-11, Session 4

A robust stamp detection framework on degraded documents

G. Zhu, S. R. Jaeger, D. S. Doermann, Univ. of Maryland/College Park

Detecting documents with a certain stamp instance is an effective and reliable way to retrieve documents associated with a specific source. However, this unique problem has essentially remained unaddressed. In this paper, we present a novel stamp detection framework based on parameter estimation of connected edge features. Using robust basic-shape detectors, the approach is effective for stamps with analytically shaped contours, when only limited samples are available. For elliptic/circular stamps, it efficiently exploits the orientation information from pairs of edge points to determine its center position and area, without computing all the five parameters of an ellipse. In our approach, we considered the set of unique characteristics of stamp patterns. Specifically, we introduced effective algorithms to address the problem that stamps often spatially overlay their background contents. These give our approach significant advantages in detection accuracy and computation complexity over traditional Hough transform method in locating candidate ellipse regions. Experimental results on real degraded documents demonstrated the robustness of this retrieval approach on large document database, which consists of both printed text and handwritten notes.

6067-12, Session 4

Adaptive pre-OCR cleanup of grayscale document images

I. Zavorin, E. Borovikov, M. I. Turner, CACI International Inc.; L. Hernandez, Army Research Lab.

This paper describes new capabilities implemented in the latest release of ImageRefiner, the automatic image enhancement system developed by CACI International Inc. ImageRefiner has been successfully used in the past to clean up bitonal (black-and-white)

document images before they are processed by commercial OCR engines. Using a single neural network, ImageRefiner learned which image enhancement transformations (filters) were best suited for a given document image and a given OCR engine, based on various image measurements (characteristics). The new release includes three new features. First, it is now possible to process grayscale document images. We have included three image filters that include thresholding and noise filtering methods, as well as five image characteristics that are all byproducts of various thresholding techniques. Our experiments indicate that OCR accuracy on enhanced grayscale images is higher than that of both the original grayscale images and the corresponding bitonal images obtained by scanning the same documents. The second new feature is a collection of new machine learning algorithms that could be used for training on both bitonal and grayscale imagery. These algorithms include a neural network ensemble as well as several “all-pairs” classifiers. We have discovered that performance of the system depends heavily on the amount of correlation that exists in the corresponding training corpus. The third new feature is a measure that evaluates overall performance of the system in terms of cumulative improvement in OCR accuracy.

6067-13, Session 4

JBIG2 text image compression based on OCR

J. Shang, C. Liu, X. Ding, Tsinghua Univ. (China)

The JBIG2 (joint bi-level image group) standard for bi-level image coding is drafted to allow encoder designs by individuals. In JBIG2, text images are compressed by pattern matching techniques. In this paper, we propose a lossy text image compression method based on OCR (optical character recognition) which compresses bi-level images into the JBIG2 format. By processing text images with OCR, we can obtain recognition results of characters and the confidence of these results. A representative symbol image could be generated for similar character image blocks by OCR results, sizes of blocks and mismatches between blocks. This symbol image could replace all the similar image blocks and thus a high compression ratio could be achieved. Experiment results show that our algorithm achieves improvements of 75.86% over lossless SPM and 14.05% over lossy PM&S in Latin Character images, and 37.9% over lossless SPM and 4.97% over lossy PM&S in Chinese character images. Our algorithm leads to much fewer substitution errors than previous lossy PM&S and thus preserves acceptable decoded image quality.

6067-14, Session 5

Active document versioning: from layout understanding to adjustment

X. Lin, H. Chao, G. Nelson, E. Durante, Hewlett-Packard Co.

This paper introduces a novel Active Document Versioning system that can extract the layout template and constraints from the original document and then automatically adjust the layout to accommodate new contents. “Active” reflects several unique features of the system: First, the need of handcrafting adjustable templates is largely eliminated through layout understanding techniques that can convert static documents into Active Layout Templates and accompanying constraints. Second, through the linear text block modeling and the two-pass constraint solving algorithm, it supports a rich set of layout operations, such as simultaneous optimization of text block width and height, integrated image cropping, and non-rectangular text wrapping. This system has been successfully applied to a wide range of professionally designed documents. This paper covers both the core algorithms and the implementation.

6067-15, Session 5

Graphic design principles for automated document segmentation and understanding

F. Vega, H. J. Santos-Villalobos, Univ. de Puerto Rico Mayagüez

Design principles provide the foundation for identifying document components and relations among them to extract implicit knowledge from the document layout. This paper describes a rule-based system that uses design principles to segment and understand document context. The system uses the design principles of repetition, proximity, alignment, similarity, and contrast as the foundation for document segmentation and understanding which is used for recognition of artifacts that may be produced in Variable Data Printing jobs by the infringement of the constraints articulated in the document layout. Two main modules in the tool are the geometric analysis module; and the design rule engine. The geometric analysis module extracts explicit knowledge from the data provided in the document. The design rule module uses the information provided by the geometric analysis to establish logical units inside the document. We used a subset of XSL-FO, sufficient for designing documents with an adequate amount complexity. The system identifies components such as headers, paragraphs, lists, images and determines the relations between them. The system provides accurate information about geometric properties of the components, detects the elements of the documents and identifies corresponding components between a proofed instance and the rest of the instances in a Variable Data Printing Job.

6067-16, Session 5

A new document authentication method by embedding deformation characters

X. Wang, X. Ding, H. Liu, C. Liu, Tsinghua Univ. (China)

Document authentication decides whether a given document is from a specific individual or not. In this paper, we propose a new document authentication method in physical (after document printed out) domain by embedding deformation characters. When an author writes a document to a specific individual or organization, a unique error-correcting code which serves as his Personal Identification Number (PIN) is proposed, and then some characters in the text line are deformed according to his PIN. By doing so, the writer’s personal information is embedded in the document. When the document is received, it is first scanned and recognized by an OCR module, and then the deformed characters are detected to get the PIN, which can be used to decide the originality of the document. So the document authentication can be viewed as a kind of communication problems in which the identity of a document from a writer is being “transmitted” over a channel. The channel consists of the writer’s PIN, the document, and the encoding rule. Experimental result on deformation character detection is very promising, and the availability and practicability of the proposed method is verified by a practical system.

6067-17, Session 5

CAPTCHA challenge strings: problems and improvements

J. L. Bentley, C. L. Mallows, Avaya Inc.

A CAPTCHA is a Completely Automated Public Test to tell Computers and Humans Apart. Typical CAPTCHAs present a challenge string consisting of a visually distorted sequence of letters and perhaps numbers, which in theory only a human can read. Attackers of CAPTCHAs have two primary points of leverage: Optical Character Recognition (OCR) can identify some characters, while nonuniform probabilities make other characters relatively easy to guess. This paper uses a mathematical theory of assurance to characterize the probability that a correct answer to a CAPTCHA is

not just a lucky guess. We examine the three most common types of challenge strings, dictionary words, Markov text, and random strings, and find substantial weaknesses in each. We therefore propose improvements to Markov text, and new challenges based on the consonant-vowel-consonant (CVC) trigrams of psychology. Theory and experiment together quantify problems in current challenges and the improvements offered by modifications.

6067-18, Session 5

An automatically updateable web publishing solution: taking document sharing and conversion to enterprise level

F. Rahman, BCL Technologies Inc.

This paper presents a novel automatic web publishing solution, PageView(r). PageView(r) is a complete working solution for document processing and management. The principal aim of this tool is to allow workgroups to share, access and publish documents on-line on a regular basis. For example, assuming that a person is working on some documents. The user will, in some fashion, organize his work either in his own local directory or in a shared network drive. Now extend that concept to a workgroup. Within a workgroup, some users are working together on some documents, and they are saving them in a directory structure somewhere on a document repository. The next stage of this reasoning is that a workgroup is working on some documents, and they want to publish them routinely on-line. Now it may happen that they are using different editing tools, different software, and different graphics tools. The resultant documents may be in PDF, Microsoft Office(r), HTML, or Word Perfect format, just to name a few. In general, this process needs the documents to be processed in a fashion so that they are in the HTML format, and then a web designer needs to work on that collection to make them available on-line. PageView(r) takes care of this whole process automatically, making the document workflow clean and easy to follow. PageView(r) Server publishes documents, complete with the directory structure, for online use. The documents are automatically converted to HTML and PDF so that users can view the content without downloading the original files, or having to download browser plug-ins. Once published, other users can access the documents as if they are accessing them from their local folders. The paper will describe the complete working system and will discuss possible applications within the document management research.

6067-19, Session 6

Automatic redaction of private information using relational information extraction

K. Taghva, R. Beckley, J. S. Coombs, J. Borsack, R. Pereda, T. A. Nartker, Univ. of Nevada/Las Vegas

We report on an attempt to build an automatic redaction system by applying information extraction techniques to the identification of private dates of birth. We conclude that automatic redaction is a promising concept although information extraction is significantly affected by the presence of OCR error.

6067-20, Session 6

Document clustering: applications in a collaborative digital library

F. Rahman, BCL Technologies Inc.

This paper introduces a document clustering method within a commercial document repository, FileShare(r). FileShare(r) is a commercial collaborative digital library offering facilities for sharing and accessing documents over a simple Internet browser (e.g. Microsoft(r) Internet Explorer(r), Netscape(r) or

Opera(r)) within groups of people working on common projects. As the number of documents increases within a digital library, displaying these documents in this environment poses a huge challenge. This paper proposes a document clustering method that uses a modified version of the traditional K-Means algorithm to categorize documents by their themes using lexical chaining within the FileShare(r) repository. The proposed algorithm is unsupervised, and has shown very high accuracy in a typical experimental setup.

6067-21, Session 6

Author name recognition in degraded journal images

A. de Bodard de la Jacopiere, L. Likforman, École Nationale Supérieure des Télécommunications (France)

A method for extracting names in degraded documents is presented in this article. The documents targeted are images of photocopied scientific journals from various scientific domains. Due to the degradation, there is poor OCR recognition, and pieces of other articles appear on the sides of the image. The proposed approach relies on the combination of a low-level textual analysis and an image-based analysis. The textual analysis extracts robust typographic features, while the image analysis selects image regions of interest through anchor components. We report results on the University of Washington benchmark database.

6067-23, Session 7

Complex document information processing: prototype, test collection, and evaluation

G. Agam, Illinois Institute of Technology; S. Argamon, inois Institute of Technology; O. Frieder, D. Grossman, D. Lewis, Illinois Institute of Technology

Analysis of large collections of complex documents is an increasingly important need for numerous applications, including information management and intelligence analysis. By "complex documents", we mean documents that typically start out on paper and are then electronically scanned. Such documents may have been produced by a combination of printing technologies (or by handwriting); and include diagrams, graphics, tables and other non-textual elements. They thus have rich internal structure, though they are often only available in image form and so this structure is currently not exploited. The state of the art today for a large document collection is essentially text search of OCR'd documents with no meaningful use of data found in images, signatures, logos, etc.

By contrast, our prototype automatically generates rich metadata about a complex document and then applies query tools to integrate the metadata with text search. To ensure a thorough evaluation of the effectiveness of our prototype, we are also developing a complex document test collection comprising about 42 million pages. The collection will include relevance judgments for queries at a variety of levels of detail and depending on a variety of content and structural characteristics of documents, as well as "known item" queries looking for particular documents.

6067-24, Session 8

Comparative evaluation of different classifiers for robust distorted character recognition

B. As-Sadhan, Z. Al Bawab, A. El Seed, M. Noamany, Carnegie Mellon Univ.

This paper compares the performance of different classification algorithms on a distorted-character recognition task. The algorithms applied are Principal Component Analysis (PCA), Individual Principal

Component Analysis (iPCA), Single-Nearest-Neighbor Method (1-NNM), Linear Discriminant Analysis (LDA), and Support Vector Machines (SVM). The dataset used is the Letter-Image Dataset [Frey and Slate 1991]. Applying SVM achieves a classification error rate of 2.15%. This performance is statistically comparable to the best number in the literature that the authors are aware of on this dataset, which is 2% and was achieved using a fully connected MLP neural network with adaboosting and running on 20 machines [Schwenk and Bengio 1997]. However, in our study, SVM runs on a single machine and requires less than 3.5 minutes of training time. We present the results achieved using different classifiers and analyze the classification errors committed by SVM. We exploit the nature of the errors committed on the development set in an attempt to combine classifiers and focus on the most discriminating features to reduce the error on the test set. Although we achieve a minor improvement, it is not statistically significant compared to the error rate committed by SVM. Future work would look into applying boosting into SVM classification.

6067-25, Session 8

Style consistent nearest neighbor classifier

S. Andra, X. Zhang, Rensselaer Polytechnic Institute

Most pattern classifiers are trained on data from multiple sources, so that they can accurately classify data from any source. However, in many applications, it is necessary to classify groups of test patterns, with patterns in each group generated by the same source. The co-occurring patterns in a group are statistically dependent due to the commonality of source. The dependence between these patterns introduces style context within a group that can be exploited to improve the classification accuracy. In this paper, we present a style consistent nearest neighbor classifier that exploits style context in groups of adjacent patterns to improve the classification accuracy. We demonstrate the efficacy of the proposed classifier on a dataset of machine-printed digits where the proposed classifier reduces the error rate by 64.5%.

6067-26, Session 8

Optimally combining a cascade of classifiers

K. H. Chellapilla, M. M. Shilman, P. Simard, Microsoft Corp.

Conventional approaches to combining classifiers improve accuracy at the cost of increased processing. We propose a novel search based approach to automatically combine multiple classifiers in a cascade to obtain the desired tradeoff between classification speed and classification accuracy. The search procedure only updates the rejection thresholds (one for each constituent classifier) in the cascade, consequently no new classifiers are added and no training is necessary. A branch-and-bound version of depth-first-search with efficient pruning is proposed for finding the optimal thresholds for the cascade. It produces optimal solutions under arbitrary user specified speed and accuracy constraints. The effectiveness of the approach is demonstrated on handwritten character recognition by finding a) the fastest possible combination given an upper bound on classification error, and also b) the most accurate combination given a lower bound on speed.

6067-27, Session 8

Versatile document image content extraction

H. S. Baird, M. A. Moll, Lehigh Univ.

We offer a preliminary report on a research program to investigate versatile algorithms for document image content extraction, that is locating regions containing handwriting, machine-print text, graphics, line-art, logos, photographs, noise, etc. To solve this

problem in its full generality requires coping with a vast diversity of document and image types. Automatically trainable methods are highly desirable, as well as extremely high speed in order to process large collections. Significant obstacles include the expense of preparing correctly labeled ("ground-truthed") samples, unresolved methodological questions in specifying the domain (e.g. what is a representative collection of document images?), and a lack of consensus among researchers on how to evaluate content-extraction performance. Our research strategy emphasizes "versatility first": that is, we concentrate at the outset on designing methods that promise to work across the broadest possible range of cases. This strategy has several important

implications: the classifiers must be trainable in reasonable time on vast data sets; and expensive ground-truthed data sets must be complemented by amplification using generative models. These and other design and architectural issues are discussed. We propose a trainable classification methodology that marries k-d trees and hash-driven table lookup and describe preliminary experiments.

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6068-21, Poster Session

CCD small signal characterization using fluoresce x-rays

K. L. Boggs, Semiconductor Technology Associates Inc.

Past and present revelations within scientific imaging have stressed the importance of CCD small signal sensitivity. Current characterization techniques use a Fe55 soft x-ray source to determine charge transfer and noise, however rendering signal sensitivity less than 1620 e- unknown. CCD evolution has brought forth innovative design and fabrication techniques to decrease device noise and increase device sensitivity, enabling low level imaging. This paper presents a simple approach to characterizing the transfer functions, linearity, noise, and output sensitivity at low signal levels, thus confirming the true capabilities of the imager. This characterization technique also validates the quality of the base material and process via low level trap testing. The characterization method uses fluoresce x-rays from target materials to illuminate the imager.

6068-30, Poster Session

An improved method for calculating the MTF of an optical system

A. Walter, S. Lashansky, Israel Air Force (Israel)

This paper presents an improved automated method for calculating the MTF (Modulation Transfer Function) of an optical system. The paper presents the theoretical background and describes various techniques for calculating the edge response and MTF. An improved method is proposed and it is shown to be more accurate and robust. An additional advantage of the proposed method is that it can be fully automated. The proposed method is valid for various optical imaging systems. The results are compared and conclusions are made regarding the validity of the technique.

6068-01, Session 1

In vitro and in vivo on-chip biofluorescence imaging using a CMOS image sensor

D. C. Ng, M. Matsuo, T. Tokuda, K. Kagawa, M. Nunoshita, J. Ohta, Nara Institute of Science and Technology (Japan)

We have designed and fabricated a 176Å-144-pixels (QCIF) CMOS image sensor for on-chip bio-fluorescence imaging of the mouse brain. In our approach, a single CMOS image sensor chip without additional optics is used. This enables imaging at arbitrary depths into the brain; a clear advantage compared to existing optical microscopy methods. Packaging of the chip represents a challenge for in vivo imaging. We developed a novel packaging process whereby an excitation filter is applied onto the sensor. This eliminates the use of a filter cube found in conventional fluorescence microscopes. The fully packaged chip is about 350 µm thick. Using the device, we demonstrated in vitro on-chip fluorescence imaging of a 400 µm thick mouse brain slice detailing the hippocampus. The image obtained compares favorably to the image captured by conventional microscopes in terms of image resolution. In order to study imaging in vivo, we also developed a phantom media. In situ fluorophore measurement shows that detection through the turbid medium of up to 1 mm thickness is possible. We have successfully demonstrated imaging deep into the hippocampal region of the mouse brain. This work is expected to lead to a promising new tool for imaging the brain in vivo.

6068-02, Session 1

An optical and potential dual-image CMOS sensor for bioscientific applications

T. Tokuda, A. Yamamoto, K. Kagawa, M. Nunoshita, J. Ohta, Nara Institute of Science and Technology (Japan)

We have fabricated a CMOS image sensor which can simultaneously capture optical and on-chip potential images. The target applications of the sensor are; 1) on-chip DNA (and other biomolecular) sensing and 2) on-chip neural cell imaging. The sensor was fabricated using a 0.35µm 2-poly, 4-metals standard CMOS process. The sensor has a pixel array that consists of alternatively aligned optical sensing pixels (88x144) and potential sensing pixels (88x144). The total size of the array is QCIF (176x144). The size of the pixel is 7.5µm x 7.5µm. The potential sensing pixel has a sensing electrode which capacitively couples with the measurement target on the sensor. It can be operated either in a wide-range (over 5V) mode or in a high-sensitivity (1.6mV/LSB) mode. The maximum frame rate of the sensor is 20 fps for single imaging operation and 5 fps for dual imaging operation. Two-dimensional optical and potential imaging function was also demonstrated. Probes with gel tips were placed on the sensor surface and potential was applied. A potential spot with diameter smaller than 50µm was successfully observed in the dual imaging operation.

6068-03, Session 1

A CMOS active pixel sensor for retinal stimulation

M. L. Prydderch, M. J. French, Rutherford Appleton Lab. (United Kingdom); K. Mathieson, C. Adams, D. Gunning, J. Laudanski, J. D. Morrison, A. R. Moodie, J. Sinclair, Univ. of Glasgow (United Kingdom)

Degenerative photoreceptor diseases, such as age-related macular degeneration and retinitis pigmentosa, are the most common causes of blindness in the western world. A potential cure is to use a microelectronic retinal prosthesis to provide electrical stimulation to the remaining healthy retinal cells. We describe a prototype CMOS Active Pixel Sensor capable of detecting a visual scene and translating it into a train of electrical pulses for stimulation of the retina. The sensor consists of a 10 x 10 array of 100 micron square pixels fabricated on a 0.35 micron CMOS process. Light incident upon each pixel is converted into output voltage pulse trains with a frequency related to the light intensity. These outputs are connected to a biocompatible microelectrode array for contact to the retinal cells. The flexible design allows experimentation with signal amplitudes and frequencies in order to determine the most appropriate stimulus for the retina. Neural processing in the retina can be studied by using the sensor in conjunction with a Field Programmable Gate Array (FPGA) programmed to behave as a neural network.

The sensor has been integrated into a test system designed for studying retinal response. We present the most recent results obtained from this sensor.

6068-04, Session 1

Noise analysis of fault tolerant active pixel sensors with and without defects

M. L. La Haye, C. G. Jung, M. H. Izadi, G. H. Chapman, K. S. Karim, Simon Fraser Univ. (Canada)

As the sizes of imaging arrays become larger both in pixel count and area the possibility of pixel defects increases during manufacturing and packaging, and over the lifetime of the sensor. A Fault Tolerant APS (FTAPS) with redundancy at the pixel level has been designed and fabricated for only a small cost in area. The noise of the standard APS and FTAPS under normal operating conditions as well as under the presence of stuck faults is analyzed. The analysis shows that under typical illumination conditions the total noise of both the standard APS and FTAPS is dominated by the photocurrent shot noise and under low illumination conditions it is dominated by the electronic noise. The worst case (no illumination) total mean squared noise of the FTAPS is only 15.5% larger than for the standard APS. Under typical illumination conditions the FTAPS noise increases by less than 0.1%. In the presence of half stuck faults the noise is small compared to a fully faulty pixel. Simulation and experimental results have shown that the FTAPS sensitivity is greater than two times that of the standard APS leading to an increased SNR by more than twice for the FTAPS with no defects.

6068-05, Session 1

A model for dark current characterization and simulation

R. L. Baer, Agilent Technologies

The dark current histogram of a silicon image sensor array does not match any common probability distribution. The histogram has only positive values, and is markedly asymmetric with a long tail on the high side. The Gaussian distribution is symmetric with negative values, while the Poisson distribution is discrete. A new distribution function that matches the experimental observations is required for image sensor characterization and simulation.

Dark current is caused by discrete randomly-distributed charge generation centers. If these centers shared a common charge-generation rate, and were distributed uniformly, a Poisson distribution would result. The fact that it does not indicates that either the generation rates vary or that the spatial distribution of defects is non-uniform. Monte Carlo simulations have been used to examine these hypotheses.

A simple analytical model for characterization and simulation based upon a non-uniform spatial distribution of charge generation been developed from the results of the Monte Carlo study. This model accurately fits experimental observations with only a few parameters.

6068-06, Session 2

An image sensor with on-die diffractive optics in 0.18-micron bulk CMOS

C. J. Thomas, R. I. Hornsey, York Univ. (Canada)

On-die optics are an attractive way of reducing package size for imaging and non-imaging optical sensors. While systems incorporating on-die optics have been built for imaging and spectral analysis applications, these have required specialized fabrication processes and additional off-die components. This paper discusses the fabrication of an image sensor with neither of these limitations. Through careful design, image sensors are implemented that use on-die diffractive optics fabricated using a standard 0.18 micron bulk CMOS process, with the resulting die capable of acting as a standalone imaging system resolving both spatial and spectral

features. The paper will discuss the design, simulation methodology, and experimental results for several configurations of CMOS active pixel sensor arrays with integrated diffractive optics.

6068-08, Session 2

CMOS long linear array for space application

G. Lepage, Cypress Semiconductor Corp. (Belgium); D. G. Dantes, Alcatel Alenia Space (France)

In the past years, it was expected that high-quality scientific imaging would remain out of reach for CMOS sensors since they lacked the required performance in noise, non-uniformity and dark signal levels and hence could not compete with high performances CCDs offering high quantum efficiency, large dynamic range and special modes as Time Delay Integration (TDI) and binning. However, CMOS imaging performs better than expected and allows today to address applications requiring:

- TDI capability coupled to image acquisition in pushbroom mode in order to enhance radiometric performances,
- Very long linear arrays thanks to stitching techniques,
- A high level of on-chip integration with both panchromatic TDI and multispectral linear sensors,
- On-chip correlated double sampling for low noise operation.

This paper presents the design of a CMOS linear array, resulting from collaboration between Alcatel Alenia Space and Cypress Semiconductor, which take advantage of each of these emerging potentialities for CMOS technologies. It has 8000 panchromatic pixels with up to 25 rows used in TDI mode, and 4 lines of 2000 pixels for multispectral imaging. Main system requirements and detector trade-offs are presented, and test results obtained with a first generation prototype are summarized and compared with predicted performances.

6068-09, Session 2

Experimental single-chip color HDTV image acquisition system with 8-Mpixel CMOS image sensor

H. Shimamoto, T. Yamashita, R. Funatsu, K. Mitani, Y. Nojiri, NHK Science & Technical Research Labs. (Japan)

We have developed an experimental single-chip color HDTV image acquisition system with CMOS image sensor that had eight million pixels. This image sensor had 3840 x 2160 effective pixels and was progressively scanned at 60 frames per second. We put RGB color filter array with Bayer's pattern on a chip so that green channel could have two times the sub-pixels in both the horizontal and vertical directions compared with conventional HDTV imager. We used this green signal to obtain enough resolution for HDTV and to decrease false color signals. We also proposed a new color filter array pattern for this 8M-pixel imager, which improved horizontal resolution when the image acquisition system output an HDTV signal.

We made an experimental image acquisition system. The captured image data was stored in a frame memory, signal processed on a PC, and output to an HDTV monitor. We compared this experimental image with a three-imager pickup HDTV camera for broadcasting, and the picture quality was better in the MTF characteristics.

6068-11, Session 2

High-sensitivity 2.5- μm pixel CMOS image sensor realized using Cu interconnect layers

K. Tatani, Y. Enomoto, A. Yamamoto, T. Goto, H. Abe, T. Hirayama, Sony Corp. (Japan)

We have adapted Cu interconnect layers to realize a high sensitivity for a small pixel CMOS image sensor with a pixel size of 2.5 x 2.5 μm^2 . We used a 1P3M CMOS process, and applied Back End of Line (BEOL) with the 90nm design rule.

The Cu process features that the fill factor is about 15% greater and that the interconnect layer height is about 40% lower than the Al process. As a result, the sensitivity at F5.6 is about 5% greater, while that at F1.2 is about 30% greater.

One of problems with the Cu process is the way that the oxidation prevention layer on the Cu interferes with the light. Furthermore, this oxidation prevention layer interacts with the SiO layer to form a multilayer, which leads to a discontinuity in the reflection characteristics at some wavelengths (ripple). The method involved removing the oxidation prevention layer together with all the layers.

To realize a 2.5 μm pixel CMOS image sensor, we developed the Cu interconnect process. We created a high-sensitivity CMOS image sensor. This technology should be effective for further reducing the pixel size to less than 2.5 μm .

6068-12, Session 2

CMOS image sensor overlaid with organic photoelectric conversion layers and the proposal of stack type solid-state imaging devices

S. Takada, M. Inuiya, Y. Araki, Fuji Photo Film Co., Ltd. (Japan)

DSCs overwhelmed film cameras in terms of sales volume in 2000 by virtue of functional merits such as use convenience in Japanese market. However capabilities of the image capture, for example capturing latitude and speed, are still superior to the digital devices. The reason of high performances would be based on the multi-photosensitive-layer stacking structure of color films. In this paper we propose the stack type solid-state imaging devices which are composed of CMOS device overlaid with an organic photoelectric conversion layer.

6068-13, Session 2

An ultrawide dynamic-range CMOS image sensor with a linear response

J. H. Park, M. Mase, S. Kawahito, Shizuoka Univ. (Japan); M. Sasaki, Sendai National College of Technology (Japan); Y. Wakamori, Yamaha Corp. (Japan); Y. Ohta, Hamamatsu Corp. (Japan)

This paper presents an ultra wide dynamic-range (DR) CMOS image sensor based on multiple exposures and high-speed signal readout technique. In the burst readout method, more than three image signals, which have a different accumulation time, can be captured in one frame period. Especially, the extremely short accumulation time, shorter than a horizontal readout period, can be obtained. As a result, the new image sensor has accumulation time of 1/24180 compared to the long accumulation time.

A key technique of the wide DR image sensor is a high-speed column parallel cyclic A/D converter. It performs 12-bit cyclic A/D conversion with built-in pixel fixed-pattern noise cancellation. During the 12-bit cyclic A/D operations, the amplifier's offset voltage is

maintained to the same value, which means the column fixed pattern noise (FPN) reduction of the image sensor in analog domain.

A prototype image sensor was fabricated in a 0.25 μm CMOS image sensor technology. A new design of the 12-b ADC with the reduced number of capacitors and a simplified switching scheme achieves a differential non-linearity of ± 0.3 LSB. Using the amplifier offset canceling technique in the column-parallel cyclic ADC, the column-to-column FPN is reduced to 0.12% without any digital domain noise canceling. Measurement results show that the image sensor has a linear response in entire illumination range with a dynamic range of 141.8dB.

6068-14, Session 2

A pulse-frequency-modulation vision chip using a capacitive feedback reset with in-pixel 1-bit image processors

K. Kagawa, S. Yamamoto, T. Furumiya, T. Tokuda, M. Nunoshita, J. Ohta, Nara Institute of Science and Technology (Japan)

We report a low-voltage digital vision chip based on a pulse-frequency-modulation (PFM) photosensor using capacitive feedback reset and pulse-domain digital image processing to explore its feasibility of low power consumption and high dynamic range even at a low power-supply voltage. An example of the applications of the vision chip is retinal prosthesis, in which supplied power is limited. The pixel is composed of a PFM photosensor with a dynamic pulse memory, pulse gates, and a 1-bit digital image processor. At the positive edges of the clock signal, the binary value stored at the dynamic pulse memory is read to the 1-bit digital image processor. The image processor executes spatial filtering by mutual operations between the pulses from the pixel and those from the four neighboring pixels. The weights in image processing are controlled by pulse gates. We fabricated a test chip in a standard 0.35- μm CMOS technology. Pixel size and pixel counts were 100 μm^2 and 32 x 32, respectively. In the experiments, four neighboring pixels were considered in image processing. The test chip successfully operated at low power supply voltage around 1.25 V. The frame rate was 26 kfps. Low-pass filtering, edge enhancement, and edge detection have been demonstrated.

6068-15, Session 3

Photon counting imaging: the DigitalAPD

S. Bellis, R. Wilcock, J. C. Jackson, SensL Technologies Ltd. (Ireland)

Geiger Mode avalanche photodiodes (APDs) offer single photon detection, however, conventional biasing and processing circuitry make arrays impractical to implement. A novel photon counting concept is proposed which greatly simplifies the circuitry required for each device, giving the potential for large, single photon sensitive, imaging arrays. This is known as the DigitalAPD. The DigitalAPD treats each device as a capacitor. During a write, the capacitor is periodically charged to photon counting mode and then left open circuit. The arrival of photons causes the charge to be lost and this is later detected during a read phase. Arrays of these devices have been successfully fabricated and a read out architecture, employing well known memory addressing and scanning techniques to achieve fast frame rates with a minimum of circuitry, has been developed. A discrete prototype has been built to demonstrate the DigitalAPD with a 4x4 array. Frame rates of up to 5MHz have been observed using discrete electronics. The frame burst can be transferred to a computer where the arrival of single photons at any of the 16 locations can be examined, frame by frame. The DigitalAPD concept is highly scalable and is soon to be extended to a fully integrated implementation for use with larger 32x32 and 100x100 APD arrays.

6068-16, Session 3

Quantitative and qualitative performance comparison of a biomimetic vision sensor with commercial CCD camera sensors

R. S. Prabhakara, C. H. G. Wright, S. F. Barrett, W. M. Harman, Univ. of Wyoming

Traditional sensors for computer vision, such as CCD and CMOS arrays, have well-known limitations with regard to detecting objects that are very small in size (that is, a small object image compared to the pixel size), are viewed in a low contrast situation, are moving very fast (with respect to the sensor integration time), or are moving very small distances compared to the sensor pixel spacing. Any one or a combination of these situations can foil a traditional CCD or CMOS sensor. Alternative sensors derived from biological vision systems promise better resolution and object detection in situations such as these. The patent-pending biomimetic vision sensor based on *Musca domestica* (the common house fly) is capable of reliable object rendition in spite of challenging movement and low contrast conditions. Adjacent sensor elements have overlapping Gaussian responses which enable objects to be detected even when the object would seem to be imaged "between" individual sensor elements; this contributes to greater static resolution and better object motion sensitivity. We discuss some interesting early results of comparing the biomimetic sensor to commercial CCD sensors in terms of contrast and motion sensitivity in situations such as those listed above.

6068-17, Session 3

Large area devices at Semiconductor Technology Associates, Inc.

K. L. Boggs, R. A. Bredthauer, Semiconductor Technology Associates Inc.

Recent discoveries show new promise for a formerly assumed extinct technology, CCDs. A primary limitation to the implementation of new ground-based astronomy measurement techniques is the inaccuracy of navigation and targeting due to error in the celestial frame of reference. This celestial frame of reference is relied upon for satellite attitude determination, payload calibration, in-course missile adjustments, space surveillance, and accurate star positions used as fiducial points. STA will describe the development of an ultrahigh resolution CCD (up to the maximum limit of a 150 mm wafer) that integrates high dynamic range and fast readout that will substantially decrease the error in the celestial reference frame. STA will also discuss prior and ongoing experience with large area CCD focal-plane arrays which include innovative design and fabrication techniques that ensure performance and yield.

6068-18, Session 3

Development of the orthogonal-transfer array

B. E. Burke, MIT Lincoln Lab.; J. L. Tonry, Univ. of Hawai'i/West O'ahu; M. J. Cooper, MIT Lincoln Lab.; P. M. Onaka, Univ. of Hawai'i/West O'ahu; D. J. Young, A. H. Loomis, MIT Lincoln Lab.

The orthogonal-transfer array (OTA) is a new CCD concept for wide-field imaging in ground-based astronomy based on the orthogonal-transfer CCD (OTCCD). This device combines an 8 * 8 array of small OTCCDs, each about 600 * 600 pixels with on-chip logic to provide independent control and readout of each CCD. The device provides spatially varying electronic tip-tilt correction for wavefront aberrations, as well as compensation for telescope shake. Tests of prototype devices have verified correct functioning of the control logic and demonstrated good CCD charge-transfer efficiency and high quantum efficiency. Independent biasing of the substrate down to -40 V has enabled fully depleted operation of 75- μ m-thick devices

with good charge PSF. Spurious charge or "glow" due to impact ionization from high fields at the drains of some of the NMOS logic FETs has been observed, and reprocessing of some devices from the first lot has resolved this issue. A second design is currently in fabrication and uses a 10- μ m pixel design resulting in a 22.6-Mpixel device measuring 50 * 50 mm. These devices will be deployed in the U. of Hawaii Pan-STARRS focal plane, which will comprise 60 OTAs with a total of nearly 1.4 Gpixels.

6068-34, Session 3

28-M CCD imager with RGB compatible binning feature for professional applications

I. Peters, C. Draijer, F. Polderdijk, L. Meessen, B. G. M. Dillen, W. Klaassens, J. T. Bosiers, DALSA Professional Imaging (Netherlands)

A 28-M pixel, 44x33mm², full-frame CCD imager with 7.2x7.2 μ m² pixel size with Bayer RGB color pattern was developed for use in professional applications. As unique option a RGB compatible binning feature was designed in this sensor. This gives the possibility to exchange resolution for read-out speed and sensitivity. Extensive 3D off-state device simulations have been performed to achieve the optimal binning performance. For this binning feature storage cells are designed parallel to the standard horizontal register. In these storage cells the different charge packets are added for each color separately by using an ingenious timing scheme.

Measurement results on this sensor show that binning is working remarkably well. The transport efficiency of charge packets from horizontal register cells to storage cells and back was better and less sensitive to the dose of the additional implant, required for the vertical transport, than expected by the simulations. When using one output, the read-out speed with the binning feature turned on is increased to 3 frames/s compared to 1 frames/s without binning. Besides the binning feature this 28-M sensor also has a high dynamic range (12 bit), excellent highlight handling (1000x overexposure), fast electronic shutter (10 μ s), low-noise output amplifier (18e-) and low dark current (0.1 pA/cm² at 60 °C).

6068-35, Session 3

Quantum efficiency characterization of CCD's part 1: the quantum efficiency machine

D. E. Groom, C. J. Bebek, M. H. Fabricius, A. Karcher, J. Steckert, Lawrence Berkeley National Lab.

During 2004 and 2005 instrumentation was developed to measure the quantum efficiency of our total-depletion CCD's, intended for astronomy and space applications. This paper describes the basic instrument. It is conventional even to the parts list, but with important innovations. A xenon arc light source was chosen for its high blue/UV and low red/IR output as compared with a tungsten light. Intensity stabilization has been difficult, but since only flux ratios matter this is not critical. Between the light source and an Oriel MS257 monochromator are a shutter and two filter wheels. High-bandpass and low-bandpass filter pairs isolate the 150-nm wide bands appropriate to the wavelength, thus minimizing scattered light and providing order blocking. Light from the auxiliary port enters a 20-inch optical sphere, and the 4-inch output port is at right angles to the input port. An 80 cm drift space produces near-uniform illumination on the CCD. Next to the cold CCD inside the horizontal dewar is a calibrated reference photodiode which is regulated to the PD calibration temperature, 300 K. The ratio of the CCD and in-dewar reference PD signals provides the QE measurement. Additional cross-calibration to a PD on the integrating sphere permits lower-intensity exposures.

6068-36, Session 3

Quantum efficiency characterization of back-illuminated CCD's part 2: reflectivity measurements

M. H. Fabricius, Lawrence Berkeley National Lab.

The usual QE measurement heavily relies on a calibrated photodiode (PD) and the knowledge of the CCD's gain. Either can introduce significant systematic errors. But $1-R \gg QE$, where R is the reflectivity. Over a significant wavelength range, $1-R = QE$. An unconventional reflectometer has been developed to make this measurement. R is measured in two steps, using light from the lateral monochromator port via an optical fiber: The beam intensity is measured directly with a PD, then both the PD and CCD are moved so that the optical path length is unchanged and the light reflects once from the CCD; the PD current is reduced by a factor R. In contrast to the traditional WV scheme this approach needs only one reflection from the CCD surface. Since the reflectivity of the LBNL CCDs might be as low as 2% this increases signal/noise dramatically. The goal is a 1% measurement. We obtain good agreement between $1-R$ and the direct QE results. In addition, we measure the QE by comparing the current in a calibrated CCD with the current from the CCD wired up as a diode.

6068-22, Session 4

Toward 1-mm depth precision with a solid state full-field range imaging system

A. A. Dorrington, Univ. of Waikato (New Zealand); D. A. Carnegie, Victoria Univ. of Wellington (New Zealand); M. J. Cree, Univ. of Waikato (New Zealand)

Previously, we demonstrated a novel heterodyne based solid-state full-field range-finding imaging system. This system is comprised of modulated LED illumination, a modulated image intensifier, and a digital video camera. A 10 MHz drive is provided with 1 Hz difference between the LEDs and image intensifier. A sequence of images of the resulting beating intensifier output are captured and processed to determine phase and hence distance to the object for each pixel. In a previous publication, we detailed results showing a one-sigma precision of 15 mm to 30 mm (depending on signal strength). Furthermore, we identified the limitations of the system and potential improvements that were expected to result in a range precision in the order of 1 mm. These primarily include increasing the operating frequency and improving optical coupling and sensitivity. In this paper, we report on the implementation of these improvements and the new system characteristics. We also comment on the factors that are important for high precision image ranging and present configuration strategies for best performance. Ranging with sub-millimetre precision is demonstrated by imaging a planar surface and calculating the deviations from a planar fit. The results are also illustrated graphically by imaging a garden gnome.

6068-23, Session 4

An ultrafast phase modulator for 3D imaging

J. Y. Cheng, Northeastern Univ.; Q. Chen, Boston Applied Technologies Inc.

In this paper we explore the potential applications of a new transparent Electro-Optic Ceramics, namely OptoCeramic, in 3D imaging as a fast phase shifter and demonstrate its performance in a newly developed Phase Shifting Interferometer (PSI). OptoCeramic is a family of transparent electro-optic ceramic materials. The phase shifter made from it has the advantages of no moving-part (does not introduce vibration), fast action (sub-microsecond) and compact compared to traditional piezoelectric or mechanical ones. Due to the

high EO effect of OptoCeramic, much lower voltage is required to achieve a two-pi phase shift compared to other EO crystalline materials. The PSI proposed in this paper features rapid phase shifting for video rate 3D imaging and adjustable reference/objective intensity ratio for maximum contrast. The system is more stable compared to traditional design because there is no movement involved during the phase shifting process. This design is especially useful for imaging weak scattering object such as biological tissues and therefore has great potential of being applied in medical imaging. It has been approved feasible by several experiments and the 3D structures of some several testing objects, such as MEMS objects, are presented in this paper.

6068-24, Session 4

Classification of luminaire color using CCDs with application to airport lighting

K. R. McMenemy, J. H. Niblock, Queen's Univ. Belfast (United Kingdom)

This paper presents a novel method for assessing the colour of luminaires using low cost single chip CCD video cameras. Images taken from a camera placed within an aircraft cockpit during a normal approach to an airport are post-processed to determine the color of each luminaire in the pattern. This process is based on a novel pixel model derived to determine the minimum pixel coverage required to accurately predict the colour of an imaged luminaire. Analysis of how many pixels are required for colour recognition and position within a CIE colour chart is given and proved empirically. From the analysis it is found that, a minimum diameter of four pixels is required for colour recognition of the major luminaires types within the lighting pattern. This is important since luminaires are far away when imaged and may cover only a few pixels since a large area must be viewed by the camera. This classification is verified by laboratory experiments with different luminaire sources. Whilst this is not a new phenomena, the authors have shown that it is possible to simulate the operation of single chip CCD imagers and illustrate the minimum pixel coverage that is required to accurately represent colored luminaires.

6068-25, Session 4

Lateral chromatic aberration correction system for ultrahigh-definition color video camera

T. Yamashita, H. Shimamoto, R. Funatsu, K. Mitani, Y. Nojiri, NHK Science & Technical Research Labs. (Japan)

We developed newly color cameras for the Super Hi-Vision, which is a 4000-scanning-line ultrahigh-definition video system, with a 5x zoom lens and a signal-processing system incorporating a function for real-time lateral chromatic aberration correction.

The chromatic aberration of the lens degrades the color image resolution. However, a lens with small chromatic aberration is apt to become large and this makes the downsizing of the zoom lens for the Super Hi-Vision cameras difficult. So in order to develop a compact zoom lens consistent with ultra-high resolution characteristics, we incorporated a real-time correction function into the signal-processing system. In the current prototype system, we focused on corrections only in relation to the focal length. The signal-processing system has a memory table for storing the correction data of each focal length on the blue and red channels. When the focal length is inputted from the lens system, the relevant correction data are selected. This system does the geometrical conversion on both channels using the correction data.

In the above way, lateral chromatic aberration was successfully reduced to an amount small enough to assure the desired image resolution quality over the entire range of the lens in real time.

6068-26, Session 4

A new direct detection camera system for electron microscopy

N. Xuong, L. Jin, A. Milazzo, P. C. Leblanc, F. Duttweiler, J. C. Bouwer, S. Peltier, M. H. Ellisman, Univ. of California/San Diego; S. Li, S. Kleinfelder, Univ. of California/Irvine

High resolution electron imaging is very important in nanotechnology and biotechnology fields. For example, Cryogenic Electron-Microscopy is a promising method to obtain 3-D structures of large protein complexes and viruses. We report design and experience of a new CMOS direct-detection camera system for electron imaging. The active pixel sensor array includes 512 by 550 pixels, each 5 by 5 μm in size, with an $\sim 8 \mu\text{m}$ epitaxial layer to achieve an effective fill factor of 100%. Simulation, experimental designs and measurements are presented demonstrate trade-offs between charge-collection efficiency, signal-to-noise ratio, pixel size and diode area. Spatial resolution of 2.3 μm for a single incident e- has been measured, with 24 μV per ionization e- sensitivity, 60 dB dynamic range and 70 frames/s readout. Electron microscope tests have been performed with 200, 300 and 400 keV beams, and high-resolution images of a nerve cell's myelin sheath are presented.

6068-27, Session 4

A novel image processing system that autonomously monitors lighting patterns with application to airport lighting

J. H. Niblock, K. R. McMenemy, G. Irwin, Queen's Univ. Belfast (United Kingdom)

This paper presents a novel measurement system that assesses the uniformity of a complete airport lighting installation. The system improves safety with regard to aircraft landing procedures by ensuring airport lighting is properly maintained and conforms to current standards and recommendations laid down by the International Civil Aviation Organisation.

The measuring device consists of a CMOS vision sensor with associated lens system fitted to the interior of an aircraft. The vision system is capable of capturing sequences of airport lighting images during a normal approach to an aerodrome. These images are then post processed to determine the uniformity of the complete pattern.

Airport lighting consists of elevated approach and inset runway luminaires. Each luminaire emits an intensity which is dependant on the angular displacement from the luminaire. For example, during a normal approach a given luminaire will emit its maximum intensity down to its minimum intensity as the aircraft approaches and finally passes over the luminaire. As such, it is possible to predict the intensity that each luminaire within the airport lighting pattern emits, at a given time, during a normal approach. Any luminaires emitting the same intensity can then be banded together for the uniformity analysis.

Having derived the theoretical groups of similar luminaires within a standard approach, this information was applied to a sequence of airport lighting images that was recorded during an approach to Belfast International Airport.

Since we are looking to determine the uniformity of the pattern, only the total pixel grey level representing each luminaire within each banded group needs to be extracted and tracked through the entire image sequence. Any luminaires which fail to meet the requirements (i.e. a threshold value depending on the performance of the other luminaires in that band) are monitored and reported to the assessor for attention.

6068-28, Session 4

Wafer-scale UV embossing of aspheric lenses in phone-camera module

D. Shin, H. Jeong, S. Kim, S. C. Lee, Y. Jin, J. E. Noh, H. R. Oh, K. Lee, SAMSUNG Electro-Mechanics Co., Ltd. (South Korea)

A compact and cost-effective camera module based on wafer-scale-replica processing was developed. A stack of several aspheric lenses for a mobile-phone camera module was first assembled by bonding multiple glass-wafers, on which 2-dimensional replica arrays of identical aspheric lenses were UV-embossed, followed by dicing of the wafer stack and packaging them with image sensor chips. We have demonstrated a VGA camera module fabricated by the wafer-scale-replica processing with various UV-curable polymer lenses having refractive indices between 1.4 and 1.6. Fabricated lens module consisted of three different glass wafers each of which had embossed aspheric lenses on both top and bottom surfaces. Implemented aspheric lenses had 230 μm maximum sag-height and aspheric coefficients of lens polynomials up to tenth order. In order to achieve high performance mobile-phone camera modules based on wafer-scale lenses, precise control and compensation of the polymer material shrinkage was found to be the most critical challenge.

6068-29, Session 4

Colony optical image acquisition system

W. Wang, Chongqing Univ. of Posts and Telecommunications (China)

Many biological procedures depend on an accurate count of the bacterial colonies and other organisms. The enumeration of such colonies is a slow, tedious task. When more than one trained operator makes counts, wide variations are often noted. Various attempts have been made to speed up the process and to improve counting precision. An automated colony counter uses an image analysis system to count colonies on both opaque and transparent agar plates and to analyze the colonies for overlap and size. Data is then viewed, stored, printed, and saved as a data file.

By investigation, some existing systems have some problems since they belong to a new technology product. One of the main problems is image acquisition. In order to acquire colony images with good quality, an illumination box was constructed as: the box includes front lightning and back lightning, which can be selected by users based on properties of colony dishes. With the illumination box, lightning can be uniform; colony dish can be put in the same place every time, which make image processing easy. A digital camera in the top of the box connected to a PC computer with a USB cable, all the camera functions are controlled by the computer.

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6069-01, Session 1

A brief history of 'pixel'

R. F. Lyon, Foveon, Inc.

The term pixel, for picture element, was first published in two different SPIE Proceedings in 1965, in articles by Fred C. Billingsley of Caltech's Jet Propulsion Laboratory. The alternative pel was published by William F. Schreiber of MIT in the Proceedings of the IEEE in 1967. Both pixel and pel were propagated within the image processing and video coding field for more than a decade before they appeared in textbooks in the 1970s. Subsequently, pixel has become ubiquitous in the fields of computer graphics, displays, printers, scanners, cameras, and related technologies, with a variety of meanings.

6069-02, Session 1

31 Mp and 39 Mp full-frame CCD image sensors with improved charge capacity and angle response

E. J. Meisenzahl, E. K. Banghart, D. N. Nichols, J. P. Shepherd, E. G. Stevens, K. Y. Wong, Eastman Kodak Co.

This paper describes the design and performance of two new high-resolution full-frame architecture CCD imaging devices for use in professional color, digital still-imaging applications. These devices are made using 6.8 μm pixels and contain a dual-split HCCD register with two outputs to increase frame rate. The 31 Mp device is designed with microlenses to maximize sensitivity, whereas the 39 Mp device is designed without microlenses to maximize incident light-angle response. Of particular interest is the implementation of UFOX lateral overflow drain (LOD) and thin lightshield process technologies that are incorporated into both devices. The new UFOX LOD structure forms the LOD under the thick-field oxide that desensitizes the dependence of the overlying gate voltage and enables much higher LOD doping levels to be used. The net result is that the LOD may be scaled to smaller dimensions, thereby enabling larger charge capacities without compromising blooming control. The thin lightshield process utilizes only the TiW portion of the TiW / Al metal bilayer to form the pixel aperture. This subsequently enables the use of thinner planarization layers which helps improve angle response (for pixels using microlenses) or critical crosstalk angles (for pixels without microlenses).

6069-03, Session 1

Improving low-light CMOS performance with four-transistor four-shared pixel architecture and charge-domain binning

F. Chu, R. M. Guidash, J. Compton, S. Coppola, W. Hintz, Eastman Kodak Co.

CMOS image sensors have offered intrinsic advantages in terms of power, system integration, form factor, and overall system cost. Since its adoption has been hampered historically by image quality issues, camera designers have primarily relied on CCD technology to provide the image quality required for consumer and professional imaging applications.

The bulk of CMOS image sensors available in the consumer market are based on a three-transistor (3T) pixel design. Although this architecture easily conforms to standard logic CMOS processes that are readily available today, there are inherent disadvantages in the design such as high thermal dark current or read noise, image lag and the lack of true Correlated Double Sampling (CDS).

To address these concerns, Kodak has developed a new pixel architecture that incorporates both design and manufacturing improvements to the standard 3T CMOS pixel. This proprietary

technology called KODAK PIXELUX technology leverages three key design elements: a four-transistor pixel architecture; use of a pinned photodiode; and a shared pixel design.

The technology incorporates a unique architecture that utilizes a common read-out circuit for multiple pixels. As such, each individual pixel can be read out individually or multiple pixels can be combined in a single read operation.

The use of a shared pixel design directly supports the charge binning of multiple pixels, leading to a significant improvement in sensitivity when the sensor is operated at reduced resolutions.

The pinned photodiode lowers the noise associated with the dark current of the photodiode, and the 4T architecture allows for true CDS to eliminate kTC noise. These factors combine to improve the overall Signal-to-Noise Ratio (SNR) of the PIXELUX pixel relative to the standard 3T pixel.

With all the features of PIXELUX such as its unique architecture, pinned-photodiode, multiple binning methods, and weighted averaging, one can achieve tremendous gains in SNR, sensitivity, noise reduction, dynamic range, low-light performance and overall image quality. Ultimately, Kodak's achievements in CMOS imaging technology will become the consumer's competitive advantage in today's demanding imaging marketplace

6069-04, Session 1

Optical interaction of space and wavelength in high-resolution digital imagers

B. G. Rodricks, K. Venkataraman, Micron Technology, Inc.; P. B. Catrysse, B. A. Wandell, Stanford Univ.

Precise simulation of digital camera architectures requires an accurate description of how the radiance image is transformed by the optics and sampled by the image sensor array. For diffraction-limited imaging and all practical lenses, the width of the optical point spread function differs at each wavelength. These differences are relatively small compared to coarse pixel sizes (6-8 μm). But as pixel size decreases (to 1.5-3 μm , for example), wavelength-dependent point spread functions have a significant impact on sensor response. We provide a theoretical treatment of how the interaction of spatial and wavelength properties influences the response of high-resolution color imagers. We then describe a model of these factors and provide an experimental evaluation of the model's computational accuracy.

6069-05, Session 1

Image recovery for a direct color imaging approach using a color filter array

T. Saito, T. Komatsu, Kanagawa Univ. (Japan)

The direct color-imaging approach is promising as an acquisition scheme of color data with high spatial-resolution. The sensor has three photo-sensing layers along its depth direction. Although each pixel has three colors, their spectral sensitivities are overlapped with each other, and the direct color-imaging approach has a problem in color separation. To cope with the problem, we present a hybrid approach. Our hybrid approach uses a direct color-imaging sensor that has three photo-sensing layers, and pastes green and magenta color filters on pixels' surfaces of the sensor according to a checkered pattern. The use of the checkered green-magenta color-filter-array improves color separation, but sensed reddish and bluish color channels still have different color spectra from those of the red and blue primary color channels. Moreover, the sensed green, reddish and bluish color channels are sub-sampled according to the checkered pattern. To recover primary color images with full spatial resolution, not only the color transformation of the reddish and

bluish color channels but also the interpolation of the sensed three color channels are needed. We present methods for the color transformation and the interpolation. Our methods achieve high spatial resolution better than the pure color-filter-array approach, and improve color separation.

6069-06, Session 2

Demosaicing: heterogeneity projection hard-decision adaptive interpolation using spectral-spatial correlation

C. Tsai, K. Song, National Chiao Tung Univ. (Taiwan)

A novel heterogeneity-projection hard-decision adaptive interpolation (HPHD-AI) algorithm is proposed in this paper for color reproduction from Bayer mosaic images. The proposed algorithm is aimed to estimate the optimal interpolation direction and perform hard-decision interpolation, in which the decision is made before interpolation. To do so, a new heterogeneity-projection scheme based on spectral-spatial correlation is proposed to decide the best interpolation direction from the original mosaic image directly. Based on the proposed heterogeneity-projection scheme, a hard-decision rule can be designed easily to perform the interpolation. We have compared this technique with two recently proposed demosaicing techniques: Gunturk's and Lu's methods, by utilizing twenty-five natural images from Kodak PhotoCD. The experimental results show that HPHD-AI outperforms all of them in both PSNR values and S-CIELab measures.

6069-07, Session 2

Iterative asymmetric average interpolation for color demosaicing of single-sensor digital camera data

Y. Takahashi, H. Kikuchi, S. Muramatsu, Niigata Univ. (Japan); N. Mizutani, Kodak Japan Ltd. (Japan)

A two-step color demosaicing algorithm for Bayer-pattern mosaic images is presented. Missing primary colors are at first estimated by an asymmetric average interpolation, and then sharpness of the initial estimate is improved by an iterative procedure.

The intensity variation along an edge is not always uniform along one direction and its opposite with respect to a target pixel to be interpolated. Spatially asymmetric averaging along an edge is hence introduced in this study, where less intensity variation is assumed to be of stronger significance in the sense of stable restoration for details. Also, we restrict ourselves to use short-kernel filters for sharpness recovery.

Spatially-adaptive filtering is involved with color demosaicing and an optical system for image acquisition and color filter array (CFA) sampling are subjected to the spatio-temporal aperture effect. Hence it is unavoidable to produce a blurred restoration to some extent. In order to overcome these difficulties and to restore a sharp image, an iterative procedure is introduced.

Experimental results have shown a favorable performance in terms of objective measures such as PSNR and CIELAB color difference and subjective visual appearances, especially in sharpness recovery.

6069-08, Session 2

Spatially adaptive superresolution sharpening-demosaicking for a single solid state color image sensor

T. Saito, T. Komatsu, Kanagawa Univ. (Japan)

We previously presented a demosaicking method that simultaneously removes image blurs caused by an optical low-pass filter used in a digital color camera with the Bayer's color filter array.

Our prototypal sharpening-demosaicking method restored only spatial frequency components lower than the Nyquist frequency corresponding to the mosaicking pattern, but it often produced ringing artifacts near color edges. To overcome this difficulty, afterward we introduced the super-resolution into the prototypal method. We formulated the recovery problem in the DFT domain, and then introduced the super-resolution by the total-variation (TV) image regularization into the sharpening-demosaicking approach. The TV-based super-resolution effectively demosaicked sharp color images while preserving such image structures as intensity values are almost constant along edges, without producing ringing artifacts. However, the TV image regularization works as the smoothing, and it tends to suppress small intensity variations excessively. Hence, the TV-based super-resolution sharpening-demosaicking approach tends to crash texture details in texture image regions. To remedy the drawback, this paper introduces a spatially adaptive technique that controls the TV image regularization according to the saliency of color edges around a pixel. Experiments demonstrate that the spatially-adaptive super-resolution sharpening-demosaicking approach does not produce ringing artifacts, and does not degrade complex image textures.

6069-09, Session 2

Generic MSFA mosaicing and demosaicing for multispectral cameras

L. Miao, H. Qi, The Univ. of Tennessee; R. Ramanath, North Carolina State Univ.

In this paper, we investigated the potential application of the multispectral filter array (MSFA) techniques in multispectral imaging for reasons like low cost, exact registration, and strong robustness. In both human and many animal visual systems, different types of photoreceptors are organized into mosaic patterns. This behavior has been emulated in the industry to develop the so-called color filter array (CFA) in the manufacture of digital color cameras. In this way, only one color component is measured at each pixel, and the sensed image is a mosaic of different color bands. We extend this idea to multispectral imaging by developing generic mosaicing and demosaicing algorithms. The binary tree-driven MSFA design process guarantees that the pixel distributions of different spectral bands are uniform and highly correlated. These spatial features facilitate the design of the generic demosaicing algorithm based on the same binary tree, which consider three interrelated issues: band selection, pixel selection and interpolation. We evaluate the reconstructed images from two aspects: better reconstruction and better target recognition. The experimental results demonstrated that the mosaicing and demosaicing process preserves the image quality effectively, which further supports that the MSFA technique is a feasible solution for multispectral cameras.

6069-10, Session 3

Dynamic focus window selection using a statistical color model

Y. Tian, Univ. of California/Berkeley

We previously demonstrated the necessity of dynamic focus window selection for autofocus systems and proposed a pupil-tracking method, where only simple modification to the viewfinder is required. Nowadays, most digital cameras are equipped with liquid crystal displays (LCD) and viewfinders are less widely used. Therefore, to require photographers to look through viewfinders poses some practical limitations on the pupil-tracking technique. Here we propose an alternative way to achieve dynamic focus window selection for an important subclass of imaging targets. When the primary imaging targets are known in advance and can be extracted from their backgrounds, pattern recognition can be used to choose focus windows. In this paper, one of such cases, when the primary imaging objects are humans, is discussed in details. We make use of

a statistical model of human skin-color distribution to detect skin regions in the target images. Then morphological operations are employed to smooth the extracted skin regions, which are chosen as the focus windows to apply the chosen focus measure. This new technique is compared with the traditional method of choosing focus windows at the center of target images with one example.

6069-11, Session 3

Combinational AE-AF system with fuzzy climbing search servo

C. Chen, C. Tseng, C. Hung, I. Yin, S. Wang, National Chiao Tung Univ. (Taiwan)

A combinational AE-AF system for digital camera is proposed. The proposed system can perform the functionalities of Auto Focus (AF) and Auto Exposure (AE) at the same time in a very efficient manner. At the first step, this system uses a DOG (Difference of Gaussian) filter to measure image's contrast and sharpness simultaneously. Then, a fuzzy logic-based scheme is proposed for the adjustment of focus and exposure. To increase the speed of the proposed system, the adjusting step size of the fuzzy climbing search servo is adapted based on previous adjustment. This system can be easily implemented with low hardware complexity.

6069-12, Session 3

Multidomain pixel analysis for illuminant estimation

F. Gasparini, R. Schettini, Univ. degli Studi di Milano-Bicocca (Italy); F. Naccari, A. Bruna, STMicroelectronics (Italy)

The illuminant estimation has an important role in many domain applications such as digital still cameras and mobile phones, where the final image quality could be heavily affected by a poor compensation of the ambient illumination effects. In this paper we present a device independent algorithm for illuminant compensation directly in digital still cameras colour filter array (CFA) domain. The algorithm proposed takes into account both chromaticity and intensity information of the image data, and performs the illuminant compensation by a diagonal transform. It works by combining an empirical designed intensity weighting profile and a spatial segmentation process aimed to select the scene objects containing more information for the light chromaticity estimation. This algorithm has been designed exploiting an experimental framework developed by the authors and it has been evaluated on a database of carefully controlled real scene images, containing uniform reflectance patches, and acquired under direct daylight, incandescent lamps, fluorescent lamps, cloudy and daylight shade. The algorithm performances are illustrated and discussed. The results show that a combined, multi domain pixel analysis, lead to an improvement of the performance when compared to single domain pixel analysis and suggest further investigations for an optimal tuning of the proposed solution.

6069-13, Session 3

Computational inexpensive two-step auto white balance method

S. R. Goma, M. Aleksic, ATI Technology (Canada)

The chromaticity of an acquired image reconstructed from a Bayer pattern image sensor is heavily dependent on the scene illuminant and the Bayer pattern filters and usually, when displayed, needs corrections to be applied to be similar with the image perceived by the eye. Some of those corrections are applied at the display level (and are related to the display performances), but some need to be applied in the sensor image-processing path to correct for image sensor specific parameters (i.e. color filters). Automatic white balancing is still an open research topic, one of the main challenges being the complexity of scene illumination.

This paper presents a method to 'white balance' an image, which is computational inexpensive for a hardware implementation, has reasonable accuracy without the need of storing the full image, and is aligned to the current technical development of the field.

The proposed method makes use of a chromaticity diagram of the image, to extract information about the resultant scene reflectance, and, is using the assumption that presence of low-saturated colors in the scene would increase the probability of retrieving accurate information of the resultant scene spectral reflectance.

6069-14, Session 4

An effective image enhancement filtering for noisy image sequences

H. Lee, D. Park, S. Lee, C. Kim, SAMSUNG Advanced Institute of Technology (South Korea)

This paper presents an efficient image enhancement filtering method that reduce the amount of noise in images and sharpens the details of images without noise amplification. To reduce the noise problem in an image sensor, if the difference between temporal filtering result and local spatial averaging value is large, this region is considered to have a high possibility for artifact along the moving object boundary, spatial filtering result is selected. Otherwise, recursive temporal noise filtering is applied. The spatial filtering is calculated by adaptively weighted average approach and weighting value for each pixel is adaptively decided by estimated noise variance and pixel difference within neighboring pixels. In the case of the temporal noise filtering, unlikely conventional temporal noise filtering, each weighting values for previous result and current frame is changed adaptively according to the degree of temporal correlation. Since the sharpness of noise filtered image can be deteriorated by proposed noise filtering, to prevent noise boost-up, the proposed sharpening filter mask can be adaptively generated to suppress the noise amplification according to the pixel similarity information within filter mask. In addition, to obtain the continuous image quality in the entire image area, the efficient gain control algorithm is also proposed.

6069-15, Session 4

Novel bilateral filter approach: image noise reduction with sharpening

M. Aleksic, M. Smirnov, S. R. Goma, ATI Technology (Canada)

One of the strong trends in wireless connectivity is the deployment of digital camera functionality in new cellular phones. The key problem is how to display and capture this type of images with good quality, and how to compress them to minimize the storage space and product cost.

In general image processing there are a lot of different types of filters for improving visual image quality, but typically they don't consider compression. The proposed filter is based on the idea of a bilateral filter. The original bilateral filter combines two kernels: spatial, which process the pixels based on their geometrical distance, and photometric, which takes into account the perceptual similarity between the currently processed pixel and the pixels in its vicinity.

Our approach to bilateral filtering enhances this basic concept in order to allow the filter to sharpen the image while at the same time reducing its noise level. We use two spatial kernels - a low-pass, and a high-pass. This way we achieve simultaneous noise reduction, and sharpening with improving JPEG compression 1.5-2 times.

6069-16, Session 4

Digital photograph stitching with optimized matching of gradient and curvature

S. T. Suen, E. Y. Lam, K. K. Wong, The Univ. of Hong Kong (Hong Kong China)

Digital photograph stitching blends multiple images to form a single one with a wide field of view. Sometimes, artifacts may arise, often due to photometric inconsistency and geometric misalignment among the images. Several existing techniques tackle this problem by methods such as pixel selection or pixel blending, which involve the matching of intensity, frequency, and gradient among the input images and adjusting them to find the optimal match with the input images. However, our experience indicates that these methods have yet fully incorporated the mathematical properties of the photometric inconsistency. In this paper we first introduce a general mathematical model describing the properties and effect of the inconsistency. This model supports our claim that matching on the intensity and even the gradient domain is insufficient. Our method thus adds the extra requirement of an optimal matching of curvature. Simulations are carried out using our method, with input images suffering different kinds of photometric inconsistency under aligned and misaligned situations. We evaluate the results using both objective and subjective criteria, and we find that our method indeed shows an improvement for certain kinds of photometric inconsistency for both situations.

6069-17, Session 4

Compensation of nonuniform flash illumination in group portrait photography

J. H. Kim, Pukyong National Univ. (South Korea); B. A. Barsky, Univ. of California/Berkeley

As a method to improve the image degradation of flash photography due to non-uniform illumination, it will be compensated a group portrait where near face used to be over brighten, compared with distant face. The proposed method is composed of a series of image processing, including the extraction of skin-colored objects and facial regions extraction, and the determination of layout pattern and the compensation of brightness in facial region, using average brightness and spatial variation. Its effectiveness is shown via the experiments with flash photography captured by usual digital camera.

6069-18, Session 5

A robotic system for digital photography

L. W. MacDonald, London College of Communication

The European collaborative research project IST-2000-28008-VITRA ('Veridical Imaging of Transmissive and Reflective Artefacts') developed an innovative system for high-resolution digital image acquisition for conservation. Using a robotic platform to carry both camera and lighting, it can capture colorimetric images up to 15 metres above floor level, thus eliminating the need for scaffold towers. Potential applications include wall-paintings, tapestries, friezes and stained glass windows in heritage buildings such as churches, cathedrals, palaces and monuments. In the course of the project a number of significant technical innovations have been made.

6069-19, Session 5

Source camera identification using footprints from JPEG compression and lens aberration

K. S. Choi, E. Y. Lam, K. K. Wong, The Univ. of Hong Kong (Hong Kong China)

Source camera identification is the process of discerning which camera has been used to capture a particular image. In this paper, we simplify this problem and try to distinguish between images captured by a limited number of camera models. Inspired by the previous work that uses sensor imperfection in this problem, we propose to use the intrinsic lens aberration in order to aid the classification. We focus our attention on lens radial distortion. For each image under investigation, parameters from pixel intensities and aberration measurements are obtained. We then employ a classifier to identify the source camera of an image. Simulation is carried out to evaluate the success rate of our

method. The results show that this is a viable procedure in source camera identification with a high probability of accuracy. Comparing with the procedures using only image intensities, our approach also shows an improvement in accuracy. We have also discovered some interesting statistics in JPEG quantization table, which may also be used to as a feature to help the classification.

6069-20, Session 6

Evaluating digital cameras

D. Wueller, Image Engineering (Germany)

The quality of digital cameras has undergone a magnificent development during the last 10 years. So have the methods to evaluate the quality of these cameras. At the time the first consumer digital cameras were released in 1996 the first ISO standards on test procedures were already on their way. At that time the quality was mainly evaluated using a visual analysis of images taken of test charts as well as natural scenes. The ISO standards lead the way to a couple of more objective and reproducible methods to measure characteristics like Dynamic ranges, speed, resolution and noise. The paper presents an overview of the camera characteristics, the existing evaluation methods and their development during the last years. It summarizes the basic requirements for reliable test methods and answers the question if it is possible to test cameras without taking pictures of natural scenes and under specific lighting conditions.

In addition to the evaluation methods the paper mentions the problems of digital cameras in the past like power consumption, shutterlag, etc. It also states existing deficits which need to be solved in the future like optimised exposure and gamma control, increasing sensitivity without increasing noise, further reduction of shutterlag etc.

6069-21, Session 6

The Imatest program: comparing cameras with different amounts of sharpening

N. L. Koren, Imatest LLC

The Imatest program enables individual photographers and imaging system developers to measure the key image quality factors in cameras, lenses, scanners, and printers. For cameras these include sharpness (MTF), noise, dynamic range, tonal response, color accuracy, lens distortion, light falloff (vignetting), and lateral chromatic aberration. For printers they include tonal response, Dmax, color response, and color gamut. Emphasis is on practical, affordable measurements.

After we summarize Imatest's features we focus on comparing cameras with differing amounts of sharpening, which can distort MTF measurements. Imatest uses an algorithm that adds or removes sharpening to make edge overshoot is relatively consistent. The sharpening amount is adjusted so that MTF at 0.3 times the Nyquist frequency is equal to MTF at low spatial frequencies. The default sharpening radius of 2, typical for compact digital cameras, can be adjusted for different camera types such as digital SLRs. Although this method improves the quality of comparisons between cameras, it does not provide a unique solution. We discuss its advantages, limitations, constraints, and prospects for future development.

6069-22, Session 7

Resolution for color photography

P. M. Hubel, Foveon, Inc.

In our previous paper we made a comparison of: Spatial Frequency Response of Color Image Sensors: Bayer Color Filters and Foveon X3. In this comparison we used the ISO 12233 standard slanted edge technique in both its normal recommended configuration and then also using a colored slanted edge rather than the standard

black and white target. As part of the five-yearly review process of ISO 12233 we have been working on the committee to add some recommendations for making resolution measurements of color targets in addition to the standard black and white methods. When we reported the slanted edge color target results at the ISO-TC42 committee in Stockholm in the spring of 2004 there was general agreement that at least some guidelines to measuring resolution of colored scenes should be added as part of the revision process.

After having heard the other proposed changes to the standard and one particular complaint about our color slanted edge target, we set to find a more acceptable method of adding color to the resolution standard. The most interesting new method of measuring resolution was presented by Dietmar Wueller in the form of a Siemens Star target and accompanying analysis software. As I believe will be discussed in his paper in this same session, the method is less susceptible to demosaicing and sharpening algorithms that concentrate on high contrast edges (at the expense of real resolution that also performs well on textures and other lower contrast scene details) and also gives resolution measurements at multiple angles which is particularly important when considering different sensor technologies. At the meeting we showed a colored Siemens star target that would allow of easy color resolution measurements with Wueller's method using only slightly modified software.

At the Stockholm meeting the JNB pointed out the difficulty we would face in the manufacture of calibrated color resolution targets either in the slanted edge form or the Siemens star target. To address this concern and to make the implementation of color resolution measurement even easier and more consistent with the current standard, I proposed (at the Orlando meeting this winter) to instead use colored filters over the camera lens (or the illumination) and keep the existing targets (both the current ISO target and the new Siemens star target) in black and white. This has the advantage that all of the targets and analysis methods in the standard could be repeated to show how well the camera detects modulation of red, green, and blue components of a scene. The use of standard color separation filters (such as Kodak Wratten filters, or the filters described in other photographic standards) was suggested at the meeting.

This paper reviews the previous work using a colored slanted edge method, and presents a new set of comparisons of the described Siemens Star Color Filter method. The comparison looks at four camera models with two different sensor technologies. The Siemens Star not only shows interesting results between the different color components, but also shows how different color components have variable resolution as a function of angle.

6069-23, Session 7

Resolution and light sensitivity tradeoff with pixel size

J. E. Farrell, Stanford Univ.; F. Xiao, Agilent Technologies; S. Kavusi, Stanford Univ.

Digital cameras are now a standard feature in cellular phones, driving the market for CMOS imagers that can fit within a small form factor. Given that the size of a CMOS imaging sensor array is fixed, the only way to increase sampling density and spatial resolution is to reduce pixel size. But reducing pixel size reduces the light sensitivity. Hence, under these constraints, there is a tradeoff between spatial resolution and light sensitivity.

We use the Image Systems Evaluation Toolbox (ISET) to simulate the effects that scene luminance, optical filtering, sensor transduction, image processing and display rendering have upon the final image quality of a digitally captured image. We use two metrics to characterize the tradeoff between spatial resolution and light sensitivity as a function of pixel size. First, we characterize spatial resolution by the Nyquist sampling frequency of an imaging sensor. Second, we characterize photometric sensitivity by the minimum scene illuminance (lux) required to reach an SNR of 30dB at

exposure duration of 1/30 second. This metric is based on our human experimental measurements that show that sensor SNR must be 30dB to render photon noise invisible.

6069-24, Session 7

Characterization of noise in digital photographs for image processing

S. Lim, Hewlett-Packard Co.

Many conventional image processing algorithms such as demosaicing, noise filtering, sharpening and deblurring assume a noise model of Additive White Gaussian Noise (AWGN) with constant noise standard deviation throughout the image. However, this noise model does not hold for images captured from typical imaging devices such as digital cameras, scanners and cell-phone imagers. Thus, when the image processing algorithms are applied to the digital photographs, they may not provide optimal image quality after processing due to inaccurate noise model. Specifically, unprocessed raw data captured straight from the image sensors contain white noise but the standard deviation of the noise is not constant. Noise can be modeled as sum of read noise, shot noise and fixed pattern noise (FPN) and since the standard deviation of the shot noise and the gain component of the FPN increase as pixel intensity increases, the total standard deviation of the noise varies with pixel intensity and hence is not constant throughout the image. Furthermore, the raw image goes through several image processing steps such as demosaicing, color correction, noise filtering, sharpening, contrast enhancement and JPEG compression, and thus the noise characteristics in the final JPEG image deviates significantly from the widely-used AWGN noise model. In this paper, we describe a noise model that better fits the images captured from typical imaging devices and describe a method to extract necessary parameters directly from the images without prior knowledge of image processing algorithms implemented in the imaging devices. We show experimental results of the noise parameters extracted from the images and discuss how it can be used for image processing algorithms.

6069-25, Session 7

Proposal for a standard procedure to test mobile phone cameras

D. Wueller, Image Engineering (Germany)

Manufacturers of mobile phones are asking for a default procedure to test the quality of mobile phone cameras. The paper presents such a default procedure based on ISO standards as far as possible and adding additional useful information based on easy to handle methods. In addition to the paper which will be a summary of the measured values with a brief description on the methods used to determine these values a white paper for the complete procedure will be available.

Here is an overview of the values which will be part of the proposal: OECF (opto-electronic-conversion-function), Dynamic range, Noise (Signal to Noise, absolute noise), ISO speed, White balancing, used digital values, Resolution and limiting resolution, sample rate, TV-Distortion, Shading/Vignetting, Chromatic Aberration, Color reproduction quality, View angle at shortest and longest focal length, shortest capture distance, maximum scaling, Pixel Defects, Autofocus accuracy, JPEG Compression, Resampling for MMS, Timing issues like Startup time and shutter delay, Image frequency [frames per second], Flash, Light source, EV/guiding number, uniformity, Display refresh rate and Display accuracy, Videocapabilities, Metadata.

Monday-Tuesday 16-17 January 2006

Part of Proceedings of SPIE Vol. 6070 Machine Vision Applications in Industrial Inspection XIV

6070-01, Session 1

Optical servoing for industrial surface machining

N. Koller, Hotvision Research GmbH (Austria); R. Ofner, P. L. O'Leary, Montan Univ. Leoben (Austria); E. Fauster, Hotvision Research GmbH (Austria)

The surface machining of cracks is a key issue to ensure the quality of steel rods and billets. The aim is to grind these defects out of the material. This paper presents a real-time optical servo-system, consisting of three image processing systems and an industrial robot, which fully automate this process. A high resolution color progressive scan camera, placed at a suitable position above the roller conveyor, observes the material and detects color markings indicating the presence of a crack. This camera system controls the roller conveyor transporting the material until a marked crack is detected. Diffuse light sources provide homogeneous lighting to ensure reliable detection of the markings. A demosaicing algorithm, RGB to HSL color modeling and thresholding with statistical morphology are used to identify the marked areas. On detecting a crack the material is automatically positioned within the working area of an industrial robot. A collineation is used to generate metric two-dimensional coordinates corresponding to the bounding rectangle of the detected error. At this point two plane-of-light scanners are used to acquire a cross section of the material to the left and the right of the robot's working area. From this, a three-dimensional model for the rod or billet surface is calculated and the two-dimensional coordinates of the color marking are projected onto this surface to generate a patch. The coordinates of this patch are sent to the 6R industrial robot, which then grinds out the defect. A new concept has been implemented which enables the calibration of the three image processing systems and the industrial robot so as to have one common coordinate system. Operational results have shown the full functionality of the system concept in the harsh environment of a steel production facility.

6070-02, Session 1

Statistical learning with imbalanced training set in a machine vision application: improve the false alarm rate and sensitivity simultaneously

J. Q. Li, Agilent Technologies, Inc.

In machine vision applications, we would like to have high performance on two conflicting metrics: a very low false alarm rate and a very high sensitivity of detection. Depending on different application domain, people often need to trade off one goal against the other for the overall best system performance. It is therefore very desirable to identify methods that can improve both metrics simultaneously. We present one such method in the context of imbalanced training set for statistical learning.

Specifically, we study an application of statistical learning in detecting manufacturing defects. The training data is naturally imbalanced because care was taken to minimize the occurrence of defects. In the dataset I use, the rate of defects is at about 500 ppm (part per million). To obtain a meaningful number of defects, say 500, one has to collect about 1 million samples. Statistical learning methods such as classification trees, support vector machines can be applied directly to this situation in principle. However, two problems exist.

In a Bayesian framework, the prior is estimated by the number of occurrence in the training data. A large prior on the majority class will skew the decision boundary to the majority class where the conditional probabilities are equal. In other words, there will be

more-than-necessary tendency to call a data point into majority class. To counter this problem, we make use of a sub-sampling method in the majority class. We will demonstrate that a sound sub-sampling method will improve the false alarm rate with a slight decrease in the sensitivity.

The cost of computation is high because of the large sample size. This problem does not prevent us from applying any statistical learning methods in principle. In practice, we found that the limitation of memory size and CPU speed render some of the computation-intensive methods such as Boosting impossible to run in a large dataset. We demonstrate that after applying the sub-sampling method followed by a computation-intensive method like Boosting, we achieve satisfactory improvements on both the false alarm rate and sensitivity.

6070-03, Session 1

Boundary detection of projected fringes for surface of inhomogeneous reflectance

J. Cheng, R. C. Chung, The Chinese Univ. of Hong Kong (Hong Kong China); E. Y. Lam, The Univ. of Hong Kong (Hong Kong China); K. S. M. Fung, F. Wang, W. H. Leung, ASM Assembly Automation Ltd. (Hong Kong China)

Boundary detection of projected fringes for surface of inhomogeneous reflectance is a challenge because when a binary pattern is projected onto the inspected surface through a set of projection lenses, the high order harmonics of the pattern are often diminished because of the lens system's limited bandwidth. Thus fringes projected on the target surface will not remain exactly black or white, but be changed to gray-level ones. In other words, the boundaries of the binary stripes will appear blurred in the image data. Furthermore, different compositions (e.g., solder bumps versus substrate surface of silicon wafers) of the target surface have different reflectance functions. Together the factors make fringe boundary detection in the image data a challenging problem. This paper proposes a solution to the problem. It makes use of the spatial-temporal image volume of the target surface, as opposed to only spatial derivatives of the data as practiced traditionally, to tackle the issue of inhomogeneous reflectance function. We shift the fringe pattern in space relative to the stationary light source and target surface and camera, and at every shifting of the fringe grating we take a new image. The observed intensity profile across the images at an image position will have the same profile of the gratings regardless of the reflectance at the involved surface point in space, and from the temporal distribution we could detect edges by almost any established method. Studies through theoretical analysis and empirical experiments on real image data show that the mechanism has a lot of advantages over the existing approaches.

6070-04, Session 1

Height inspection of wafer bumps without explicit 3D reconstruction

M. Dong, R. C. Chung, Y. Zhao, The Chinese Univ. of Hong Kong (Hong Kong China); E. Y. Lam, The Univ. of Hong Kong (Hong Kong China)

Direct die-to-die bonding requires placement of solder bumps not on PCB but on the wafer itself. Such wafer solder bumps, which are much miniaturized from the counterparts on PCB, still need to have their heights meet the specification, or else electrical connection could be compromised, or the dies be crushed, or even the manufacturing equipments be damaged. Yet the tiny size, typically tens of microns in diameter, and the textureless and mirror nature of the bumps pose great challenge to the 3D inspection process. This

paper proposes a measure which is sensitive to global and local deviations of the bump heights while having tolerance to repeatability error in wafer placement, thus allowing a large number of such wafer bumps to have their heights massively checked against the specification. We first present a design of the imaging and illumination setup that exploits the mirror nature of the bumps, which is used to be causing difficulty to inspection, to capture image point correspondences over two planes: one that contains the bump peaks, and the other that corresponds to the substrate surface. With such correspondences, the homography matrices associated with the two planes and the fundamental matrix of the cameras could be determined. With such data, we synthesize a matrix we refer to as the Biplanar Disparity Matrix. This matrix reveals information about the bumps' heights in a direct way without the need of going through explicit 3D reconstruction. We describe how the above imaging and illumination setup allows the measure matrix to be revealed from the image data so acquired. We also show both synthetic and real data experimental results to illustrate the effectiveness of the proposed system.

6070-05, Session 2

Fast recognition method for metallic topographies by the "Three-Color Selective Stereo Gradient Method" (Three-Color SSGM)

M. Hossfeld, Technische Univ. Hamburg-Harburg (Germany); M. Adameck, Hella KGaA Hueck & Co. (Germany); M. Eich, Technische Univ. Hamburg-Harburg (Germany)

This paper presents a machine-vision solution for real-time classification of moving objects with highly reflective metallic surfaces and complex 3D-structures. As an application example of our Three-Color Selective Stereo Gradient Method (Three-Color SSGM) a classification system for the three main coin denominations of Euro coins is presented. The coins are quickly moving in a coin validation system. The objective is to decide only from comparison of measured 3D-surface properties with characteristic topographical data stored in a database whether a coin belongs to one of the reference classes or not. Under illumination of a three-color LED-ring a single image of the moving coin is captured by a digital camera. Exploiting the spectral properties of the illumination sources, which correspond to the special spectral characteristics of the camera, three independent subimages can be extracted from the first. Comparison between these subimages leads to a discrimination between a coin with real 3D-surface and a photographic image of a coin of the same type. After the coin has been located and segmented, grey value based rotation and translation invariant features are extracted from a normalized image. In combination with template matching methods, a coin can be classified. Statistical classification results will be reported.

6070-06, Session 2

Robustness of texture parameters for color texture analysis

A. Marin, A. Roman, Univ. de Bourgogne (France); D. R. Connah, J. Y. Hardeberg, Gjøvik Univ. College (Norway); P. Gouton, Univ. de Bourgogne (France)

This article proposes to deal with noisy and variable size color textures. It also proposes to deal with quantization methods and to see how such methods change final results. The method we use to analyze the robustness of the textures consists of an auto-classification of modified textures. Texture parameters are computed for a set of original texture samples and stored into a data base. Such a database is created for each quantization method. Textures from the set of original samples are then modified, eventually quantized and classified according to classes determined from a

pre-computed database. A classification is considered incorrect if the original texture is not retrieved. This method is tested with 3 textures parameters: auto-correlation matrix, co-occurrence matrix and directional local extrema and 3 quantization methods: principal component analysis, color cube slicing and RGB binary space slicing. These two last methods apply only to 3 RGB bands images but could be extended to more.

First results show that autocorrelation matrix parameter is less sensitive to noise and to scaling than the two other tested texture parameters. This implies that autocorrelation matrix should probably be preferred for texture analysis with non controlled condition, typically industrial applications where images could be noised.

6070-07, Session 2

Real-time multispectral imaging application for poultry safety inspection

B. Park, K. C. Lawrence, W. R. Windham, M. P. Snead, U.S. Dept. of Agriculture

Food safety is an important issue for public health, because reduction in the potential health risks to consumers from human pathogens in food is the most important public concern. In a processing plant environment, fecal contaminants are a food safety risk because of a correlation between feces and pathogenic bacteria. Federal regulations require that no poultry carcass can have visible fecal contamination prior to the carcass entering the ice-water chiller tank. Currently, poultry inspection system is based on what inspectors could see: diseases, defects, and contamination on carcasses. Detecting fecal contamination can be quite a challenging task because contaminants can vary with intestinal location, diets, and disease. Compounding these challenges, are the requirement to identify contaminants with high speed in a wet and harsh environments. Recently, the ARS has developed a real-time multispectral imaging system for fecal and ingesta contaminant detection on broiler carcasses. The system includes a common aperture camera with three optical trim filters. The on-line testing results showed that the multispectral imaging technique can be used effectively for detecting feces and ingesta on the surface of poultry carcasses with a commercial processing speed. The accuracy for the detection of fecal and ingesta contaminates was 96%.

6070-08, Session 2

Flushing analysis by machine vision and fuzzy logic at molten steel for the automation process

C. Pfob, K. S. Niel, Fachhochschule Wels (Austria); R. Rössler, voestalpine Mechatronik GmbH (Austria)

For the homogenisation of the molten steel it is necessary to rinse the melting bath. Therefore two porous plugs are installed in the bottom of the casting ladle through which the gas is blown into the ladle. The movement of the melting surface is chaotic. Other process stages, which are distortions to the image processing system, like steam or mechanical parts moving within the scene have to be taken into consideration too. Standard straight forward analytic algorithms fail. The uncertainties cannot be handled in a proper way. We decided to use a RGB binary converter followed by a fuzzy classifier. If the flushing is active molten steel breaks through the slag. This molten steel areas show a certain colour spectrum. The RGB-binary conversation is necessary to detect the molten cast breaking the slag. The size of these colour areas is direct proportional to the intensity of the flushing. The fuzzy block felts the results of the binary conversation and splits them into the intensity grades. This method allows the detection of five stages of the flushing under the given conditions at the melting process and it is able to detect steam or other disturbing parts moving through the scene as well.

6070-09, Session 2

Color influence in accuracy of 3D scanner based on structured light

S. Voisin, The Univ. of Tennessee and Univ. de Bourgogne (France); D. L. Page, The Univ. of Tennessee; S. Foufou, F. Truchetet, Univ. de Bourgogne (France); M. A. Abidi, The Univ. of Tennessee

The characterization of commercial 3D scanners allows acquiring precise and useful data. The accuracy of range and, more recently, color for 3D scanners is usually studied separately, but when the 3D scanner is based on structured light with a color coding pattern, color influence on range accuracy should be investigated. The commercial product that we have tested has the particularity that it can acquire data under ambient light instead of a controlled environment as it is with the most of available scanners. Therefore, based on related works in the literature and on experimental experiences we have done on a variety of standard illuminants, we have designed an interesting experimental setup to control illuminant interference. Basically the setup consists of acquiring the well-known Macbeth ColorChecker under a controlled environment and also ambient daylight. The results varied with respect to the color. We have performed several statistical studies to show how the range results evolve with respect to the RGB or the HSV channels. In addition, a systematic noise error has also been identified. This noise depends on the object color. A subset of colors shows strong noise errors while other colors have minimal or even no systematic error under the same illuminant.

6070-10, Session 3

Novel view synthesis for projective texture mapping on real 3D objects

T. Molinier, D. Fofi, P. Gorria, Univ. de Bourgogne (France)

We aim to estimate a novel view from two captured views in order to do augmented reality by projecting a synthesized view on a real 3D object (for virtual texturing, virtual painting or mixing physical and virtual textures). This can be helpful in many applications such as rendering architecture, reverse engineering, industrial designing and so on. For instance, it may be useful for engineers or architect to visualize how the object they have created will look with different material or under different conditions before real painting or mass production.

Our machine vision system is composed of two cameras and one digital light projector but can be generalized to any projector-camera system. Once our system is calibrated, we can transfer the points of the two views to the projector frame in order to project them onto the object surface.

This transfer, or retro-projection, is based on the trifocal geometry, extracted from the calibration of the system, and the point correspondences of the views of the cameras. This step consists in estimating a novel view, which can be considered as a third image of the object grabbed by a virtual camera that would have the same parameters and position than the data projector.

6070-11, Session 3

3D translucent object reconstruction from artificial vision

F. Truchetet, Univ. de Bourgogne (France)

A model and a method allowing a 3D reconstruction of a given translucent object from a series of acquisitions performed with various focusing settings is proposed. The object is observed by transmission and refraction, reflection and diffusion effects are neglected. It is modelled as a stack of translucent planes whose positions are denoted by abscissa x . A first degree order discrete expansion of the transmission coefficient is proposed. The optical device is assumed to be linear, its blurring function depends on the focusing distance. All the images acquired with various focusing distances are lexicographically sorted in a vector S and, calling E the images of the

absorption coefficients of the object, the acquisition process can be described by a set of linear equations: $S = HE$. Taking advantage from the peculiar structure of H we propose a very efficient inversion technique with a complexity $O(n)$ allowing practical applications with simple lap top computer in very reasonable time. Examples of results with a simulated 3D translucent object will be presented. When no perturbation is assumed, the model is reconstructed with no visible error from the blurred acquisitions.

6070-12, Session 3

Real-time 3D wood panel surface measurement using laser triangulation and low-cost hardware

H. Ramoser, L. Cambrini, H. Rötzer, Advanced Computer Vision (Austria)

High quality wood sanding machines need information about the wood surface shape in order to control actuators pushing the sanding paper onto the wood surface. In order to improve the quality of the sanding process we have developed a 3D measurement system within the EU FP6 project MEPOS. Several constraints (especially, panel size and available measurement volume) prohibit using off-the-shelf measurement systems.

The measurement system is based on laser line triangulation and consists of two inclined 675nm lasers equipped with line diffraction optics, a high resolution camera, and a standard PC all mounted into a rigid frame. Two mirrors direct the laser light onto the wood panel moving beneath the measurement system. The surface resolution is 1.1mm/pixel and the depth resolution is 0.4mm/pixel.

Measurements are performed at a rate of 25 frames/sec. The projected lines are detected with subpixel accuracy and converted into world (x , y , z) coordinates using calibration data. The measurement accuracy is approximately identical over the full width of the measurement system. In x and z direction the surface resolution is constant. In y direction the resolution depends on the panel shape and speed. In case of shadowing (i.e. when only one line is visible) the resolution is ≈ 10 mm otherwise it is High quality wood sanding machines need information about the wood surface shape in order to control actuators pushing the sanding paper onto the wood surface. In order to improve the quality of the sanding process we have developed a 3D measurement system within the EU FP6 project MEPOS. Several constraints (especially, panel size and available measurement volume) prohibit using off-the-shelf measurement systems.

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6070-14, Session 4

Aerial platform attitude measurement by artificial vision

F. Truchetet, O. Aubreton, P. Gorria, O. Lalignat, Univ. de Bourgogne (France)

Two measurement systems based on electronic imagers for attitude determination of light and low-cost airborne vectors in clear weather condition are presented. Our devices are based on the following

scheme: firstly a binarized sky line image is selected as referential, then each shot, after binarization is segmented in two parts whose mean values are subtracted to the corresponding data computed from referential image. From this comparison analogical or digital values are deduced that give way to estimating the roll and pitch variation angles. The first system is made of off-the-shelf devices: black and white CMOS camera and processing unit made of a dedicated electronic. A second proposition is presented. It makes use of a CMOS retina, developed by our team, dedicated to real time, analogical intercorrelation computing. A simple external processing implemented in a microcontroller completes the system. A model for the embarked imaging system and an equation for an ideal horizon image with respect to rolling and pitch angles are proposed. The method for estimating these angles from the image and errors induced by the various approximations of the model are then presented. In the next part a series of experimental results obtained from real images confirms the previous propositions. The last section is dedicated to a presentation of the retinal imager solution, experimental results are also provided in this part.

6070-15, Session 4

A new algorithm for real-time multistage image thresholding

S. H. Lin, R. Giesen, D. Nair, National Instruments

Image binarization under non-uniform lighting condition is required in many industrial machine vision applications. Many local adaptive thresholding algorithms have been proposed in the literature for this purpose. Local thresholding algorithms compute thresholds for individual pixels based on the local statistics of their neighborhood instead of finding a single threshold based on the entire image. Local thresholding algorithms have proved to be advantageous over global thresholding for complex scene image segmentation under non-uniform lighting conditions. However, the existing local adaptive thresholding algorithms are either not robust enough or too expensive for real-time implementation due to very high computation cost. This paper presents a new algorithm that combines local and global statistics in a multi-stage thresholding framework. In the first stage, a mean filtering algorithm with kernel-size independent computation cost is proposed for background modeling to eliminate the non-uniform lighting effect. In the second stage, a background-corrected image is generated based on the background color. In the final stage, a global thresholding algorithm is applied to the background-corrected image. The Kernel-size independent computation algorithm reduces the order of computation cost of background modeling from NML^2 to approximately for an NM by M image with a $L \times L$ kernel. This reduction in computation cost enables the real-time processing of arbitrary-size objects. Experiments show that the proposed algorithm performs better than other local thresholding algorithms, such as the Niblack algorithm, in terms of both speed and segmentation result for many machine vision applications under non-uniform lighting condition.

6070-16, Session 4

Simultaneous photometric correction and defect detection in semiconductor manufacturing

Y. Shen, E. Y. Lam, The Univ. of Hong Kong (Hong Kong China)

In this paper, we focus on the treatment of photometric correction during the process of defect detection. We noted that this problem has some resemblance to the change detection problem in real time image analysis. In particular, the changes between the two images are analogous to the defects in our machine vision system. We therefore applied several detection methods and examined their applicability to defect detection. We first performed a sub-pixel image registration, using a phase correlation method together with a singular value

decomposition factorization of the correlation matrix to compute the necessary alignment. We then tested a few change detection methods, including the shading model, derivative model, statistical change detection, linear dependence change detector and Wronskian change detection model. We subjected this system to our collection of raw data acquired from an industrial system, and we evaluated the different methods with respect to the detection accuracy, robustness, and speed of the system. We had some promising results at the stage, especially in detecting the blob and line defects that are mostly common found, and when the lighting variation is within a certain threshold. Future research may include defect detection of the die images which are not only translation shifted, but also rotated.

6070-17, Session 4

Automatic mura detection system for liquid crystal display panels

L. Fang, H. Chen, I. Yin, S. Wang, C. Wen, C. Kuo, National Chiao Tung Univ. (Taiwan)

We propose an automatic inspection system, which can automatically detect four types of muras on an LCD panel: cluster mura, v-band mura, rubbing mura, and light leakage mura. To detect cluster muras, the Laplacian of Gaussian (LOG) filter is used. A multi-resolution approach is proposed to detect cluster muras of different scales. To speed up the processing speed, this multi-resolution approach is actually implemented in the frequency domain. To detect v-band muras, we check the variation tendency of the projected 1-D intensity profile. Then, v-band muras are detected by identifying these portions of the 1-D profile where a large deviation occurs. To detect rubbing muras, we designed a frequency mask to detect distinct components in the frequency domain. To detect light leak muras, we apply image mirroring over the boundary parts and adopt the same LOG filter that has been used in detecting cluster muras. All four types of mura detection are integrated together in an efficient way and simulation results demonstrate that this system is indeed very helpful in detecting mura defects.

6070-18, Session 4

New developments in image-based characterization of coated particle nuclear fuel

J. R. Price, D. Aykac, J. D. Hunn, A. K. Kercher, R. N. Morris, Oak Ridge National Lab.

In this paper, we describe further work on inspecting and characterizing coated particle nuclear fuel using optical microscopy and digital imaging. This work is being performed in support of the U.S. Department of Energy's (DOE) Advanced Gas Reactor (AGR) Fuel Development and Qualification Program. As in our earlier work, we process two types of images: backlit (or shadow) images and cross-sectional images. For the shadow images, we describe a new curvature-based metric that is computed in the FFT domain using a low-frequency sinusoidal representation of the particle boundary. To get to the FFT domain, however, we require equally spaced samples around the particle perimeter, but we often have missing boundary points due to abutting particles and/or dirt. Hence, we also describe how such missing points are estimated using band-limited interpolation that is consistent with the low-frequency FFT representation. For the cross-section images, we describe a simple Bayesian-like approach for segmenting the different layers. We also describe a new approach that employs profilometry measurements for estimating the true (mid-plane) layer thicknesses from the off mid-plane cross-section images.

6070-19, Session 5

Real-time detection of elliptic shapes for automated object recognition and object tracking

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The detection of varying 2D shapes is a recurrent task for Computer Vision applications, and camera based object recognition has become a standard procedure. Due to the discrete nature of digital images and aliasing effects, shape recognition can be complicated. There are many existing algorithms that discuss the identification of circles and ellipses, but they are very often limited in robustness or speed or require high quality input data. Our work considers the application of shape recognition for processes in industrial environments and, especially the automatization requires reliable and fast algorithms at the same time. We take a very practical look at the automated shape recognition for common industrial tasks and present a very fast novel approach for the detection of deformed shapes which are in the broadest sense elliptic. Furthermore, we consider the automated recognition of different colonies of bacteria, coded markers for 3D object tracking and an automated camera calibration procedure.

6070-20, Session 5

Discrete circles measurement for industrial inspection

F. Mairesse, T. M. Sliwa, S. Binczak, Y. Voisin, Univ. de Bourgogne (France)

This article deals with the problem of the determination of characteristics of imperfect circular objects on discrete images mainly the radius and center's coordinates. Imperfections are provided by discretization, noise and interior distortions present in some production processes. To this end, a multi-level method based on active contours was developed and tested on, noisy or not, misshaped or not, simulated or not circles whose centers and radius were known. The adequacy of this approach was tested with several methods, among them several Radon based ones. More particularly, this study indicates the relevance of the use of active contours combined with a Radon transform based method, using a description of circles from their tangents, improved thanks to a fitting considering the discrete implementation of Radon transform. Through this study, an active region algorithm based on stationary states of a non linear diffusion principle is proposed. Its originality is to obtain a set of geometric envelopes in one pass, with a correspondence between level threshold of the grayscale result and a regularity scale, more or less close to the original shape. This set of geometric envelopes gives a multiscale representation, from a very regular approximation to a full detailed and roughest representation. Then, a more robust measure of the circle parameters can be computed.

6070-21, Session 5

Twin and scratch detection and removal in micrograph images of Inconel 718

G. Jakob, A. Rinnhofer, Joanneum Research (Austria); H. Bischof, Technische Univ. Graz (Austria); W. Benesova, Joanneum Research (Austria)

Grain size of forged nickel alloy is an important feature for the mechanical properties of the material. For fully automatic grain size evaluation in images of micrographs it is necessary to detect the boundaries of each grain. This grain boundary detection is influenced directly by artefacts like scratches and twins. Twins can be seen as parallel lines inside one grain, whereas a scratch can be identified as a sequence of colinear line segments that can be

spread over the whole image. Both kinds of artefacts introduce artificial boundaries inside grains. To avoid wrong grain size evaluation, it is necessary to remove these artefacts prior to the size evaluation process. For the generation of boundary images various algorithms have been tested. The most stable results were achieved by greyscale reconstruction and a subsequent watershed segmentation. A modified line hough transform with a third dimension in the hough accumulator space, describing the distance of the parallel lines, is used to directly detect twins. Scratch detection is done by applying the standard line hough transform followed by a rule based segment detection along the found hough lines. The results of these operations give a detection rate of more than 90 percent for twins and more than 50 percent for scratches.

6070-22, Session 5

Tracking fluorescent spots in wide-field microscopy images

L. A. Muresan, B. Heise, E. P. Klement, Johannes Kepler Univ. Linz (Austria)

Single protein tracking in wide-field microscopy image sequences is a novel and promising approach to understand biological processes within the cell. Automation of the task is necessary, since the manual detection of fluorescent spots and their trajectories is tedious, subjective and difficult to replicate.

The task consists of reliably detecting the fluorescent spots in each frame of the movie and performing a data association step, in which trajectories are constructed. This task presents several challenges such as low signal-to-noise ratio (typical for wide-field microscopy images), photobleaching of the fluorophores, movement of proteins on the z-axis (making fluorescent spots look dimmer or brighter), occlusions of spots, clutter, lack of an a priori motion model, among others.

This paper discusses several known algorithms adapted to intracellular image sequences. In each case a pre-processing denoising step is performed first. Several denoising algorithms were implemented and analyzed, among them: spatial-tonal normalized convolution, variational approach, adaptive filter, anisotropic diffusion. Spot detection is performed via an à trous algorithm.

For the tracking part, two models of motion were considered: Brownian motion and drift. Tracking is performed by a modified version of Sethi and Jain's algorithm (adapted for both motion models), a version of the IPAN point tracking and mean shift. The algorithms were tested on a simulation sequence as well as on real images.

6070-23, Session 5

Development of method based on Hough transform or Gabor filtering to discriminate crop and weeds in agronomic image

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In precision agriculture, to detect in the fields the local heterogeneities of soil, crop and weeds, imaging devices provide useful information. In particular, the reduction of herbicides applications requires an accurate weed patches detection. From image detection, to quantify weeds infestation, it would therefore be necessary to firstly identify crop rows from a line detection algorithm and secondly identify weeds. For images, the main line detection algorithms are based on strip analysis, blob analysis, linear regression, Hough transform and Gabor filter.

We will present a line detection including Hough transform to detect on agronomic images and classified crop and weeds using a region-based segmentation. Another method will be presented using a Gabor filter.

6070-24, Session 6

A refined range image registration technique applied to multistriple laser 3D scanner

C. Matabosch, J. Salvi, Univ. de Girona (Spain); D. Fofi, F. Meriaudeau, Univ. de Bourgogne (France)

Nowadays, in several applications, the visual inspection is very important in the control quality process. However, the complexity of 3D objects built is impossible to control with 2D images; a surface is required to compare with respects to the model. However, most part of sensors can reconstruct objects in movement. To solve this problem a 3D hand sensor is developed to reconstruct 3D surfaces by means of one single projection.

As the goal is to design a 3D hand sensor, surfaces must be reconstructed using a single view to avoid misalignments produced for vibrations of the sensor. To solve this problem, 19 planes are projected simultaneously onto the surface. As one surface is not enough to represent the object, several consecutive surfaces are obtained and the motion between them is obtained using a point-to-plane pair-wise registration technique in order to fusion them. Furthermore, a refinement step is used to avoid the propagation of the error

Several experiments are realized obtaining good reconstruction. Quality and quantity experiments will be presented in the final paper. Each partial surface is reconstructed with a precision of less than 0.5 mm when the sensor is placed on a distance of 30 cm of the object.

6070-25, Session 6

Surface orientation recovery of specular microsurface via binary pattern projection

Z. Song, R. C. Chung, J. Cheng, The Chinese Univ. of Hong Kong (Hong Kong China); E. Y. Lam, The Univ. of Hong Kong (Hong Kong China)

With the continuous effort of the electronic industry in miniaturizing device size, the task of inspecting the various electrical parts becomes increasingly difficult. For instance, solder bumps grown on wafers for direct die-to-die bonding need to have their 3D shape inspected for assuring electrical contact and preventing damage to the processing equipments or to the dies themselves in the bonding process. Yet, the inspection task is made difficult by the tiny size and the highly specular and textureless nature of the bump surfaces. In an earlier work we proposed a mechanism for reconstructing such highly specular micro-surfaces as wafer bumps. However, the mechanism is capable of recovering 3D positions only. In this paper we describe a new mechanism that recovers surface orientations as well which are as important in describing a surface. The mechanism is based upon projecting light from a point or parallel light source to the inspected surface through a specially designed binary grid. The grid consists of a number of black and transparent blocks, resembling a checker board. By shifting the grid in space a number of times in a direction not parallel to either boundary of the grid elements, and each time taking a separate image of the illuminated surface, we could determine the surface orientations of the inspected surface at points which appear in the image data as grid corners. More precisely, for any point C of the inspected surface which appears as a grid corner in the image data, the light source and the boundary tangent of the associated grid element in space define a plane which we refer to as the Shifting Projection Plane (SPP) of C. On the other hand, the camera center and the image flow at C induced by the spatial motion of the grid define another plane which we refer to as the Image Flow Plane (IFP) of C. The surface normal at point C can then be worked out as the cross product of the surface normals of the planes SPP and IFP of C. Experimental results on real objects are shown to illustrate the effectiveness of the proposed mechanism.

6070-26, Poster Session

Constructing a simple parametric model of shoulder from medical images

H. Atmani, F. Mérienne, École Nationale Supérieure d'Arts et Métiers (France); D. Fofi, P. Trouilloud, Univ. de Bourgogne (France)

This paper deals with the problem of modeling the bones of human shoulder for computer-assisted surgery. Our aim is to provide a light and easy-handling shoulder model for surgeons in order to ease the preoperative and peroperative work when substituting the articulation by prosthesis. Due to the lack of data (CT slices are not always available), the reconstruction of a model for each patient is not feasible. Moreover, the deformation or morphing of generic model may require the measurement of many 3D control points on the patient shoulder, which could be a drawback. That is why, in collaboration with orthopaedists, we decided to model the scapulo-humeral joint by means of simple geometric forms that allow to obtain a parametric model from a minimal set of data extracted from medical images and, besides, that permit to consider the main characteristics involved in the mobility of the shoulder. In the paper, both the image processing method and the modelling of the shoulder will be detailed.

Image processing:

Our approach consists in the automatic (or sometimes supervised) extraction of relevant parameters from various medical images (CT slices, X-ray images, etc.) The different steps of the image processing algorithm are:

- conversion from colour to gray-level;
- binarization to extract the bones from medical images;
- filtering;
- morphological operations in order to reject irrelevant regions and to differentiate the scapula from the humerus.

These steps are obviously adapted to the kind of images (threshold, prior knowledge on the relative positioning of the scapula/humerus, etc.) and parameters we want to extract. The image processing method will be clearly detailed in the final article.

In accordance with orthopaedists, the following parameters of interest have been chosen:

- ray of the humeral diaphysis;
- ray of the humeral head;
- position of the lateral bicipital groove with respect to the centre of the humeral head;
- maximal distance between the epiphysis and the greater tuberosity of humerus;
- height and width of the glenoid cavity;
- position of the coracoid with respect to the centre of the glenoid cavity;
- coracoidal ray;
- length of the coracoid;
- position of the acromion with respect to the centre of the glenoid cavity.

Shoulder modelling :

After the MRI, CT or X-ray images have been processed, the relevant parameters for the mobility of the shoulder are injected into the generic model in order to fit the size and shape of the patient shoulder. To provide a light and easy-handling representation of the shoulder, a simple model composed of quadrics and planes is proposed. In addition, logical operations as subtraction or intersections can be easily computed on this simple model so that the drilling and cutting can be simulated on the model and a virtual operation can be considered.

For instance, the humerus is mainly made of a sphere and a cylinder. A Dupin cyclid is added to ensure the continuity and completeness of the model and the lateral bicipital groove is modelled by carving a cylinder into the humeral head. The scapula is composed of planes, ellipsoids, cylinders and so on. The complete model will be detailed and the link between relevant parameters and simple form parameters that legitimate our choice will be stated.

6070-27, Poster Session

A study of automatic monitoring and measuring vehicles by using image analysis

W. Wang, Chongqing Univ. of Posts and Telecommunications (China)

Recently, as vehicle production quick development in China, traffic problem increases sharply almost in every middle-large city. One of the techniques for resolving the problem is digital image processing and analysis. This paper presents our study of automatic monitoring and measuring vehicles by using image analysis. In the study, a digital camera is located at a T-junction cross of a traffic road in SHAPINGBA in Chongqing city of China, the vehicles which pass through the road cross are monitored and analyzed in real time. To analyze the traffic volume and situation, the online images are obtained and transferred into a PC computer and the implemented image processing and analysis algorithms are applied for the images. For each analysis, three images are taken before traffic light turns from green into red. To identify the moving vehicles in images, the non-moving vehicles, background, building or other non-moving objects should be removed from the image. As moving vehicles close to non-moving vehicles on city roads, we can estimate the location of the tile (the last vehicle) in non-moving vehicle queue. Thus, the real non-moving vehicle queue length can be calculated by transferring image coordinates to earth coordinates (global coordinates). The congestion status of the traffic in roadway can be reflected by the real length.

6070-28, Poster Session

An active contour algorithm for detecting the circular features in a PCB x-ray image

Y. Chen, C. Wu, W. Hu, Yuan Ze Univ. (Taiwan)

Detection of circular information including drill holes and inside connection metal rings, plays a key role for the automatic inspection of a multi-layer printed circuit board (PCB). An approach is presented to automatically extract whole circular information from an x-ray image acquired from a multi-layer PCB. By analyzing the x-ray image with a series of some image processing procedures, the basic circular information can be obtained and be treated as an initial contour for further processing. An effective modular active contour is then presented to guide the initial contour to locate the circular information more precisely. Experimental analyses have shown that the proposed approach can reach at the performance of 0.5 pixel average error under 20% random noise added. Experiments on real PCB x-ray images have also confirmed the feasibility of the proposed approach.

6070-30, Poster Session

Human vision based detection of nonuniform brightness on LCD panels

J. H. Kim, Pukyong National Univ.; B. A. Barsky, Univ. of California/Berkeley

A method to detect the defects due to spatially non-uniform brightness on LCD panels by using machine vision technique is proposed. The detection method is based on human vision so that proper subjective assessment experiments were conducted to investigate the correlation between the parameters related to non-uniformity and the degree how easily it is observable. The visibility of the defects reveals to depend mainly on the spatial gradient of brightness variation. The detection method is composed of four parts, those are, the extraction of contours, the calculation of spatial gradient, decision of defects and the display of defects, where the spatial gradient calculated by using extracted contours will be utilized to detect the defects due to non-uniform brightness.

6070-31, Poster Session

Optimized texture classification by using hierarchical complex networks

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Although still lacking a definitive definition, texture has motivated many investigations and applications in image analysis and computer vision. Examples of traditional methods of texture analysis include but are not limited to Fourier-based methods and Co-occurrence matrices and derived measurements. Basically, a specific texture pattern is characterized by the repetition of some basic element or property of the image. Because of such a repetition, the nature of texture becomes more global than local, implying the consideration of a minimal area or image around each point in order to provide statistical relevance while defining the classes of textures present in an image. As a consequence, the proper characterization and identification of textures requires a methodology capable of expressing the local context around each point, integrating local and global features of the image field.

As suggested recently (<http://arxiv.org/abs/cond-mat/0403346>), it is possible to use complex networks concepts and measurements in order to obtain useful information about the texture properties of regions and objects in images. In order to do so, a graph is first obtained from the image by incorporating edges between pixels which have similar properties (gray-scale, color, position, etc.). Several measurements, including the degree and clustering coefficient, can then be estimated from such graphs and used in order to classify the types of textures in the image, or segment the latter with basis on textural differences. Note that such measurements are particularly relevant for texture characterization because they provide a good compromise between local (i.e. the measurements are centered at each image point) and global (i.e. the measurements take into account the immediate context of the image properties around the reference point) information.

Preliminary investigations by using the node degree and clustering coefficient with respect to publicly available databases of textures revealed a promising potential of such an approach. However, because of the fact that only the most immediate neighborhood of each node in the graph is considered for obtaining the feature vector characterizing the textures, there is a good potential for further optimization of the complex network approach to texture characterization by using a set of hierarchical measurements proposed in (<http://arxiv.org/abs/cond-mat/0412761>). These measures provide an extension of the concepts of node degree and clustering coefficient to several neighborhoods around each node of the graph, therefore providing a powerful means for controlling the balance between locality and generality during texture analysis. Actually, the hierarchical level defined with respect to each node endows our methodology with multiscale functionalities.

The current manuscript reports a novel methodology for texture characterization by using the hierarchical measurements of complex networks as described above. After describing how the complex networks are extracted from the images and illustrating each hierarchical measurement, we present a series of classification results obtained by considering several publicly available texture databases. Special attention is given to the identification and selection of those hierarchical measurements which contribute more decisively for the texture discrimination.

6071-01, Session 1

The effects of frame rate and resolution on users playing first person shooter games

M. Claypool, Worcester Polytechnic Institute; K. Claypool, F. Damaa, Univ. of Massachusetts/Lowell

The rates and resolutions for frames rendered in a computer game directly impact the player performance, influencing both the overall game playability and the game's enjoyability. Insights into the effects of frame rates and resolutions can guide users in their choice for game settings and new hardware purchases, and inform system designers in their development of new hardware, especially for embedded devices that often must make tradeoffs between resolution and frame rate. While there have been studies detailing the effects of frame rate and resolution on streaming video and other multimedia applications, to the best of our knowledge, there have been no studies quantifying the effects of frame rate and resolution on user performance for computer games. This paper presents results of a carefully designed user study that measures the impact of frame rate and frame resolution on user performance in a first person shooter game. Contrary to previous results for streaming video, frame rate has a marked impact on both player performance and game enjoyment while resolution has little impact on performance and some impact on enjoyment.

6071-02, Session 1

Real-time 3D video compression for tele-immersive environments

Z. Yang, Y. Cui, Z. Anwar, R. Bocchino, N. Kiyancilar, K. Nahrstedt, R. H. Campbell, Univ. of Illinois at Urbana-Champaign; W. J. Yurcik, National Ctr. for Supercomputing Applications

Tele-immersive systems can improve productivity and aid communication via a shared immersive experience among distributed parties. The TEEVE project at the University of Illinois at Urbana-Champaign and the University of California at Berkeley seeks to foster the deployment of tele-immersive environments through a holistic integration of existing components that capture, transmit, and render 3D scenes in real time. However, the transmission of 3D video poses significant challenges as it is very bandwidth-intensive and existing compression schemes for 2D video cannot be applied directly because 3D video contains depth as well as color information. Our goal is to explore 3D video compression with trade-offs including complexity, compression ratio, quality, and real-time performance. We present and evaluate two simple schemes incorporating different compression methods for color and depth data. Our experimental results based on 3D videos captured from a real tele-immersive environment show that both schemes achieve high visual fidelity and real-time performance for tele-immersive applications.

6071-03, Session 1

An integrated visual approach for music indexing and dynamic playlist composition

M. Crampes, S. Ranwez, Ecole des Mines d'Alès (France); F. Velickovski, C. Mooney, Univ. of New South Wales (Australia); N. Mille, Netia, Inc. (France)

This paper presents a new integrated visual approach for indexing music and automatically composing personalized playlists for radios or chain stores. To efficiently index hundreds of music titles by hand with artistic descriptors, the user only needs to drag and drop them onto a dynamic music landscape. To help the user we propose different dynamic visualization tools, such as the semantic spectrum

and semantic field lenses. An algorithm then propagates artistic values that are hidden in the landscape into the titles being indexed. Different propagation algorithms are tested and compared. The dynamic composition methodology is then described with its class n-gram algorithm and its means for personalization based on the same music map as the visual indexing method. The new tools and techniques presented in this paper enable us to turn musical experience into an integrated visual experience that may generate new music knowledge and emotion.

6071-04, Session 1

Efficient rate-distortion optimized media streaming for tree-reducible packet dependencies

M. Röder, Univ. of Konstanz (Germany); J. Cardinal, Univ. Libre de Bruxelles (Belgium); R. Hamzaoui, Univ. of Konstanz (Germany)

In packetized media streaming systems, the decoding dependencies between the encoded data packets are often modeled as a directed acyclic graph called the dependency graph. We consider the situation where the transitive reduction of the dependency graph, obtained by removing redundant edges, is a tree. This occurs, for instance, in MPEG1 video streams that are packetized at the frame level. Other video coding standards such as H.264 also allow tree-structured dependencies. We propose in this context efficient exact dynamic programming algorithms for finding rate-distortion optimal transmission policies. We also provide thinning methods for reducing the complexity of these algorithms at the cost of a controllable increase in distortion. The proposed algorithms are much faster than previous exact algorithms developed for arbitrary dependency graphs.

6071-05, Session 1

Popular song and lyrics synchronization and its application to music information retrieval

K. Chen, S. Gao, Y. Zhu, Q. Sun, Institute for Infocomm Research (Singapore)

An automatic synchronization system of the popular song and its lyrics is presented in the paper. The system includes two main components: a) automatically detecting vocal/non-vocal in the audio signal and b) automatically aligning the acoustic signal of the song with its lyric using speech recognition techniques and positioning the boundaries of the lyrics in its acoustic realization at the multiple levels simultaneously (e.g. the word / syllable level and phrase level). The GMM models and a set of HMM-based acoustic model units are carefully designed and trained for the detection and alignment. To eliminate the severe mismatch due to the diversity of musical signal and sparse training data available, the unsupervised adaptation technique such as maximum likelihood linear regression (MLLR) is exploited for tailoring the models to the real environment, which improves robustness of the synchronization system. To further reduce the effect of the missed non-vocal music on alignment, a novel grammar net is build to direct the alignment. As we know, this is the first automatic synchronization system only based on the low-level acoustic feature such as MFCC. We evaluate the system on a Chinese song dataset collecting from 3 popular singers. We obtain 76.1% for the boundary accuracy at the syllable level (BAS) and 81.5% for the boundary accuracy at the phrase level (BAP) using fully automatic vocal/non-vocal detection and alignment. The synchronization system has many applications such as multi-modality (audio and textual) content-based popular song browsing and retrieval. Through the study, we would like to open up the

discussion of some challenging problems when developing a robust synchronization system for large-scale database.

6071-06, Session 2

MMS: a multihome-aware media streaming system

A. Habib, Siemens Technology to Business Ctr.; J. Chuang, Univ. of California/Berkeley

Multihoming provides highly diverse redundant paths in terms of average hop count, latency, loss ratio, and jitter. In this paper, we first explore topological path diversity and show that multihoming can significantly reduce the path overlap when a multihomed receiver conducts media streaming from a set of suppliers. We then design a multihome-aware media streaming system (MMS) that exploits topological path diversity by splitting a streaming session over the available physical links to reduce path overlap among the suppliers, and migrating a connection from one path to another if the current path is congested. A network tomography-based monitoring mechanism is developed to identify congested path segments.

Through a series of experiments in the wide area Internet, we show that multihoming provides streaming at a higher rate comparing to a single service provider. On average the quality of streaming sessions is improved by 30% or more.

6071-07, Session 2

Streamline: a scheduling heuristic for streaming applications on the grid

B. Agarwalla, N. Ahmed, D. Hilley, U. Ramachandran, Georgia Institute of Technology

Streaming applications such as video-based surveillance, habitat monitoring, and emergency response are good candidates for executing on high-performance computing (HPC) resources, due to their high computation and communication needs. Scheduling such an application on HPC resources has to be sensitive to the computation and communication needs of each stage of the application dataflow graph to ensure QoS criteria such as latency and throughput. Since the grid has evolved out of traditional high-performance computing, the tools available for scheduling are more appropriate for batch-oriented applications. Our scheduler, called Streamline, considers the dynamic nature of the grid and runs periodically to adapt scheduling decisions using application requirements (per-stage computation and communication needs), application constraints (such as co-location of stages), and resource availability. The performance of Streamline is compared with an Optimal placement, Simulated Annealing (SA) approximations, and E-Condor, a streaming grid scheduler built using Condor. For kernels of streaming applications, we show that Streamline performs close to the Optimal and SA algorithms, and an order of magnitude better than E-Condor under non-uniform load conditions. We also conduct scalability studies showing the advantage of Streamline over other approaches.

6071-08, Session 2

A novel unbalanced multiple description coder for robust video transmission over ad hoc wireless networks

F. Huang, L. Sun, Y. Zhong, Tsinghua Univ. (China)

Robust transmission of live video over ad hoc wireless networks presents new challenges: high bandwidth requirements are coupled with delay constraints; even a single packet loss causes error propagation until a complete video frame is coded in the intra-mode; ad hoc wireless networks suffer from bursty packet losses that drastically degrade the viewing experience. Accordingly, we propose

a novel UMD coder capable of quickly recovering from losses and ensuring continuous playout. It uses 'peg' frames to prevent error propagation in the High-Resolution (HR) description and improve the robustness of key frames. The Low-Resolution (LR) coder works independent of the HR one, but they can also help each other recover from losses. Like many UMD coders, our UMD coder is drift-free, disruption-tolerant and able to make good use of the asymmetric available bandwidths of multiple paths. The simulation results under different conditions show that the proposed UMD coder has the highest decoded quality and lowest probability of pause when compared with concurrent UMDC techniques. The coder also has a comparable decoded quality, lower startup delay and lower probability of pause than a state-of-the-art FEC-based scheme. To provide robustness for video multicast applications, we propose non-end-to-end UMDC-based video distribution over a multi-tree multicast network. The multiplicity of parents decorrelates losses and the non-end-to-end feature increases the throughput of UMDC video data. We deploy an application-level service of LR description reconstruction in some intermediate nodes of the LR multicast tree. The principle behind this is to reconstruct the disrupted LR frames by the correctly received HR frames. As a result, the viewing experience at the downstream nodes benefits from the protection reconstruction at the upstream nodes.

6071-09, Session 2

A transform for network calculus and its application to multimedia networking

K. Pandit, Technische Univ. Darmstadt (Germany); J. Schmitt, C. Kirchner, Univ. Kaiserslautern (Germany); R. Steinmetz, Technische Univ. Darmstadt (Germany)

The rapid increase of multimedia traffic has to be accounted for when designing IP networks. A key characteristic of multimedia traffic is that it has strict Quality of Service (QoS) requirements in a heterogeneous manner. There are many different traffic types which have different throughput and delay requirements. In such a setting, scheduling by service curves is a useful method as it allows for assigning each flow exactly the service it requires.

Network calculus is well suited to model networks with QoS sensitive multimedia traffic. The min-plus convolution is a key operation in network calculus. We introduce a transform with which insight on the min-plus convolution is gained.

In the second part, the results are applied to bandwidth/delay decoupled scheduling disciplines. The relationship between the network service curve and the node service curves is established. We can then derive the optimal service curves for the nodes along a path. Further, by reallocating the service curves the admission control be improved as well as deficiencies of nodes compensated. On a broader scale, this paper advances the research in analytically modeling packet-switched networks by pointing out novel properties and a new application of Network Calculus.

6071-10, Session 3

A method to deliver multi-object content in a ubiquitous environment

T. Mori, M. Katsumoto, National Institute of Information and Communications Technology (Japan)

We propose a multi-object content delivery method for use in a ubiquitous environment where many nodes are connected. In our target applications, a node receive multiple objects from multiple nodes to display content. We assume that each object is encoded by multiple description coding (MDC) and copies of the descriptions are stored in multiple nodes. We define evaluation functions for descriptions. The parameters of these evaluation functions are a user requirement and the number of copies of the descriptions which we intend to evaluate. We calculate an evaluate values for

each descriptions and determine the quality of each object based on the evaluate values and the network bandwidth available for use by nodes. In addition, to reduce the impact of node removal, sending nodes are selected using a heuristic algorithm that reduces the number of overlapping nodes in the delivery path. Since a problem to determine the quality of each object and sending nodes is NP-Complete problem, we divide the problem into small problems and introduce a heuristic algorithm. We implemented our method and performed some experiments. Experimental results showed that our method could determine the quality of objects, the sending nodes, and efficient delivery paths within a reasonable time.

6071-11, Session 3

Correlation-aware multimedia content distribution in overlay networks

Y. Zhu, B. Li, Univ. of Toronto (Canada)

The prevalent form of multimedia content distribution is streaming, which demands a sustained flow rate from the streaming source to each of the receivers. A significant amount of work has focused on overlay streaming latencies. In contrast, in this paper, we address the most critical Quality of Service parameter: the achievable rate of multimedia content distribution. We seek to answer the question: What is the best way to construct a mesh overlay topology for multimedia content distribution, such that the highest streaming rate can be achieved? We make the observation that overlay link capacities exhibit correlations with each other. Since it is not feasible to obtain a complete set of constraints, the challenge is to construct a correlation-aware overlay with low probing overhead. We model these correlations as linear capacity constraints. We propose a distributed and scalable algorithm that constructs an overlay mesh which incorporates linear capacity constraints that are heuristically inferred. In our simulations, we investigate how accurately these approximate and localized constraints represent overlay link dependencies in capacity. Moreover, our results show that enhancing an existing mesh construction strategy with limited constraints leads to improvement with respect to the achievable flow rate.

6071-12, Session 3

QBIX-G: a transcoding multimedia proxy

P. Schojer, L. Boeszoermenyi, H. Hellwagner, Univ. Klagenfurt (Austria)

An adaptive multimedia proxy is presented which provides (1) caching, (2) filtering, and (3) media gateway functionalities. The proxy can perform media adaptation on its own, either relying on layered coding or using transcoding and transrating in the decompressed domain. A cost model is presented which incorporates (1) user requirements, (2) terminal capabilities, and (3) video variations in one formula. Based on this model, the proxy acts as a general broker of different user requirements and of different video variations. This is a first step towards "What You Need is What You Get" (WYNIWYG) video services, which deliver videos to users in exactly that quality they need and are willing to pay for. The MPEG-7 and MPEG-21 standards enable this in an interoperable way. To the best of our knowledge, this is the first work on a quality aware video cache that combines partial caching in the quality domain with a differentiated model of (1) user preferences, (2) video variations, and (3) the caching costs. A detailed evaluation based on a series of simulation runs is provided. Based on the simulation results, the algorithms were integrated into our "Quality Based Intelligent Proxy", the evaluation of which is in progress.

6071-13, Session 3

Preventing DoS attacks in peer-to-peer media streaming systems

W. G. Conner II, K. Nahrstedt, I. Gupta, Univ. of Illinois at Urbana-Champaign

This paper presents a framework for preventing both selfishness and denial-of-service attacks in peer-to-peer media streaming systems. Our framework, called Oversight, achieves prevention of these undesirable activities by running a separate peer-to-peer download rate enforcement protocol along with the underlying peer-to-peer media streaming protocol.

This separate Oversight protocol enforces download rate limitations on each participating peer. These limitations prevent selfish or malicious nodes from downloading an overwhelming amount of media stream data that could potentially exhaust the entire system. Since Oversight is based on a peer-to-peer architecture, it can accomplish this enforcement functionality in a scalable, efficient, and decentralized way that fits better with peer-to-peer media streaming systems compared to other solutions based on central server architectures. We evaluated our Oversight solution through simulations and our results show that applying Oversight to peer-to-peer media streaming systems can prevent both selfishness and denial-of-service attacks by effectively limiting the download rates of all nodes in the system.

6071-14, Session 4

Playstation and multimedia

K. Hofrichter, Sony Computer Entertainment America

No abstract available

6071-15, Session 5

Investigating a stream synchronization middleware for the NEES MAST system

J. C. Beyer, S. K. Chirravuri, D. H. Du, Univ. of Minnesota

This paper describes the streaming synchronization middleware research conducted while investigating how to provide a collaborative experimentation system for the NEES Multi-Axial Sub-Assemblage Testing (MAST) Experimental setup at the University of Minnesota. The transmission of real-time multimedia streams over high-speed best-effort networks has been both an interesting and challenging research area for the past few years. Continuous multimedia streams such as those produced by MAST experiments are characterized by well-defined temporal relationships between subsequent media units (MUs). The information present in these streams can only be presented correctly when these time-dependent relationships are maintained during presentation time. Even if these relationships change during transportation (e.g. due to network delays), they need to be reconstructed at the client (sink) before playout. Whereas most previous work addresses synchronization at the application level by modifying the end system, our goal is to leave the end-system largely unchanged and simply add a new synchronization middleware application control system. This paper presents our three proposed algorithms that ensure the continuous and synchronous playback of distributed stored multimedia streams across a communications network via a middleware controlled commercial media player.

6071-16, Session 5

A performance model of effective memory management in HYDRA: a large-scale data stream recording system

K. Fu, R. Zimmermann, Univ. of Southern California

Presently, scant attention has been paid to servers that can record such streams in real time. However, more and more devices produce direct digital output streams. Hence, the need arises to capture and store these streams with an efficient recorder that can handle both recording and playback of many streams simultaneously and provide a central repository for all data. Because of the continuously decreasing cost of memory, more and more memory is available on a large scale recording system. Unlike most previous work that focuses on how to minimize the server buffer size, this paper investigates how to effectively utilize the additional available memory resources in a recording system. We propose an effective resource management framework that has two parts: (1) a dynamic memory allocation strategy, and (2) a deadline setting policy (DSP). Furthermore, to find the optimal memory configuration, we construct a probability model based on the classic M/G/1 queueing model and the recently developed Real Time Queueing Theory (RTQT). Our model can predict (a) the missed deadline probability of a playback stream, and (b) the blocking probability of recording streams. The model is applicable to admission control and capacity planning in a recording system.

6071-17, Session 5

Sender-driven bandwidth differentiation for transmitting multimedia flows over TCP

J. K. H. Lau, J. Y. B. Lee, The Chinese Univ. of Hong Kong (Hong Kong China)

Over the years the Transmission Control Protocol (TCP) has demonstrated extraordinary scalability and robustness despite the explosive growth of the Internet. With the rapid growth of multimedia contents in the Internet, the many strengths of TCP are slowly imposing bottlenecks in multimedia data delivery where different media data flows often have different needs for bandwidth. As TCP's congestion control algorithm enforces fair bandwidth sharing, different media data flows will receive the same bandwidth irrespective of the actual needs of the multimedia data being delivered. This work addresses this limitation by proposing a Virtual Packet Substitution (VPS) algorithm to achieve non-uniform bandwidth allocation among TCP flows originating from the same sender passing through the same network bottleneck to multiple receivers. VPS has four desirable features: (a) it allows allocation of bottleneck bandwidth between a group of TCP flows; (b) the resultant traffic flows as a whole, maintain the same fair bandwidth sharing property with other competing TCP flows; (c) it can be implemented entirely in the sender's TCP protocol stack; and (d) it is compatible with and does not require modification to existing TCP protocol stack at the clients.

6071-18, Session 5

FlexSplit: a workload-aware adaptive load balancing strategy for media clusters

Q. Zhang, College of William & Mary; L. Cherkasova, Hewlett-Packard Labs.; E. Smirni, College of William & Mary

A number of technology and workload trends motivate us to consider a new request distribution and load balancing strategy for streaming media clusters. First, in emerging media workloads, a significant portion of the content is short and encoded at low bit rates. Additionally, media workloads display a strong temporal and

spatial locality. This makes modern servers with gigabytes of main memory well suited to deliver a large fraction of accesses to popular files from memory. Second, a specific characteristic of streaming media workloads is that many clients do not finish playing an entire media file which results from the browsing nature of a large fraction of client accesses. In this paper, we propose and evaluate two new load-balancing strategies for media server clusters. The proposed strategies, FlexSplit and FlexSplitLard aim to efficiently utilize the combined cluster memory by exploiting specific media workload properties by "tuning" their behavior to media file popularity changes. The ability of the proposed policies to self-adapt to changing workloads across time while maintaining high performance makes these strategies an attractive choice for load balancing in media server clusters.

6071-19, Session 5

Cascades: scalable, flexible, and composable middleware for multimodal sensor networking applications

J. Huang, W. Feng, N. Bulusu, W. Feng, Portland State Univ.

This paper describes the design and implementation of Cascades, a scalable, flexible and composable middleware platform for multimodal sensor networking applications. The middleware is designed to provide a way for application writers to use pre-packaged routines as well as incorporate their own application-tailored code when necessary. As sensor systems become more diverse in both hardware and sensing modalities, such systems support will become critical. Furthermore, the systems software must not only be flexible, but also be efficient and provide high performance. Experimentation in this paper compares and contrasts several possible implementations based upon testbed measurements on embedded devices. Our experimentation shows that such a system can indeed be constructed.

6071-20, Session 5

Compression by indexing: an improvement over MPEG-4 body animation parameter compression

S. Chattopadhyay, S. M. Bhandarkar, K. Li, The Univ. of Georgia

MPEG-4 Body Animation Parameters (BAP) are widely used for the animation of virtual human models (avatars). MPEG-4 BAP data is typically compressed using a standard MPEG-4 compression pipeline. However, MPEG-4 compressed BAP data is inefficient for use in power-constrained devices, since decompression requires extra CPU cycles, and hence consumes power. In this paper, we present a novel method for compressing BAP data, which renders the compressed BAP data suitable for use in power and network resource constrained devices. The proposed compression scheme indexes the BAP data, and constructs corresponding lookup tables for the indices. Decompression does not require additional CPU cycles, as simple lookup from the lookup tables suffice. Structural information from the hierarchical structure of the skeletal avatar model is exploited in the compression scheme in order to minimize motion distortion resulting from compression. We have measure power used for decompression (in terms of CPU cycles) and power used by a wireless network interface card to receive streaming BAP data (in terms of m-Joules). In both cases, MPEG-4 compressed BAP data requires significantly more power for decompression and streaming, compared to Indexed-BAP. We conclude that power-and-network resource constrained devices benefit more from BAP-Indexing, compared to MPEG-4 BAP compression.

6071-21, Session 6

DagStream: locality aware and failure resilient peer-to-peer streaming

J. Liang, K. Nahrstedt, Univ. of Illinois at Urbana-Champaign

Live peer to peer (P2P) media streaming faces many challenges such as peer unreliability and bandwidth heterogeneity. To effectively address these challenges, general “mesh” based P2P streaming architectures have recently been adopted. Mesh-based systems allow peers to aggregate bandwidth from multiple neighbors, and dynamically adapt to changing network conditions and neighbor failures. However, a drawback of mesh-based overlays is that it is difficult to guarantee network connectivity in a distributed fashion, especially when network locality needs to be optimized. This paper introduces a new P2P streaming framework called DagStream, which (1) organizes peers into a directed acyclic graph (DAG) where each node maintains at least k parents, thus has provable network connectivity (and hence failure resilience), and (2) enables peers to quickly achieve locality awareness in a distributed fashion, thus ensures efficient network resource usage. Our experiment results in both simulation and wide area environment show that with our DagStream protocol, peers can quickly self-organize into a locality aware DAG. Further, by selecting additional parents as needed, peers can achieve good streaming quality commensurate with their download bandwidth.

6071-22, Session 6

Characterizing files in the modern Gnutella network: a measurement study

S. Zhao, D. Stutzbach, R. Rejaie, Univ. of Oregon

The Internet has witnessed an explosive increase in the popularity of Peer-to-Peer (P2P) file-sharing applications during the past few years. As these applications become more popular, it becomes increasingly important to characterize their behavior to improve performance and quantify the impact on the network. In this paper, we present a measurement study on characteristics of available files in the modern Gnutella system. We develop a new methodology to capture accurate “snapshots” of available files in a large scale P2P system by capturing the entire overlay topology where each peer in the overlay is annotated with its available files. We captured dozens of snapshots of the Gnutella system and conduct three types of analysis on available files: (i) Static analysis, (ii) Topological analysis and (iii) Dynamic analysis. Our results include the following: video files make up only around 6% of all files but more than 50% of all bytes, the number of shared files and contributed storage space of peers follow power-law distributions, and files are randomly distributed with no strong correlation to the topology. In summary, we present several interesting properties of available files that can be leveraged to improve the design and evaluations of P2P file-sharing applications.

6071-23, Session 6

Sampling cluster endurance for peer-to-peer based content distribution networks

V. Darlagiannis, Technische Univ. Darmstadt (Germany); A. U. Mauthe, Lancaster Univ. (United Kingdom); R. Steinmetz, Technische Univ. Darmstadt (Germany)

Several types of Content Distribution Networks (CDNs) are being deployed over the Internet today, based on different architectures to meet their requirements (e.g., scalability, efficiency and resiliency).

Peer-to-Peer (P2P) based CDNs are promising approaches that have several advantages. Structured P2P networks, for instance, take a proactive approach and provide efficient routing mechanisms. Nevertheless, their maintenance can increase considerably in highly

dynamic P2P environments. In order to address this issue, a two-tier architecture that combines a structured overlay network with a clustering mechanism is suggested in a hybrid scheme. In this work, we examine several sampling algorithms utilized in the aforementioned hybrid network that collect local information in order to apply a selective join procedure.

The algorithms are based mostly on random walks inside the overlay network. The aim of the selective join procedure is to provide a well balanced and stable overlay infrastructure that can easily overcome the unreliable behavior of the autonomous peers that constitute the network.

The sampling algorithms are evaluated using simulation experiments where several properties related to the graph structure are revealed.

6071-24, Session 6

How efficient is BitTorrent?

G. Wu, T. Chiueh, Stony Brook Univ.

BitTorrent is arguably the most popular media file distribution protocol used in Internet today. So far no other peer-to-peer file distribution systems are able to outperform BitTorrent in any significant way. Even though empirically BitTorrent seems to be both efficient and scalable, there has been very little research on the detailed dynamics of its built-in control mechanisms, and their effectiveness across a wide variety of network configurations and protocol parameters. Moreover, it is not known how much room is available for further performance optimization. The main goal of the paper is to answer the question of how close BitTorrent is to the optimum, and as a corollary how much room there is for further performance improvement.

In this paper, we first propose a centrally scheduled file distribution (CSFD) protocol, which can probably minimize the total elapsed time of a one-sender-multiple-receiver file distribution task. Then we develop a discrete-event simulator for the BitTorrent protocol to study the performance impacts of its various design decisions and to compare it with CSFD across a wide variety of system configurations and algorithm parameters. Finally, we analyze the suitability of BitTorrent in supporting real-time media streaming applications and suggest necessary modifications.

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6072-01, Session 1

New blind steganalysis and its implications

M. Goljan, J. Fridrich, T. S. Holotyak, Binghamton Univ.

The contribution of this paper is two fold. First, we describe an improved version of a blind steganalysis method previously proposed by Holotyak et al. The features for the blind classifier are calculated in the wavelet domain as higher-order absolute moments of the noise residual obtained by a denoising filter. This method clearly shows the benefit of calculating the features from the noise residual because it increases the features' sensitivity to embedding, which leads to excellent detection results. Second, using this detection engine, we attempt to answer some fundamental questions, such as "what is the best method to hide messages in images stored in a raster format?" or "how much can we improve the reliability of steganalysis given a priori knowledge of the image source?" In particular, we experimentally compare the security of three steganographic schemes - (1) pseudo-random ± 1 embedding using ternary matrix embedding, (2) spatially adaptive ternary ± 1 embedding, and (3) perturbed quantization while converting color images to grayscale.

6072-02, Session 1

Statistical modeling and steganalysis of DFT-based image steganography

Y. Wang, P. Moulin, Univ. of Illinois at Urbana-Champaign

An accurate statistical model of the cover image is essential to the success of both steganography and steganalysis. We study the statistics of the full-frame 2-dimensional DFT coefficients of natural images and show that the i.i.d unit exponential distribution model is not a sufficiently accurate description of the statistics of normalized image periodograms. Consequently, the stochastic quantization index modulation (QIM) algorithm aimed at preserving this model (Moulin and Briassouli, 2004) is detectable in principle. Ideally, we could develop a statistically optimal test on the DFT coefficients if only we know their before-and-after-embedding statistics. However, in reality accurate parametric distributions are not available. Therefore, we resort to a learning system trained on cover and stegoimages to discriminate between them. Building upon a state-of-the-art steganalysis method using the statistical moments of wavelet characteristic functions (Xuan et al., 2005), we propose new features that are more sensitive to data embedding. With the addition of the new features, the receiver operating characteristic (ROC) curve is significantly improved.

6072-03, Session 1

Fourth-order structural steganalysis and analysis of cover assumptions

A. D. Ker, Univ. of Oxford (United Kingdom)

We extend our previous work on "Structural Steganalysis" of LSB replacement in digital images, making use of the effect of LSB operations on groups of four pixels. Some of the method carries over straightforwardly. However we discover new complexities in the specification of a cover image model. There are many reasonable "symmetry" assumptions which we can make about parity and structure in natural images, only some of which provide detection of steganography, and the challenge is to identify the symmetries a) completely, and b) concisely (without redundancy). Further, we want to assign an appropriate weight to each.

We give a list of possible symmetries and then reduce them to a complete, non-redundant, and independent set. Some experimental results suggest that all useful symmetries are thus described. A weighting is proposed and its approximate variance stabilization verified empirically. Finally, we apply these new insights to create a novel "quadruples" detector for LSB replacement steganography. Experimental results show some improvement, in most cases, over previous work. However the gain in performance is somewhat moderate compared with the increased complexity in the detection algorithm, and we suggest that, without new insight, further extension of "Structural Steganalysis" may provide diminishing returns.

6072-04, Session 1

Application of conditional entropy measures to steganalysis

J. A. Marsh, T. Knapik, E. Lo, SI International; C. D. Heitzenrater, Air Force Research Lab.

Many commercial steganographic programs use least significant bit (LSB) embedding techniques to hide data in 24-bit color images. We present a supervised learning based steganalysis technique that identifies the presence (or absence) of data hidden by the commercial programs Hide4PGP and stegHide. The data hiding algorithms use both sequential and distributed LSB embedding. Our results include a 98.5% correct classification rate with data embedding rate of 0.2 bits per pixel. The corresponding rates of false positives and false negatives were 2% and 1%, respectively. Classification was performed using a two-class support vector machine (SVM). Our technique is based on the idea that preexisting correlations between bit planes and color planes in images will be disrupted when information is embedded into the image. We quantify this effect by calculating Shannon entropy and conditional entropies between all bit plane and color plane combinations, resulting in 240 entropic features. The operation of the algorithm was optimized using a genetic algorithm, which reduced the number of entropic features to 48. Our research used the SVMlite package, due T. Joachims, with MATLAB interface by T. Briggs.

6072-05, Session 1

Improving steganalysis by fusion techniques: a case study with image-based steganography

M. Kharrazi, T. H. Sencar, N. D. Memon, Polytechnic Univ.

In the past few years we have witnessed a number of steganalysis techniques proposed in the literature. These techniques could be categorized as either specific or universal. Each category of techniques has a set of advantages and disadvantages by definition. A steganalysis technique specific to an embedding method would perform well when tested only on that embedding method, and might fail on all other steganographic algorithms. On the other hand, universal steganalysis method which in theory should be independent of the embedding algorithm perform less accurately overall but still provide acceptable results in many cases. In practice, the steganalyst will have to select one or more techniques which she will employ on a set of suspected stego objects. And what should she do when the results produced by the techniques are in contradiction? In this work, we propose and investigate information fusion techniques, that combine a number of steganalysis techniques. We start by reviewing possible fusion techniques which are applicable to steganalysis. After which we

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illustrate, through a number of case studies, how one is able to obtain performance improvements as well as scalability by employing suitable fusion techniques.

6072-06, Session 1

A two-factor error model for quantitative steganalysis

R. Böhme, Technische Univ. Dresden (Germany); A. D. Ker, Univ. of Oxford (United Kingdom)

Quantitative steganalysis refers to the exercise of not only detecting the presence of hidden stego messages in carrier objects, but also of estimating the secret message length. This problem is well studied, with many detectors proposed but only a sparse analysis of errors in the estimators. A deep understanding of the error model, however, is a fundamental requirement for the assessment and comparison of different detection methods. This paper presents a rationale for a two-factor model for sources of error in quantitative steganalysis, and shows evidence from a dedicated large-scale nested experimental set-up with a total of more than 200 million attacks. Apart from general findings about the distribution functions found in both classes of errors, their respective weight is determined, and implications for statistical hypothesis tests in benchmarking scenarios or regression analyses are demonstrated. The results are based on a rigorous comparison of five different detection methods under many different external conditions, such as size of the carrier, previous JPEG compression, and colour channel selection.

6072-07, Session 1

Compression-based steganalysis of LSB embedded images

C. G. Boncelet, Jr., Univ. of Delaware; L. M. Marvel, A. J. Raglin, Army Research Lab.

We present a new method of steganalysis, the detection of hidden messages, for least significant bits (LSB) replacement embedding. The method uses lossless image compression algorithms to model images bitplane by bitplane. The basic premise is that messages hidden by replacing LSBs of image pixels do not possess the same statistical properties and are therefore likely to be incompressible by compressors designed for images. In fact, the hidden data are usually compressed files themselves that may or may not be encrypted. In either case, the hidden messages are incompressible. In this work, we study three image compressors, one a standard and two we developed. The results are that many images can be eliminated as having possible steganographic content since the LSBs compress more than a hidden message typically would.

6072-08, Session 2

Natural language processing with linguistic information for digital fingerprinting and watermarking

O. Uzuner, Massachusetts Institute of Technology

Digital fingerprinting, watermarking, and tracking technologies gained visibility in the recent years in response to growing problems such as digital copyright infringement. While fingerprints and watermarks can be generated in many different ways, use of natural language processing for these purposes has so far been limited. We believe that natural language processing and linguistic information can be useful for accurate fingerprinting and watermarking.

Measuring similarities between literary works for automatic copyright infringement detection requires identifying and comparing creative expression of content. Expression refers to the way people convey

particular content; it captures both the information and the manner of its presentation. In this paper, we take a linguistic approach to automatically fingerprinting novels. We generate “expression fingerprints” that consist of both syntactic and semantic elements of language, i.e., syntactic and semantic elements of expression.

Syntactic and semantic elements of expression enable accurate fingerprinting of books and their paraphrases, providing a significant improvement over copy recognition techniques used in text classification literature. We believe that expression fingerprints can be used to label or otherwise watermark works; they identify those features that are essential to the character of works and that remain fairly consistent in the works even when works are paraphrased.

6072-09, Session 2

Attacks on linguistic steganography systems using text analysis

C. M. Taskiran, Motorola, Inc.; M. Topkara, E. J. Delp III, Purdue Univ.

Text data still forms the bulk of Internet traffic and other forms of data that people encounter daily. Being able to perform steganalysis for natural language text is more important than attacking steganography in images, audio or video data since it is much easier for users to manipulate text and have covert communication using text as the medium of carrier of information. Even though steganographic approaches for text has started to attract great interest, there has been no study on attacking these systems. In this paper we examine the robustness of some of the natural language steganography systems proposed in the literature to statistical text analysis attacks. In our study, we train SVMs based on several statistical features derived from text that correlate with textual style. Results and performance analyses are provided for a number of natural language steganography systems.

6072-10, Session 2

Natural language watermarking: research challenges and applications

M. Topkara, Purdue Univ.; G. Riccardi, D. Hakkani-Tür, AT&T Labs. Research; M. J. Atallah, Purdue Univ.

This paper discusses the results of experiments on an end-to-end “natural language processing based text watermarking system”. With natural language watermarking, we mean embedding the watermark into a text document, using the natural language components as the carrier, in such a way that the modifications are imperceptible to the readers and the embedded information is robust against possible attacks. Natural language watermarking is required when there is a need for meta-data binding on the text documents in such a way that the text and the meta-data are not separable. This meta-data can be anything from the owner of the document to the original physical features of the document. Even though being able to search and access immense amount of knowledge online has become a part of life, the owner or the authors of this digital text do not have control on how their data is distributed or re-used. Full control on the distribution of digital text can be provided through the use of natural language watermarking. In addition, natural language watermarking provides an integrity checking method that “travels with the content” when it is used or misused, which makes it very valuable for applications that involve private communication.

6072-11, Session 3

Scale estimation in two-band filter attacks on QIM watermarks

J. Wang, Technische Univ. Delft (Netherlands) and Nanjing Univ. (China); I. D. Shterev, R. L. Lagendijk, Technische Univ. Delft (Netherlands)

This paper presents a scheme for estimating two-band amplitude scale attack within a quantization-based watermarking context. Quantization-based watermarking schemes comprise a class of watermarking schemes that achieves the channel capacity in terms of additive noise attacks. Unfortunately, reliable watermark reception for these schemes is vulnerable to amplitude modification of the attacked host signal. The solutions proposed so far to deal with amplitude scale attack, in the framework of QIM watermarks, have been mainly focused on linear amplitude modification (fixed gain attack), or simple non-linear amplitude modification such as gamma correction. However, in practical watermarking applications, attacks are not constrained to the ones mentioned above. One particularly interesting class of attacks is Linear Time Invariant (LTI) filtering. We concentrate on a two-band amplitude scaling attack that modifies the spectrum of the signal using an analysis/synthesis filter bank. First we derive the probability density function (PDF) of the attacked data. Second, using a simplified approximation of the PDF model, we derive a Maximum Likelihood (ML) procedure for estimating two-band amplitude scaling factor. Finally, experiments are performed with real audio signals showing the good performance of the proposed estimation technique under realistic conditions.

6072-12, Session 3

High-rate quantization data hiding robust to arbitrary linear filtering attacks

F. Pérez-González, C. Mosquera, M. Alvarez-Diaz, Univ. de Vigo (Spain); R. L. Lagendijk, Technische Univ. Delft (Netherlands)

Rational Dither Modulation (RDM) is a high-rate data hiding method invariant to gain attacks. We propose an extension of RDM to construct a scheme that is robust to arbitrary linear time-invariant filtering attacks, as opposed to standard Dither Modulation (DM) which we show to be extremely sensitive to those attacks. The novel algorithm, named Discrete Fourier Transform RDM (DFT-RDM) basically works in the DFT domain, applying the RDM core on each frequency channel. This operation guarantees that each channel nearly behaves with respect to the watermark as an arbitrary complex gain. However, depending on the DFT size, among other factors, the filtering operation will distort the host components; this host-induced noise will typically be the major source of errors in the communication of the hidden bits. This effect is theoretically modeled in such a way that it is possible to predict and quantify the behavior of DFT-RDM facing filtering attacks. Closed-form upper and lower bounds to the bit error probability are also given. Increasing the DFT-size, windowing and projecting onto lower dimensional domains are proposed as three complementary ways of reducing the host-induced distortion and then improving performance.

Finally, we illustrate the practical feasibility of DFT-RDM by passing the watermarked signal through an implementation of the "Winamp" graphical equalizer: the error probability in many channels is small enough to justify the workability of adding a coding with interleaving layer to DFT-RDM.

6072-13, Session 3

Countermeasure for collusion attacks against digital watermarking

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NOTE: this is only the short abstract. the long version with figures is attached.

Customer identification watermarking today is one of the most promising application domains of digital watermarking. It enables to identify individual copies of otherwise indistinguishable digital copies. If done without any precautions, those individual watermarking are vulnerable to a number of specialized attacks based on an attacker collecting more than one individual copy. Fingerprinting algorithms are used to create watermarks robust against these attacks, but the resulting watermarks require a high payload of the watermarking algorithm. As soon as a large number of copies need to be distinguished and more than two copies are available to the attacker, the watermarks are too long to be embedded with current algorithms. We present a novel alternative method to fight attacks aimed at individual customer identification watermarks. This is achieved by modifying the watermarked material in a way collusion attacks produce artifacts which significantly reduce the perceived quality while they do not affect the quality of the individual copies.

6072-14, Session 3

The blind Newton sensitivity attack

P. Comesaña Alfaro, L. L. Pérez-Freire, F. Pérez-González, Univ. de Vigo (Spain)

The sensitivity attack is considered as a serious threat to the security of spread-spectrum-based schemes, since it provides a practical method of removing watermarks with minimum attacking distortion. This paper presents an overview of previous research and introduces a new method based on a general formulation. This new method, named the Blind Newton Sensitivity Attack, does not require any knowledge about the detection function nor any other system parameter, but just the binary output of the detector, being suitable for attacking most known watermarking methods; the soundness of this new approach is tested by attacking several of those methods.

6072-15, Session 3

Achieving non-ambiguity of quantization-based watermarking

X. Kang, Sun Yat-Sen Univ. (China) and New Jersey Institute of Technology; Y. Shi, New Jersey Institute of Technology; J. Huang, Sun Yat-Sen Univ. (China)

Ambiguity attack is to derive a valid watermark from a media to defeat the ownership claim of the real owner. Most of the research suggests that it is difficult to design a provably secure non-ambiguity watermarking without a trusted third party (TTP). Recently, Li and Chang² have provided a specific blind additive spread spectrum watermarking scheme as an example that was claimed to be provable non-ambiguity. However, it might be impractical because the watermarking needs the length of watermark $n > 3070,000,000$ according to our analysis. In our paper, a framework for quantization based schemes and non-blind spread spectrum watermarking scheme to achieve non-ambiguity is proposed. As a result, many of the existent watermarking schemes can achieve provable non-invertibility via using this framework. We have determined and analyzed the framework's false positive rate, and the conditions to achieve non-invertibility. The length of key of

pseudo random sequence generator is extended to $m=c*n$, so the cardinality of the valid watermark set is extended to 2^{c*n} , thus leading to more security to exhaustive searching attack than the Li and Chang's schemes, which has $m=\sqrt{n}$. Then we propose a noninvertible and robust quantization-based watermarking scheme. To our best knowledge, our work is the first to explore a practical watermarking schemes which is noninvertible without TTP and robust simultaneously.

6072-17, Session 4

Analyzing handwriting biometrics in metadata context

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Active biometrics like online handwriting have achieved a powerful position in user authentication systems recently. However, these new methods have not yet been researched in the context of metadata sufficiently. Here Metadata is used to describe the technical aspects of data acquisition environments well the biometric data's owner in particular. In this article we introduce a methodology that models personal metadata, implement a storing database and relate the metadata to features of handwriting data of differing cultural background. Biological information, along with cultural aspects like language skills and general experiences frame this personal metadata. Handwriting data collected in English language from German, Indian and Italian test subjects is evaluated with respect to accuracy for biometric user authentication. By relating the personal metadata to biometric handwriting features based on visual and dynamic parameters, impacts of the personal background to active biometrics are elaborated. For this purpose, hypotheses concerning usability and security aspects are formulated. Usergroups and settings of differing security environments including forgery scenarios are developed. By calculating and comparing Equal Error Rates (EER) the hypotheses are evaluated. This leads to distinct design recommendations for active biometric applications for usergroups of specific cultural background with respect to different aspired security levels.

6072-18, Session 4

3D face recognition by projection-based features

B. Sankur, H. Dutagaci, Bogaziçi Univ. (Turkey); Y. Yemez, Koç Univ. (Turkey)

In this paper, we investigate recognition performances of various projection-based features applied on registered 3D scans of faces. Some features are data driven, such as ICA-based features or NMF-based features. Other features are obtained using DFT or DCT-based schemes. We apply the feature extraction techniques to four different representations of registered faces, namely, 3D point clouds, 2D depth images, 3D voxel representations and 2D vertical slices. We consider both global and local features. Global features are extracted from the whole face data, whereas local features are computed over the blocks partitioned from 2D depth images or 3D voxel data representing the face. The block-based local features are fused both at feature level and at decision level. The resulting feature vectors are matched using L2 norm with or without applying Linear Discriminant Analysis. Experiments using different combinations of representation types and feature vectors are conducted on the 3D-RMA dataset.

6072-19, Session 4

Face biometrics with renewable templates

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This paper addresses a method for privacy protection of biometric templates from 2D face data. We use the so-called reliable component scheme. One of the key steps in this method is to derive binary feature vectors from the face data. We explain how the binary feature vectors can be derived and investigate their statistical properties. Experimental results for a subset of the FERET and Caltech databases show that there is only a slight degradation in classification results when using the binary rather than the real-valued feature vectors. Finally, the scheme to extract the binary vectors is combined with a helper data scheme leading to renewable and privacy preserving facial templates with acceptable classification results provided that the within-class variation is not too large.

6072-20, Session 4

Safety of templates in biometric person authentication using error-correcting code

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Recently, biometric person authentication has become a spotlight. However, in conventional biometric person authentication systems, each individual's template is stored as it is in the system. Hence, when a registered template is not properly protected, the risk of impersonation using biometric information restored due to template leakage by a third party arises. In this paper we propose a method whereby template information is either split or partly deleted, and restoration of the template by the desired individual is made possible by not using the registered template information only, but rather using error-correcting code. The proposed method can be applied to a general biometric authentication system. In this paper the safety of templates is evaluated by simulation of a speaker verification system.

6072-65, Session 4

Reference point detection for improved fingerprint matching

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One of the important stages of fingerprint recognition is the registration of the fingerprints with respect to the original template. This is not a straightforward task as fingerprint images may have been subject to rotations and translations. Popular techniques for fingerprint registration use a reference point to achieve alignment. The drawback of existing methods of core/reference point detection is their poor performance on rotated images. In this paper, we propose a new approach for rotation invariant and reliable reference point detection applicable to fingerprints of different quality and types. Our approach is based on the integration of a directional vector field (representing the doubled ridge orientations in fingerprints) over a closed contour. We define the reference point as the point of the highest curvature. Areas of high curvature in the fingerprint are characterized by large differences in the orientations and correspond to high curvatures in the directional vector fields. Closed contour integral of orientation vector field over a circle centered around the reference point corresponds to maximal closed curve integrals, and the values associated with such integrals are rotation invariant. Experimental results prove that with the proposed

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approach we can locate the reference point with high accuracy. Comparison with existing methods is provided.

6072-21, Session 5

On the comparison of audio fingerprints for extracting quality parameters of compressed audio

P. J. Doets, M. Menor Gisbert, R. L. Lagendijk, Technische Univ. Delft (Netherlands)

Audio fingerprints can be seen as hashes of the perceptual content of an audio excerpt. Applications include linking metadata to unlabeled audio, watermark support, and broadcast monitoring.

Existing systems identify a song by comparing its fingerprint to pre-computed fingerprints in a database. Small changes of the audio induce small differences in the fingerprint. The song is identified if these fingerprint differences are small enough. In addition, we found that distances between fingerprints of the original and a compressed version can be used to estimate the quality of the compressed version.

In this paper, we study the relationship between compression bit-rate and fingerprint differences. We present a comparative study of the response to compression using three fingerprint algorithms (each representative for a larger set of algorithms), developed by Philips, Polytechnic University of Milan, and Microsoft, respectively. We have conducted experiments both using the original algorithms and using versions modified to achieve similar operation conditions, i.e., the fingerprints use the same number of bits per second. Our study shows similar behavior for these three algorithms. If the variance of the response to compression within each algorithm can be reduced, fingerprint differences can indicate the quality of a compressed version of a song.

6072-22, Session 5

Fingerprinting with Wow

S. A. Craver, Binghamton Univ.

Wow, or time warping caused by speed fluctuations in analog audio equipment, provides a wealth of applications in watermarking. Very subtle temporal distortion has been used to defeat watermarks, and as components in watermarking systems. In the image domain, the analogous warping of an image's canvas has been used both to defeat watermarks and also proposed to prevent collusion attacks on fingerprinting systems. In this paper, we explore how subliminal levels of wow can be used for steganography and fingerprinting. We present both a low-bitrate robust solution and a higher-bitrate solution intended for steganographic communication. As already observed, such a fingerprinting algorithm naturally discourages collusion by averaging, owing to flanging effects when misaligned audio is averaged. Another advantage of warping is that even when imperceptible, it can be beyond the reach of compression algorithms. We use this opportunity to debunk the common misconception that steganography is impossible under "perfect compression."

6072-23, Session 6

Limited distortion in LSB steganography

Y. Kim, Z. Duric, D. Richards, George Mason Univ.

It is well known that all information hiding methods that modify the least significant bits (LSBs) introduce distortions into the cover objects. Those distortions have been utilized by steganalysis algorithms to detect that the objects had been modified. It has been proposed that only coefficients whose modification does not introduce large distortions should be used for embedding. In this paper we propose an efficient algorithm for hiding information in the

LSBs of JPEG coefficients. Our algorithm uses parity coding to choose the coefficients whose modifications introduce minimal additional distortion. We derive the expected value of the additional distortion using order statistics as a function of the message length and the probability distribution of the JPEG quantization errors of cover images. Our experiments show close agreement between the theoretical prediction and the actual additional distortion.

6072-24, Session 6

Multiclass blind steganalysis for JPEG images

J. Fridrich, T. Pevny, Binghamton Univ.

In this paper, we construct a blind steganalyzer for JPEG images that is also capable of classifying stego images to known steganographic programs. Each JPEG image is characterized using 23 calibrated features calculated from the luminance component. Most of these features are calculated directly from the quantized DCT coefficients as their first order and higher-order statistics. The features for cover images and stego images embedded using various JPEG steganography programs with three different relative message lengths are then used for supervised training. For the classifier, we use a Support Vector Machine with Gaussian kernel to construct a set of binary classifiers. The binary classifiers are then joined into a multi-class SVM using the Max-Win algorithm. We report results for six JPEG steganographic schemes (F5, OutGuess, Model based steganography, Model based steganography with deblocking, JP Hide&Seek, and Steghide). The main bulk of results is for single compressed images (avoiding double-compressed images in F5 and OutGuess). We also report some preliminary results for double-compressed images using F5 and OutGuess. This paper demonstrates that it is possible to reliably classify stego images to their embedding techniques. Moreover, this approach shows promising results for tackling the difficult case of double compressed images.

6072-25, Session 6

MPsteg: hiding a message in the matching pursuit domain

G. Cancelli, M. Barni, G. Menegaz, Univ. degli Studi di Siena (Italy)

In this paper we propose a new steganographic algorithm based on Matching Pursuit image decomposition. Many modern approaches to detect the presence of hidden messages are based on the analysis of higher-order statistical regularities. The idea behind this work is to adaptively choose the elements of a redundant basis to represent the host image. In this way, the image is expressed as the composition of a set of structured elements resembling basic image structures such as lines and flat regions. We argue that embedding the watermark at this, more semantic, level results in a lower modification of the low-level statistical properties of the image. Our conjecture is confirmed by experimental results obtained on a dataset of 400 images.

6072-26, Session 6

Stego sensitivity measure and multibit plane based steganography using different color models

S. S. Agaian, J. P. Perez, B. M. Rodriguez II, The Univ. of Texas at San Antonio

There are several steganographic methods that embed in palette-based images. In general these schemes are using RGB palette models. The restrictions of palette-based image formats impose limitations on existing models. For example, how to divide colors from a palette-vector for embedding purposes without causing

visual degradation to the image. Another important difficulty is how to embed using more bit planes while still preserving the images information. The possible solution to these problems could be: a) using a multi-bit embedding procedure; b) using other color models and c) embedding only in non-informative regions. Therefore we present a new secure high capacity palette based steganographic method used to embed in multiple bit planes using different color models. The performance of the developed algorithm will press the following advantages shown through experimental computer simulations: 1) BPCS Steganographic method for palette-based images 2) Provides additional security through a simple selective color and cover image algorithm. 3) The proposed method offers an increased capacity by embedding in multiple bit planes. 4) Finally, the secure media storage system contains an independent steganographic method that provides an additional level of security. The proposed method was proven to be immune to Chi-square and Pairs Analysis steganalysis attacks. In addition, when the presented method uses the YCbCr color model it was also immune to RS Steganalysis detection method.

6072-27, Session 7

Zero knowledge ST-DM watermarking

A. Piva, D. Corazzi, A. De Rosa, Univ. degli Studi di Firenze (Italy); M. Barni, Univ. degli Studi di Siena (Italy)

Recently the research in the watermarking field has concentrated its attention to the security aspects. In a watermarking application one of the most sensitive steps from the point of view of security, is the watermark extraction process: here, a prover has to prove to a verifier that a given watermark is present into the content. In the design of the system, it has to be considered that the prover is not a trusted party: the prover could try to exploit the knowledge acquired during watermark extraction to remove the embedded code and, consequently, to undermine the security of the watermarking system. To tackle this particular issue, it has been proposed to use some cryptographic techniques, defined zero-knowledge protocols, for building a secure layer on top of the watermarking channel, able to protect the watermarking algorithm against a possible information leakage. Up till now, zero-knowledge protocols have been applied to spread-spectrum based detectable watermarking algorithms. In this paper, a novel zero-knowledge protocol designed for a Spread Transform Dither Modulation (ST-DM) watermarking algorithm, belonging to the class of the informed watermarking systems, is proposed.

6072-28, Session 7

Compression and rotation resistant watermark using a circular chirp structure

C. E. Fleming, B. G. Mobasseri, Villanova Univ.

The increasing ease in which consumers can access, transfer, and manipulated digital media with watermarks impedes its aptitude to determine its ownership. While digital watermarks can be subjected to several attacks, geometric manipulation and more specifically rotation, is arguably one of the more difficult operations to survive. In addition, compression's manipulative effects should not be overlooked, since it is a common operation on digital media. Therefore, the subject of this work is the creation of a compression and rotation robust digital watermark. The spreading function used is a two-dimensional chirp. This spreading function's spectral characteristics are implemented to avoid JPEG compression's effects. Rotational resilience on the other hand, is achieved by implementing this spreading function in a polar form. The resulting watermark is a circular chirp, which is then subjected to a series of trials in an effort to tailor the watermark to its cover image and attain optimal results.

6072-29, Session 7

Rotation/scale insensitive spread spectrum image watermarking game

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Using electronic watermarks as copyright protection for still images requires robustness against geometrical attacks. In this paper we propose a watermarking scheme that is robust to rotation and scaling distortions. The watermark detection is performed in a 1-D invariant signature whereas the embedding process takes place in the DFT domain.

This embedding procedure allows the watermarking signal to be shaped in the frequency domain. This shaping is determined solving a game opposing the watermarker and the attacker. Statistically significant roc curve test results under several attacks are presented.

6072-30, Session 7

New results on robustness of secure steganography

M. T. Hogan, F. Balado, N. J. Hurley, G. C. M. Silvestre, National Univ. of Ireland/Dublin (Ireland)

Steganographic embedding is guided by two constraints at the encoder. Firstly, as in watermarking, all the codewords must conform to an average power constraint. Also, for the embedding to be statistically undetectable it is required that the density of the codebook must be equal to the density of the host signal. If this is not the case statistical steganalysis will have a probability of error less than 0.5. Recent work has shown that some common watermarking algorithms can be modified such that both conditions are met. In particular, spread spectrum (SS) communication can be secured by a specific scaling of the host before embedding. Also, a side informed scheme called Stochastic QIM (SQIM), maintains security with the use of an additive stochastic element during the embedding. In this work the robustness of both techniques is analysed under the AWGN channel assumption. It will be seen that the robustness of both schemes is lessened by the steganographic constraints, when compared to the standard algorithms on which they are based. Specifically, the probability of decoding error in the SS technique increases and the achievable rate of SQIM is shown to be lower than that of dither modulation.

6072-31, Session 7

Sphere-hardening dither modulation

F. Balado, N. J. Hurley, G. C. M. Silvestre, National Univ. of Ireland/Dublin (Ireland)

Spread-Transform Dither Modulation (STDM) is a side-informed data hiding method based on the quantization of a linear projection of the host. This projection affords a spreading gain which is exploited by Dither Modulation (DM). Similarly, it is possible to use to the same end the signal-to-noise ratio gain granted by the so-called sphere hardening effect on the norm of a random vector. In this paper we propose and describe Sphere-hardening Dither Modulation (SHDM), which is based on the application of DM to the magnitude of a host signal vector. We analyze its properties and we show that SHDM performs similarly as STDM in front of additive independent distortions, but with the particularity that this performance is achieved through noticeably different quantization regions. Indeed, the quantization hyperplanes which characterize STDM are replaced by quantization spheres in SHDM. This owes to the fact that SHDM can be seen as the side-informed counterpart of multiplicative SS with repetition coding in the same sense that STDM is the side-informed counterpart of additive SS with repetition coding. As

quantization spheres are only possible for some particular keys, we study the critical question of how to secure SHDM in a general case.

6072-32, Session 7

Secret dither estimation in lattice-quantization data hiding: a set membership approach

L. L. Pérez-Freire, F. Pérez-González, P. Comesaña Alfaro, Univ. de Vigo (Spain)

In this paper, security of lattice-quantization data hiding is considered under a cryptanalytic point of view. Security in this family of methods is implemented by means of a pseudorandom dither signal which randomizes the codebook, preventing unauthorized embedding and/or decoding. However, as it was theoretically shown in previous works dealing with scalar quantizers, the observation of several watermarked signals can provide sufficient information for an attacker willing to estimate the dither signal. We extend in this paper the theoretical analysis to the multidimensional case, and we show how set-membership estimation techniques can be successfully applied with low complexity to this scenario, providing accurate estimates of the dither using a small number of observed watermarked signals, highlighting this way the security weaknesses of lattice-quantization data hiding.

6072-33, Session 7

Performance analysis of nonuniform quantization-based data hiding

J. E. Vila-Forcén, S. V. Voloshynovskiy, O. J. Koval, T. Pun, Univ. de Genève (Switzerland)

The design of practical data-hiding methods is a complex task, which involves a trade-off among security, visibility and performance in terms of, for instance, the achievable rate of communications or corresponding probability of error for a fixed rate. Leaving the optimal solution to this trade-off outside of the scope of this paper, we will mostly concentrate on the maximization of the achievable rate as well as on the analysis of the error probability functions for the additive white Gaussian noise (AWGN) channel.

In the scope of this study, two classes of embedding methods are of particular interest: spread spectrum and quantization-based data-hiding techniques. It was demonstrated that the spread-spectrum data-hiding methods have superior performance versus the uniform-quantization-based data-hiding methods in terms of achievable rate and error probability at the low watermark-to-noise ratio (WNR) regime while the opposite is true for the high-WNRs.

Since no one technique provides optimal performance at all WNRs, to interchange between the different techniques is necessary. Still, in the middle-WNR we can observe a significant gap that remains to be closed in order to approach the capacity of the AWGN channel.

In this paper, we analyze the proposed nonuniform quantization data-hiding, demonstrating that a single technique achieves the optimal performance in terms of both achievable rate and error probability at all the WNRs.

6072-34, Session 8

Detecting digital image forgeries using sensor pattern noise

J. Lukas, J. Fridrich, M. Goljan, Binghamton Univ.

We present a new approach to detection of forgeries in digital images under the assumption that either the camera that took the image is available or other images taken by that camera are available. Our method is based on detecting the presence of the

camera pattern noise, which is a unique stochastic characteristic for all imaging sensors, in individual regions in the image. The forged region is determined as the one that lacks the pattern noise. The presence of the noise is established using correlation as in detection of spread spectrum watermarks. We proposed two approaches. In the first one, the user selects an area for integrity verification. The second method attempts to automatically determine the forged area without assuming any a priori knowledge. The methods are tested on examples of real forgeries. We also investigate how further image processing applied to the forged image, such as lossy compression or filtering, influences our ability to verify image integrity.

6072-35, Session 8

Fingerprinting digital elevation maps

H. Gou, M. Wu, Univ. of Maryland/College Park

Digital elevation maps (DEMs) provide a digital representation of 3-D terrain information. In commercial applications, high-precision DEMs carry a high commercial value owing to the large amount of effort in acquiring them; while in military applications, DEMs are often used to represent critical geospatial information in sensitive operations. These call for new technologies to prevent unauthorized distribution and to trace traitors in the event of information leak related to DEMs. In this paper, we propose a new digital fingerprinting technique to protect DEM data from illegal re-distribution. The proposed method enables reliable detection of fingerprints from both the 3-D DEM data set and its 2-D rendering, whichever format that is available to a detector. Our method starts with extracting from a DEM a set of critical contours corresponding to certain topographic features of the terrain. Fingerprints are then embedded into these critical contours by employing parametric curve modeling and spread spectrum embedding. Finally, a fingerprinted DEM is constructed to incorporate the marked 2-D contours. Through experimental results, we demonstrate the robustness of the proposed method against a number of challenging attacks applied to either DEMs or their contours.

6072-36, Session 8

Information embedding and extraction for electrophotographic printing processes

A. K. Mikkilineni, P. Chiang, G. T. Chiu, J. P. Allebach, E. J. Delp III, Purdue Univ.

Most current methods of embedding security features into a printed document modify the data before being sent to the printer and are thus limited to creating structures which can be resolved through a standard print process. On the other hand, our proposed methods will focus on modifying the actual print process. By moving the encoding to the hardware in the printer we gain more control over the type of marks which can be added to the document and also deter hacking or modification of the encoded data before it is printed. This embedded information will be referred to as the extrinsic signature of the document.

Embedding extrinsic features into the document requires knowledge of the specific print mechanism. During the past few years, many techniques to reduce banding artifacts have been successfully demonstrated by modulating various process parameters such as laser intensity/timing/pulse width (exposure modulation). These techniques can also be used to inject artificial banding signals that are not intrinsic to the printer.

Our research has focused on the amplitude modulation technique of exposure control because of the relative ease of its implementation. Because we have control over the laser voltage on each individual scan line, we are not limited to only sinusoidal signals as in the banding reduction case. We will explore various embedding techniques and also develop suitable detection algorithms.

6072-37, Session 8

An online system for classifying computer graphics images from natural photographs

T. Ng, S. Chang, Columbia Univ.

We describe an online system for classifying computer generated images from the camera-captured photographic images, as part of our effort in building a complete blind-passive system for image tampering detection. Users will be able to submit any image from a local or an online source to the system and get classification results with confidence scores. Specifically, we describe the important algorithmic issues involved for achieving satisfactory performances in both speed and accuracy. The online system includes the geometry-based classifier, which we recently proposed for addressing the problem of classifying photorealistic computer graphic (PRCG) and photographic images (PIM), in the context of passive-blind image forgery detection. Apart from being founded on the physics of the image formation processes, the geometry-based approach also shows better classification accuracy as compared to the approaches in the prior work. Besides the geometry classifier, our online system also showcases the wavelet and the cartoon classifier proposed in the prior work. In order to cope with the unconstrained types of input images, the online classifiers broaden the scope for the computer graphics class to include non-photorealistic computer graphics. One of the unique requirements for online detection engine is the speed; users prefer to have the test results returned in less than a few seconds. For such efficiency reason, we need to explore the pre-processing options of downsizing or cropping the input images. The reduction in the processed image area uniformly degrades the accuracy of the classifiers. To address the accuracy degradation, we propose a fusion method to leverage multiple complementary classifiers and boost the performance. We found such fusion approach to be advantageous as the ensemble fusion of classifiers is generally more effective on weak classifiers, which match the case of our classifiers due to the reduced area of the processed image. To prepare a sufficiently large pool of classifiers as input to the fusion process, we also generate an expanded set of weakened base classifiers by sub-partitioning of the training set. Our experiments have shown that the fusion strategy is able to improve the classification accuracy, reaching the original un-degraded accuracy level while enjoying a substantial speed-up in feature extraction. Such improvements are crucial for deploying an online test engine that is acceptable to public users. In addition to the online publicly accessible test engine, we also describe a publicly available benchmark data set which contains 3040 diverse images of both PRCG and PIM categories.

6072-38, Session 9

Text data-hiding for digital and printed documents: theoretical and practical considerations

R. Villan, Sr., S. V. Voloshynovskiy, O. J. Koval, J. E. Vila-Forcén, E. Topak, F. Deguillaume, Y. B. Rytsar, T. Pun, Univ. de Genève (Switzerland)

In this paper, we propose a new theoretical framework for the data-hiding problem of digital and printed text documents. We explain how this problem can be seen as an instance of the well-known Gel'fand-Pinsker problem. The main idea for this interpretation is to consider a text character as a data structure consisting of multiple quantifiable features such as shape, position, orientation, size, color, etc. We also introduce color quantization, a new semi-fragile text data-hiding method that is fully automatable, has high information embedding rate, and can be applied to both digital and printed text documents. The main idea of this method is to quantize the color of each character in such a manner that the human visual system is not

able to distinguish between the original and quantized characters, but it is possible for a specialized reader machine. We also describe halftone quantization, a related method that applies mainly to printed text documents. Since these methods may not be completely robust to printing and scanning, an outer coding layer is proposed to solve this issue. Finally, we describe a practical implementation of the color quantization method and present experimental results for comparison with other previously proposed methods.

6072-39, Session 9

E-capacity and security analysis of data-hiding channels with geometrical attacks

E. Topak, S. V. Voloshynovskiy, O. J. Koval, Univ. de Genève (Switzerland); M. E. Haroutunian, National Academy of Sciences of Armenia (Armenia); J. E. Vila-Forcén, T. Pun, Univ. de Genève (Switzerland)

In a data-hiding communications scenario, geometrical attacks lead to loss of reliable communications conditions due to synchronization problems when the applied attack is unknown. In the previous work, information-theoretic analysis of this problem was performed for theoretic setups, i.e., when the length of communicated data sequences asymptotically approaches infinity. Assuming that the applied geometrical attack is from a set of finite cardinality, it is demonstrated that it does not affect asymptotically the achievable rate contrarily to the scenario without any attack. The main goal of this paper is to investigate the upper and lower bounds on the rate reliability function that can be achieved in the data-hiding channel with some geometrical state. In particular, we investigate the random coding and sphere packing bounds in channels with random parameter for the case when the interference (channel state) is not taken into account at the encoder. Furthermore, only those geometrical transformations that preserve the input dimensionality and that do not necessitate an interpolation for their output are considered. For this case we are showing that similar conclusion obtained in the asymptotic case is valid, meaning that within the class of considered geometrical attacks the rate reliability function is bounded in the same way as in the case with no geometrical distortions.

6072-40, Session 9

Image data hiding based on capacity-approaching dirty-paper coding

Y. Yang, Y. Sun, V. Stankovic, Z. Xiong, Texas A&M Univ.

In this paper, we present a high-capacity image data-hiding scheme based on near-capacity dirty-paper codes. Our scheme operates in the DCT domain and modifies mid-frequency DCT coefficients among each DCT block. To reduce the perceptual distortion due to data hiding, the mid-frequency DCT coefficients are first perceptually scaled according to Watson's model. Then a rate-1/3 projection matrix in conjunction with a rate-1/5 capacity-approaching dirty-paper code is applied. Under the same simulation conditions, we are able to embed 1500 information bits into 256*256 images, besting the payload of the currently best known dirty-paper coding scheme by 33%. Robustness tests against attacks such as low-pass filtering, image scaling, and lossy compression show our scheme is a good candidate for high-capacity image data-hiding applications.

6072-41, Session 9

Wet paper codes with improved embedding efficiency

J. Fridrich, M. Goljan, D. Soukal, Binghamton Univ.

Wet paper codes were previously proposed as a general tool for construction of steganographic schemes in which the sender and the receiver do not have to share the knowledge about the location of embedding changes. This empowers the sender as now he is able to use an arbitrary side information, including a high-resolution version of the cover object (perturbed quantization steganography), local properties of the cover (adaptive steganography), and even pure randomness, e.g., coin flipping, for public key steganography. In this paper, we propose a new approach to wet paper codes using random linear codes of small codimension that at the same time improves the embedding efficiency (number of message bits embedded per embedding change). We describe practical algorithms, test their performance experimentally, and compare the results to theoretically achievable bounds. We point out an interesting "ripple" phenomenon that must be taken into account by practitioners. The proposed coding method can be modularly combined with most steganographic schemes to allow them to use non-shared selection channels and, at the same time, improve their security by decreasing the number of embedding changes.

6072-42, Session 10

New modulation-based watermarking technique for video

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Successful watermarking algorithms have been already developed for various applications ranging from meta-data tagging to forensic tracking. Nevertheless, it is commendable to develop alternative watermarking techniques that provide a broader basis for meeting emerging services, usage models and security threats. To this end, we propose a new multiplicative watermarking technique for video, which is based on the principles of our successful MASK audio watermark. In audio-MASK, we have embedded the watermark by modulating the short-time envelope of the audio signal. For detection, we have used a simple envelope detector followed by a SPOMF (symmetrical phase-only matched filter). In video-MASK, we take a similar approach and modulate the image luminance by a slowly varying envelope. We further control the watermark strength based on the luminance sensitivity of the human visual system. Along with a detailed description, we will present a theoretical model of the system with underlying assumptions and preliminary robustness and perceptual transparency tests in the conference.

6072-45, Session 11

Temporal synchronization of marked MPEG video frames based on image hash system

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Most of the MPEG watermarking schemes can only be embedded into I-frames. The other frames will not be marked. Different attacks like frame rate changing can change the frame type of the marked I-frames. Thus the watermark could be detected from wrong I-frames.

Dependent on these attacks an important issue of digital watermarking solutions for MPEG video is the temporal synchronization of the video material to the proportions before the attacks to detect the watermark successfully. The synchronization information can be embed as part of the information watermark or as a second watermark. The weakness point is with the destruction

of the synchronization information the watermark can not be detected more.

We provide a solution which analyzes the I-frames by a robust image hash system. The hash solution was developed for JPEG images and can also be used for MPEG I-frames because of their similar structure. The hash values are robust against common manipulations, like compression, and can be used to detect the marked frames also after manipulations at the video material. We present a new developed concept and the first results.

6072-46, Session 11

Towards robust compressed-domain video watermarking for H.264

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As H.264 digital video becomes more prevalent, the industry needs copyright protection and authentication methods that are appropriate for this standard. The goal of this paper is to propose a robust watermarking algorithm for H.264. To achieve this goal, we employ a human visual model adapted for a 4x4 DCT block to obtain a larger payload and a greater robustness while minimizing visual distortion. We use a key-dependent algorithm to select a subset of the coefficients with visual watermarking capacity for watermark embedding to obtain robustness to malicious attacks. Furthermore, we spread the watermark over frequencies and within blocks to avoid error pooling. The error pooling effect, introduced by Watson, has not been considered in previous perceptual watermarking algorithms. Our simulation results show that we can increase the payload and robustness while keeping the perceptual quality the same as previous algorithms by reducing this effect. We embed the watermark in the residuals to avoid decompressing the video, and to reduce the complexity of the watermarking algorithm. However, we extract the watermark from the decoded video sequence to make the algorithm robust to intra-prediction mode changes. Our simulation results shows that we obtain robustness to filtering, 50% cropping, and requantization attacks.

6072-47, Session 11

Selective encryption of low-complexity source coding for mobile terminals

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Selective encryption can be used to reduce the power consumed by the encryption function for digital content when the content is protected by digital rights management systems. Selective encryption is a technique to save computational complexity or enable interesting new system functionality by only encrypting a portion of a compressed bitstream while still achieve security. For selective encryption to work, we need to rely not only on the beneficial effects of redundancy reduction described by Shannon, but also on a characteristics of many compression algorithms to concentrate important data about reconstruction in a relatively small fraction of the compressed bitstream. These important elements of compressed data become candidates for selective encryption.

However, the selective encryption for distributed source coding has not been explored, and that is the focus of our research. In this paper, we combined the encrypting and compressing processes in distributed source coding to consider the choices of which types of bits are most effective in the selective encryption sense when they are changed. And so, instead of encrypting the whole video data bit by bit, we changed only these highly sensitive bits. Moreover, by combining the compression and encryption tasks and reducing the total encryption work required, we can achieve a savings in system complexity.

6072-48, Session 11

VLC pair tree: a paradigm for MPEG-2 watermarking

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Presented herein is a MPEG-2 watermarking algorithm which embeds watermark bits directly in the compressed domain. The algorithm provides high embedding rates while preserving both file-size and visual quality. At the same time, its bitstream implementation eliminates the need for full or even partial decompression thus making it ideal for real-time video applications. The embedding process is two-step and utilizes a unique method of variable length code (VLC) mapping. First, the video is parsed block-by-block identifying all VLC pairs which never occur together in any intra-coded block. This list of unused pairs is systematically generated by the intersection of "pair trees." The second step requires mapping one of the VLC pairs in a given block to one of the unused pairs. The resulting process generates a watermark block. Moreover, the watermarked video remains syntax compliant, meaning it conforms completely to the original MPEG standard, while simultaneously achieving maximum security at the decoder via a required secret key indicating the VLC pairs used for watermarking. Extensive results show that the watermarked video is reasonably resistant to forgery attacks and remains secure to watermark detection attempts. Testing included both standard videos and UAV video for authentication and metadata embedding applications.

6072-16, Session 12

On the fundamental tradeoff between watermark detection performance and robustness against sensitivity analysis attacks

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Despite their popularity, spread spectrum techniques have been proven to be vulnerable to sensitivity analysis attacks. Moreover, the number of detection operations needed by the attacker to estimate the watermark is simply linear in the size of the signal available to him. This holds not only for a simple correlation detector, but also for a wide class of detectors. Therefore there is a vital need for more secure detection methods. In this paper, we propose a randomized detection method that increases the robustness of spread spectrum embedding schemes. However, this is achieved at the expense of detection performance. For this purpose, we provide a framework to study the tradeoff between these two factors using classical detection-theoretic tools: large deviation analysis and Chernoff bounds. To gain more insight into the practical value of this framework, we apply it to image signals, for which good statistical models are available.

6072-49, Session 12

Information-theoretic analysis of electronic and printed document authentication

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Text documents are still the most common and almost unavoidable form of information communication among humans. Text documents are omnipresent everyday in the form of newspapers, books, web pages, contracts, advertisements, checks, identification documents, etc. At the same time, they can be widely distributed in the electronic form via Internet communications. Besides the high significance of the text documents, their copyright protection,

authentication and tracking still remain an open and challenging problem. That is why we formulate the main goal of this paper as information-theoretic study of theoretic limits of text document authentication in both electronic and printed forms. Trying to be as general as possible from the point of view of the used apparatus of information-theoretic analysis, we distinguish three main practical scenarios: (a) electronic document authentication: the documents are stored and converted only in electronic formats that is typical for Internet communications and database management; (b) hybrid electronic-analog document authentication: the documents are stored/communicated in electronic formats as well as can be printed in certain circumstances that is typical for research, education, small and medium business; (c) analog document authentication: the document final destination is only envisioned in analog (printed) form that is typical for large-scale industrial applications. We analyze the performance and consider the optimal design rules for these three scenarios.

6072-50, Session 12

Joint data hiding and source coding with partially available side information

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Channel Coding with Side Information at the encoder (CCSI) can be visualized as a blind watermarking problem: the original host signal for embedding the watermark is known at the encoder but not at the decoder. Similarly, the Rate Distortion with Side Information at the decoder (RDSI) is known as distributed source coding: the rate distortion limits of an input source if a noisy observation of that source is available only at the decoder. There is a strong duality between CCSI and RDSI.

This paper proposes a system that exploits the generalized versions of the two information theoretical dualities of CCSI and RDSI together within a unique setup. The question is "Can we combine these two separated dual problems (blind watermarking and distributed source coding) within a single problem?". The proposed scheme can be viewed as "Data Hiding within Distributed Source Coding". The setup contains the cascade of the generalized versions of CCSI and RDSI where there exist two side information; one is available only at the encoder and the other at the decoder. The preliminary experimental results are given using the theoretical findings of the duality problem.

6072-51, Session 12

Asymmetrically informed data-hiding optimization of achievable rate for Laplacian host

J. E. Vila-Forcén, O. J. Koval, S. V. Voloshynovskiy, E. Topak, T. Pun, Univ. de Genève (Switzerland)

In data-hiding based on the Costa setup, the issue of the achievable rate maximization is closely related to the problem of the host interference cancellation. The optimal host interference cancellation relies on the knowledge of the host realization and of the channel statistics (the additive white Gaussian noise (AWGN) variance) available at the encoder a priori to the transmission. This assumption can be rarely met in practical situations.

Another benchmarking strategy consists in the evaluation of the achievable rate in the AWGN channel assuming that its variance varies within a predefined interval. The encoder is assumed to have a fixed structure only optimal for the largest noise variance (the worst case scenario in the minimax formulation). However, a deviation from this variance value leads to a rate loss in performance

Contrarily to the Costa set-up attempting the encoder optimization for the particular state of the independent and identically distributed (i.i.d.) Gaussian attacking channel, we address the problem of

asymmetrically informed data-hiding optimal encoder design assuming that the interference probability density function is an i.i.d. Laplacian and the channel variance lies on some interval. The presented experimental results advocate the advantages of the developed embedding strategy.

6072-52, Session 12

Some theoretical aspects of watermarking detection

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This paper considers watermarking detection, also known as zero-bit watermarking. A watermark, carrying no hidden message, is inserted in host content. The watermark detector checks for the presence of this particular weak signal in the content. The paper aims at looking to this problem from a classical detection theory point of view, but with side information enabled at the embedding side. This means that the watermarking signal is a function of the host content. Our study is twofold. The first issue is to design the best embedding function for a given detection function (a Neyman-Pearson detector structure is assumed). The second issue is to find the best detection function for a given embedding function. This yields two conditions, which are mixed into one 'fundamental' differential equation. Solutions to this equation are optimal in these two senses. Interestingly, there are other solutions than the regular quantization index modulation scheme. The JANIS scheme, for instance, invented in a heuristic manner several years ago, is justified as it is one of these solutions.

6072-53, Session 12

A framework for the design of good watermark identification codes

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The fundamental difference between the data-hiding and watermark signature verification problems was highlighted in a 2001 paper by Steinberg and Merhav. In data hiding, the maximum number of messages that can be reliably decoded is essentially 2^{nC} , where n is the host sequence length and C is the data-hiding capacity. A dramatically different result is obtained for signature verification: in principle one can discriminate between a doubly exponential number of signatures: $2^{2^{nC}}$, where C is the identification capacity. This paper proposes a systematic design of codes for the latter application and compares the results with current designs in the literature. Our codes are obtained by concatenating QIM codes for the Modulo Lattice Additive Noise channel with hashing codes based on efficiently representable binary constant weight codes for a noiseless identification channel. Moreover, this family of codes is optimal in the sense that the identification capacity can be approached with arbitrary accuracy for large n .

6072-54, Session 13

Profiles for evaluation: the usage of audio WET

A. Lang, J. Dittmann, Otto-von-Guericke-Univ. Magdeburg (Germany)

The evaluation of digital watermarks has developed into an important research area. There are different types of attacks (geometric attacks, lossy compression, security or protocol attacks) available and often used to evaluate the robustness of digital watermarks. Furthermore, different attack strategies like single attacks or profile attacks are developed and useful for the evaluation process. During the evaluating of the watermarking algorithm, the

signal of the content and the embedded watermark is modified with the goal to remove or weaken the watermark information.

In this paper, the focus is set on audio signals. We classify the evaluation process of an existing benchmark service, the Audio Watermark Evaluation Testbed (Audio WET) by using five different audio watermarking algorithms, which work in time, frequency and wavelet domain. Therefore, we introduce basic, extended and application profiles which are used for evaluating watermarking algorithms. Whereas the basic profiles measure single properties on a watermarking algorithm, the extended and application profiles reflect real world application scenarios. Furthermore, the usage of Audio WET is introduced and a test scenario, test environment and test results for the evaluation of the five audio watermarking algorithms used are described.

6072-55, Session 13

A benchmark assessment of the WAUC watermarking audio algorithm

D. Megías Jiménez, J. Herrera-Joancomarti, J. Serra i Ruiz, J. Minguiellón Alfonso, Univ. Oberta de Catalunya (Spain)

This paper presents the WAUC digital audio watermarking scheme which relies on MPEG 1 Layer 3 compression to determine where and how the embedded mark must be introduced. The mark is embedded by modifying the magnitude of the spectrum at several frequencies which are chosen according to the difference between the original and the compressed audio content. The main advantage of the scheme is that the perceptual masking of the compressor is implicitly used and, thus, the scheme can be directly tested with different maskings by replacing the compressor. Since repeat coding of the mark is used, a majority voting scheme is applied to improve robustness. The scheme also uses a dual Hamming error correcting code for the embedded mark, which makes it possible to apply it for fingerprinting, achieving robustness against the collusion of two buyers. Several tuning parameters affect the embedding and reconstruction processes, the values of which are chosen according to the tuning guidelines obtained in previous works. In order to illustrate the robustness of the method, the WAUC scheme has been tested against several benchmarks, such as the StirMark Benchmark for Audio, MP3 compression attacks and, finally, the attacks introduced in the Watermark Evaluation Testbed (WET) for audio.

6072-56, Session 13

Transparency benchmarking on audio watermarks and steganography

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The evaluation of transparency plays an important role in the context of watermarking and steganography algorithms. This paper introduces a general definition of the term transparency in the context of steganography, digital watermarking and attack based evaluation of digital watermarking algorithms.

For this purpose the term transparency is first considered individually for each of the three fields of application (steganography, digital watermarking and watermarking algorithm evaluation). From the three results a general definition for the overall context is derived in a second step.

The relevance and applicability of the definition given will be evaluated in practice using existing audio watermarking and steganography algorithms (which work in time, frequency and wavelet domain) as well as an attack based evaluation suite for audio watermarking benchmarking - StirMark for Audio (SBMA).

For this purpose selected attacks from the SBMA suite are modified by adding transparency enhancing measures using a psychoacoustic model. The transparency and robustness of the evaluated audio watermarking algorithms by using the original and

modified attacks are compared. Results for the evaluation are presented and discussed in detail. In a conclusion the relevance of this definition for IT-security considerations will be indicated.

6072-57, Session 13

Shape quality measurement for 3D watermarking schemes

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Shape quality assessment is a new challenge for a wide set of 3-D graphics applications and particularly for emerging 3-D watermarking schemes. In order to measure distortions new metrics have to be drawn between an original 3-D surface and its deformed version. These metrics are necessary to determine whether a deformation is perceptually acceptable and therefore whether this deformation should be considered while testing the robustness of a 3-D watermarking scheme.

In this paper, we propose an objective metric based on the comparison of 2-D projections of the deformed and original versions of the shape. Rendering conditions are carefully specified as they play a key role on the human perception of the 3-D object. We compare the behaviours of this objective metric and of state-of-the-art metrics to subjective human perception for a set of deformations caused by 3-D watermarking schemes and usual 3-D watermarking attacks on several 3-D meshes. The protocol of these subjective psychovisual experiments is presented in detail. We discuss these experimental results for the purpose of the benchmarking of 3-D watermarking schemes.

6072-58, Session 13

Reliability engineering approach to digital watermark evaluation

H. C. Kim, E. J. Delp III, O. Guitart, E. J. Delp III, Purdue Univ.

Robust watermarks are evaluated in terms of image fidelity and robustness. We extend this framework and apply reliability testing to robust watermark evaluation. Reliability is the probability that a watermarking algorithm will correctly detect or decode a watermark for a specified fidelity requirement under a given set of attacks and images. In reliability testing, a system is evaluated in terms of quality, load, capacity and performance. To measure quality that corresponds to image fidelity, we compensate for attacks to measure the fidelity of attacked watermarked images. We use the conditional mean of pixel values to compensate for valumetric attacks such as gamma correction and histogram equalization. To compensate for geometrical attacks, we use error concealment and perfect motion estimation assumption. We define capacity to be the maximum embedding strength parameter and the maximum data payload. Then, load is defined to be the actual embedding strength and data payload of a watermark. To measure performance, we use Bit Error Rate (BER) and Receiver Operating Characteristics (ROC) and area under the curve (AUC) of the ROC curve of a watermarking algorithm for different attacks and images. We evaluate robust watermarks for various quality, loads, attacks, and images.

6072-59, Session 13

New functionalities in watermark evaluation testbed (WET)

O. Guitart, H. C. Kim, E. J. Delp III, Purdue Univ.

While Digital Watermarking has received much attention within the academic community and private sector in recent years, it is still a relatively young technology. As such there are few accepted tools/metrics that can be used to validate the performance claims asserted by members of the research community and evaluate the

suitability of a watermarking technique for a specific application. This lack of a universally adopted set of metrics/methods has motivated us to develop a web-based digital watermark evaluation system called the Watermark Evaluation Testbed or WET. This system has undergone several improvements since the first version. The ultimate goal of this work has always been to develop a platform, where any watermarking researcher can test not only the performance of known techniques, but also their own developed techniques. This goal has been reached by the last version of the system where some new tools and concepts are used to achieve the desired improvements and its full description is provided in the paper. Moreover, we also summarize the developing process of the whole project as well as introduce new ideas for future steps. We feel that these improvements will allow watermarking researchers to demonstrate how new techniques are moving forward the state of the art.

6072-60, Session 14

Protection and governance of MPEG music player MAF contents using MPEG-21 IPMP tools

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MPEG (Moving Picture Experts Groups) are currently standardizing Multimedia Application Format (MAF) which targets to provide simple but useful and practical multimedia applications to the industry. The MAF aims at combining many existing well-known technologies as a single application format so that more added values can be offered to the industry. In this paper, we apply our idea of providing a protection mechanism to one of the ongoing MAFs called the Music Player MAF. The Music Player MAF repacks the MP3 song together with JPEG image(s) and also a complete metadata so that more advanced applications with added functionalities of music search by metadata and music album in JPEG images can be deployed faster in music and player device manufacturing industry. The proposed protection mechanism shall allow various protection tools to be used in the protection. This is possible by adopting the MPEG-21 IPMP (Intellectual Property Management and Protection) by which we can signal the tools that are used in a standard way. In our implementation, we show how the form of the signaling description of the protection and also how our proposed technology can be easily synchronized to all three file formats of Music Player MAF. By doing so, the applied protection fulfill three important requirements: flexibility, extensibility, and granularity.

6072-61, Session 14

Watermarking of 3D objects based on 2D apparent contours

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We propose a new approach to watermark 3D objects via contour information. Unlike most conventional 3D object watermarking techniques, for which both insertion and extraction of the mark are performed on the object itself (3D/3D approach), we propose in this paper an asymmetric 3D/2D procedure. This procedure consists of inserting the mark on the 3D object but being able to retrieve it from 2D views.

Given a known 3D object consisting of a geometric definition (represented by 3D polygonal meshes), to insert the mark, we first fix a number of k characteristic viewing angles and we extract corresponding 3D silhouettes. Second, we insert some information on extracted contours to get watermarked 3D object. To detect the mark from a given 2D suspicious view, we compute its (2D) contour, which will be compared to the previously extracted 3D silhouettes in order to select the most suitable one (i.e. the one which is the most

similar after projection to the suspicious 2D contour). The selected silhouette is then considered to check the presence or not of the watermark.

The proposed approach is important as it is usually more frequent to locate and recover suspect images (obtained after projection of 3D objects) than 3D object itself: as soon as the 3D object is displayed or inserted on a video, only one or several projection are still available.

6072-62, Session 14

Quality assessment of watermarked 3D polygonal models

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We present the design and results of subjective tests for evaluating the perceptibility of digital watermarks in 3D polygonal models. Based on the results we investigate different types of metrics with respect to their usefulness as predictors for the perceived visual quality of models that have been modified using a specific watermarking algorithm.

Two experiments with models that have been watermarked using controlled free form deformations (Benedens, 2002) are described. The first experiment was conducted in supervised mode with still images of rendered models as stimuli and used the Two Alternative Forced Choice (2AFC) method. The second experiment was based on animated sequences and run in 2AFC mode with additional ratings of the perceived differences, but without assistance by the experimenter.

We present a transparency analysis of the results and investigate the ability of image-based and geometry-based metrics to predict the perceived quality of the watermarked models. Our results show that the effectiveness of prediction depends on the type of model and in particular on the feature positions selected by the watermarking algorithm.

6072-63, Session 14

Reducing the processing time of the hierarchical watermark detector when applied to unmarked images

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In this paper, we improve the performance of the hierarchical detector we previously proposed for real-time software or low-cost hardware implementation. Although the original hierarchical detector is faster than sub-sampled brute force-base detector when processing marked images, it unnecessarily continues to process unmarked images looking for a watermark that is not present. This processing is time-consuming; hence, it represents a significant deployment obstacle. The improved detector, however, avoids most of the processing of the unmarked areas of an image by exploiting the presence of a reference signal usually included with the embedded watermark. This reference signal enables the detector to synchronize the image after it has been subjected to a geometric transformation (scaling, rotation, and translation). The improved detector refrains from searching an image area any further whenever the level of the reference signal is very weak or the estimated scale factors and rotation angles associated with this reference signal are not consistent among the processed blocks within the same layer in the hierarchy. The proposed detector has been implemented, and the experimental results indicate that the proposed detector is computationally more efficient with unmarked images, while achieving a detection rate similar to that of the original hierarchical detector.

6072-64, Session 15

Exploring QIM-based anti-collusion fingerprinting for multimedia

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Digital fingerprinting is an emerging class of technologies to protect multimedia from unauthorized use by embedding a unique fingerprint into each user's copy. Robust embedding technique, such as through spread spectrum embedding, is an important building block of a fingerprinting system to make fingerprints resistant to various distortions. In this paper, we explore the use of another class of embedding methods, the Quantization Index Modulation (QIM), for fingerprinting applications. We first extend the existing binary QIM technique to embed multiple symbols by constructing different dither sequences. We then develop a generalized theoretical model and show that the collusion resistance performance of the fingerprinting scheme can be enhanced by reducing the correlation between the fingerprints. Based on our analysis, we introduce an improved QIM fingerprinting scheme that reduces the correlation between fingerprints and thus achieves better performance. Simulation results show that the improvement algorithm enhances the collusion resistance, while there is still a performance gap with the existing spread spectrum based fingerprinting. We analyze the reasons for this gap and identify possible directions to further examine QIM based fingerprinting.

6072-66, Session 15

Sheet music fingerprinting based on graphical representation

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Research and development of perceptual hashing or fingerprinting methods has been focused on audio content, images and video content. Although printed music scores can be considered as an image, perceptual hashing methods for images cannot be applied to music scores.

Nevertheless there are applications which require the identification of printed sheet music or the digital representation thereof. For example, music scores publishers are strongly interested in the identification of plagiarisms or the prevention of illegal distribution of their content.

This article presents our approach for developing a perceptual hashing algorithm for printed sheet music. This algorithm extracts simple graphical features for each staff. Our first implementation, which is described in this article, is based on graphical envelopes and projections.

We discuss the individual steps that are required to result in a compact representation. The obtained algorithm - respectively the fingerprint - is evaluated using a large collection of music scores in terms of its robustness and discrimination performance. The evaluation results show that the developed method for identification of printed sheet music performs well for not or slightly distorted sheet music. Hence in the conclusion and outlook our next steps and further improvements are described.

6072-67, Session 15

A web-oriented and interactive buyer-seller watermarking protocol

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Digital watermarking is considered a main technology for the copyright protection of multimedia digital contents distributed on the Internet. However, for watermarking procedures to be able to give an effective support to copyright protection processes, they have to be

applied by employing specific watermarking protocols, which define the scheme of the interactions that have to take place among the entities involved in the content protection and distribution. To this end, many proposals concerning with watermarking protocols are able to attain several important achievements, such as the correct authentication of buyers without exposing their identities during the purchase web transactions and the capability of resorting to trusted watermark certification authorities in order to ensure a copyright protection process able to correctly take into account the rights of both buyers and sellers. However, these protocols are often not suited to be adopted in web contexts, where buyers are usually neither provided with digital certificates issued by trusted certification authorities nor able to autonomously perform particular security actions to purchase digital contents distributed by web content providers. This paper presents a watermarking protocol able to overcome the drawbacks affecting the major proposals existing in literature. To this end, the protocol has been developed by following a novel design approach able to make the protocol well suited to be adopted in web contexts.

6072-68, Session 16

Matrix embedding for large payloads

J. Fridrich, D. Soukal, Binghamton Univ.

Matrix embedding is a general coding method that can be applied to most steganographic schemes to improve their embedding efficiency—the number of message bits embedded per one embedding change. Because smaller number of embedding changes is less likely to disrupt statistic properties of the cover object, schemes that employ matrix embedding generally have better steganographic security. This gain is more important for long messages than for shorter ones because longer messages are easier to detect. Previously introduced approaches to matrix embedding based on Hamming codes are, however, not efficient for long messages. In this paper, we present novel matrix embedding schemes that are efficient for embedding messages close to the embedding capacity. One is based on a family of codes constructed from simplex codes and the second one on random linear codes of small dimension. We describe pseudo-codes for practitioners and evaluate the embedding efficiency with respect to theoretically achievable bounds.

6072-69, Session 16

Simple reversible watermarking schemes: further results

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This paper continues the researches on a recently proposed reversible watermarking approach based on an integer transform defined for pairs of pixels. The transform is invertible and, besides, for some pairs of pixels, the original values are recovered even if the LSBs of the transformed pixels are overwritten. Two watermarking schemes, a simple one and a modified version, have been developed. At detection, original image is exactly recovered by using a map which locates the transformed pairs and the LSBs of the unchanged pairs of pixels. The main contribution of this paper is the generalization of the transform for groups of n pixels. Transforming groups larger than 2 pixels, the size of the map decreases and thus, the hiding capacity of the scheme can increase. In this general context, it appears that the behavior of the transform depends on the parity of n , namely n even is more appropriate for reversible watermarking. It is also shown that, for groups greater than 4, the simple scheme and the modified one give very similar data hiding capacity, i.e., the performance of the modified scheme is obtained at the extremely low computational cost of the simple scheme.

6072-70, Session 16

A new watermark detector for spread-spectrum based image watermarking using underdetermined independent component analysis framework

H. M. Malik, A. A. Khokhar, R. Ansari, Univ. of Illinois at Chicago

This paper presents a novel blind watermark detection/decoding scheme for spread spectrum (SS) based image watermarking, exploiting the fact that in SS-based embedding schemes the embedded watermark and the host image are mutually independent and obey non-Gaussian distribution. The proposed scheme employs the theory of independent component analysis (ICA) and poses the watermark estimation as a blind source separation problem. The proposed blind watermark detector uses underdetermined blind source separation based independent component analysis framework for watermark estimation from the watermarked image. The mean field theory based undetermined blind source separation scheme is used for watermark estimation. Analytical results are presented showing that the proposed detector performs significantly better than the existing correlation based blind detectors traditionally used for SS-based image watermarking. The paper also shows that the detection performance approaches to that of an informed detector as interference due to the host signal in the estimated watermark approaches to zero. The proposed ICA-based blind detection/decoding scheme has been simulated using real-world digital images. The simulation results show that the ICA-based detector can detect and decode watermark with extremely low decoding bit error probability against common image watermarking attacks and benchmark degradations.

6072-71, Session 16

Optimal detector for an additive watermarking scheme based on human auditory system

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One requirement for audio watermarking is that the embedded watermark should be imperceptible and does not alter the audio signal quality. To achieve this goal, existing audio watermarking methods use a power constraint or more sophisticated human auditory system (HAS) models for the embedding of the watermark. At the detection side, these methods use pre-processing algorithms (for example Wiener and inverse filtering) to remove the masking filter effect and limit host signal effect. Then, the correlation detector, which is the Maximum Likelihood (ML) optimal detector, is applied considering Gaussian assumption for the signals. In this paper we have derived a new ML detector assuming a Weibull distribution for the modulus of the Discrete Fourier Transform of the signal received at the detection side. Performances of the new Weibull ML detector in the presence of noise addition, cropping, level modifications and AAC coding are given and compared to those of the classical Gaussian ML detector. The experimental results reveal that the new ML detector performs significantly better than the classical detector, especially for desynchronisation by cropping.

6072-72, Session 16

A hypothesis testing approach for achieving semi-fragility in multimedia authentication

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This paper studies the problem of achieving watermark semi-fragility in multimedia authentication through a composite hypothesis testing approach. The embedding of a semi-fragile watermark serves to distinguish legitimate distortions caused by signal processing manipulations from illegitimate ones caused by malicious tampering. This leads us to consider authentication verification as a composite hypothesis testing problem with the watermark as a priori information. Based on the hypothesis testing model, we investigate the best embedding strategy which assists the watermark verifier to make the correct decision. Our results show that the quantization-based watermarking method is more appropriate than the spread spectrum method to achieve the best tradeoff between two error probabilities. This observation is confirmed by a case study of additive Gaussian white noise channel with Gaussian source using two figures of merit: relative entropy of the two hypothesis distributions and the receiver operating characteristic. Finally, we focus on certain common signal processing distortions such as JPEG compression and image filtering, and investigate the best test statistic and optimal decision regions to distinguish legitimate and illegitimate distortions. The results of the paper show that our approach provides insights for authentication watermarking and allows better control of semi-fragility in specific applications.

6072-73, Session 16

A DWT-based robust semi-blind image watermarking algorithm using two bands

E. Elbasi, A. M. Eskicioglu, The City Univ. of New York

Robustness of a watermark embedded into an image is the ability to detect it after intentional attacks and normal audio/visual processes. A recent DWT image watermarking paper embeds a PRN sequence as a watermark in three bands, excluding the low pass subband, using coefficients that are higher than a given threshold T_1 . During watermark detection, all the coefficients higher than another threshold T_2 ($T_2 \geq T_1$) are chosen for correlation with the original watermark. In this paper, we extend the idea to embed the same watermark in two bands (LL and HH). Our experiments show that for one group of attacks (i.e., JPEG compression, resizing, adding Gaussian noise, low pass filtering, and rotation), the correlation with the real watermark is higher than the threshold in the LL band, and for another group of attacks (i.e., histogram equalization, contrast adjustment, gamma correction, and cropping), the correlation with the real watermark is higher than the threshold in the HH band. As the DWT coefficients in the LL band are higher than the DWT coefficients in the HH band, for each band we use a smaller scaling factor for the lower band, and larger T_1 and T_2 values.

6072-74, Session 16

Evaluating the visual quality of watermarked images

A. Shnayderman, A. M. Eskicioglu, The City Univ. of New York

A recent image quality measure, M-SVD, can express the quality of distorted images either numerically or graphically. Based on the Singular Value Decomposition (SVD), it consistently measures the distortion across different distortion types and within a given distortion type at different distortion levels. The SVD decomposes every real matrix into a product of three matrices $A = USVT$, where U and V are orthogonal matrices, $UTU = I$, $VTV = I$ and $S = \text{diag}(s_1, s_2,$

...). The diagonal entries of S are called the singular values of A , the columns of U are called the left singular vectors of A , and the columns of V are called the right singular vectors of A . M-SVD, as a graphical measure, computes the distance between the singular values of the original image block and the singular values of the distorted image block, where $n \times n$ is the block size. If the image size is $k \times k$, we have $(k/n) \times (k/n)$ blocks. The set of distances, when displayed in a graph, represents a "distortion map." The numerical measure is derived from the graphical measure. It computes the global error expressed as a single numerical value. In this paper, we will extend the SVD-based image quality measure to evaluate the visual quality of watermarked images using several watermarking schemes.

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6073-31, Poster Session

A tree-based paradigm for content-based video retrieval and management

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A tree-based structure is built for video retrieval system in this paper. Such retrieval can be characterised via two approaches, top-down and bottom up. While top down is to divide the input videos into shot layer and key-frame layer to allow temporal and spatial analysis, the bottom-up is to analyse all the key frames and shots via low-level image processing techniques and pattern recognition to extract high level information towards extracting semantic knowledge rules for content based video retrieval and management. Our contribution so far can be summarised as: (a) successful construction of the semantic tree structure with two layers, shot layer and key-frame layer; (b) our proposed shot cut detection and key-frame extraction outperforms existing techniques, which ensures that the tree structure derived is able to accurately characterize the input video content; (c) a paradigm is now in place, where some low-level content-based video retrieval can be carried out without significant extra work. Based on this structure, a video database can be managed efficiently for its indexing and retrieval.

6073-32, Poster Session

Tangible interactive system for document browsing and visualization of multimedia data

Y. B. Rysar, S. V. Voloshynovskiy, O. J. Koval, F. Deguillaume, E. Topak, Univ de Genève (Switzerland); S. Startchik, Anteleon Imaging (Switzerland); T. Pun, Univ. de Genève (Switzerland)

In this paper we introduce and develop a framework for document interactive navigation in large multimodal databases. First, we analyze the main open issues of existing multimodal interfaces and then discuss two applications that include interaction with documents in several human environments, i.e., the so-called smart rooms. Second, we propose a system set-up dedicated to the efficient navigation in the printed documents. This set-up is based on the fusion of data from several modalities that include images and text. Both modalities can be used as cover data for hidden indexes using data-hiding technologies as well as source data for robust visual hashing. The particularities of the proposed robust visual hashing are described in the paper. Finally, we address two practical applications of smart rooms for tourism and education and demonstrate the advantages of the presented solution. The proposed system considerably enriches material presentation and enhances the flexibility of the information update as well as facilitates the access to various multimedia data. Moreover, no additional data embedding is needed since this tangible interactive system can be applicable for already existing printed materials. Additionally, the system remains extremely simple in use and does not need any special user training or expensive equipment.

6073-33, Poster Session

Semantic segmentation of video collections using boosted random fields

B. Janvier, E. Bruno, S. Marchand-Maillet, T. Pun, Univ. de Genève (Switzerland)

The problem of semantic video structuring is vital for automated management of large video collections. The goal is to automatically extract from the raw data the inner structure of a video collection ; so that a whole new range of applications to browse and search video collections can be derived out of this high-level segmentation. To reach this goal, we exploit techniques that consider the full spectrum of video content ; it is fundamental to properly integrate technologies from the fields of computer vision, audio analysis, natural language processing and machine learning. In this paper, a multimodal feature vector providing a rich description of the audio, visual and text modalities is first constructed. Boosted Random Fields are then used to learn two types of relationships : between features and labels as for traditional classifiers and between the association of labels to capture contextual information of the various modalities for an improved consistency of the results. The parameters of this enhanced model are found iteratively by using two successive stages of Boosting. We experimented using the TRECvid corpus and show results of a large scale evaluation that validate the contextual approach over existing studies.

6073-34, Poster Session

Annotating 3D contents with MPEG-7 for reuse purposes

I. M. Bilasco, J. Gensel, M. Villanova-Oliver, H. Martin, Institut d'Informatique et Mathématiques Appliquées de Grenoble (France)

The continuous evolution of computer capacities and the emergence of the X3D standard have recently boosted the 3D domain. Still, lot of resources are needed to properly create and to manage 3D objects. In order to speed up the construction of new 3D objects, the reuse of existing objects is to be considered.

The pure geometric description of 3D scenes does not provide sufficient criteria for retrieving and reusing 3D data. Adding some semantics to 3D objects can fill up this gap.

We proposes a generic semantic annotation model for 3D, called 3DSEAM (3D SEmantics Annotation Model). 3DSEAM considers visual, geometric, topological and semantic features of 3D data. These features can be indexed and then combined in order to formulate complex queries.

In order to offer a large visibility to our model we propose a MPEG-7 instantiation of 3DSEAM. We describe a set of 3D-specific localisation descriptors. 3D objects can then be considered as common pieces of multimedia content inside MPEG-7 frameworks. Hence, all media sharing the same 3D scene: images and videos (textures), sounds (environment) and 3D objects (shapes and geometry) can be indexed and annotated in an uniform manner using a unique framework.

6073-35, Poster Session

Multimedia for art retrieval (M4ART)

E. L. van den Broek, Vrije Univ. Amsterdam (Netherlands); T. Kok, T. E. Schouten, E. Hoenkamp, Radboud Univ. Nijmegen (Netherlands)

The prototype for an online Multimedia for Art ReTRieval (M4ART) system is introduced, that provides entrance to the digitized collection of the National Gallery of the Netherlands (the Rijksmuseum). The current online system of the Rijksmuseum is text-based and requires expert knowledge concerning the work searched for, else it fails in retrieving it. M4ART extends this system by allowing the user to query with an example image that can be uploaded, or to select it by browsing the collection. The global color distribution of the example image, and perhaps a set of texture features, are then extracted and compared with those of the images in the collection. Thus, the collection can be queried based on text as well as content-based features. Moreover, the matching process of M4ART can be scrutinized. With this feature, M4ART not only integrates the means to give expert and lay equal access to the system, it also lets the user understand the system's inner workings. These qualities make M4ART unique in its ability to let the user access, enhance, and retrieve the knowledge available in digitized art collections.

6073-36, Poster Session

Application of image visual characterization and soft feature selection in content-based image retrieval

K. Jarrah, I. Lee, Ryerson Univ. (Canada); M. J. Kyan, The Univ. of Sydney (Australia); L. Guan, Ryerson Univ. (Canada)

Fourier descriptors (FFT) and Hu's seven moment invariants (HSMI) are among the most popular shape-based image descriptors and have been used in various applications, such as recognition, indexing, and retrieval. In this work, we propose to use the invariance properties of HSMI, as shape feature descriptors, for relevance identification in content-based image retrieval (CBIR) systems. The purpose of relevance identification is to find a collection of images that are statistically similar to, or match with, a query image from within a large visual database. The automatic relevance identification module in the search engine is structured around an unsupervised learning algorithm, the self-organizing tree map (SOTM). In this paper we have also proposed a new ranking function in the structure of the SOTM that exponentially ranks the retrieved images based on their similarities with respect to the query image. Furthermore, we propose to extend our studies to optimize the contribution of individual feature descriptors through a weight detection process for enhancing the retrieval results.

6073-37, Poster Session

Video shot retrieval using a kernel derived from a continuous HMM

A. Velivelli, T. S. Huang, Univ. of Illinois at Urbana-Champaign; A. G. Hauptmann, Carnegie Mellon Univ.

In this paper, we propose a discriminative approach for retrieval of video shots characterized by a sequential structure. The task of retrieving shots similar in content to a few positive example shots is more close to a binary classification problem. Hence, this task can be solved by a discriminative learning approach. For a content-based retrieval task the twin characteristics of rare positive example occurrence and a sequential structure in the positive examples make it attractive for us to use a learning approach based on a generative model like HMM. The properties of both generative and discriminative classifiers are combined by using a Fisher score kernel. This kernel is derived from a continuous HMM and is incorporated into the SVM classification framework. A test set video

shot is ranked based on its proximity to the positive class side of hyperplane. A new kernel called Modified score kernel is also derived from a continuous HMM. The aim of the Modified score kernel is to increase the rank of the positive examples which are at lower ranks for a Fisher score kernel. We evaluate the performance of the derived kernels by retrieving video shots of airplane takeoff. The retrieval performance using the derived kernels is found to be much better compared to linear and RBF kernels.

6073-38, Poster Session

Moving camera moving object segmentation in an MPEG-2 compressed video sequence

J. Wang, Wanye State Univ.; N. Patel, W. Grosky, Univ. of Michigan/Dearborn

In the paper, we address the problem of camera and object motion detection in compressed domain. The estimation of camera motion and the moving object segmentation have been widely stated in a variety of context for video analysis, because they are capable of providing essential clues for interpreting high-level semantic meanings of video sequences. A novel compressed domain motion estimation and segmentation scheme is presented and applied in this paper. The proposed algorithm uses MPEG-2 compressed motion vectors to undergo a spatial and temporal interpolation over several adjacent frames. An iterative rejection scheme based upon the affine model is exploited to effect global camera motion detection. The foreground spatiotemporal objects are separated from the background using the temporal consistency check to the output of the iterative segmentation. This consistency check process can help conglomerate the resulting foreground blocks and weed out unqualified blocks. Illustrative examples are provided to demonstrate the efficacy of the proposed approach.

6073-39, Poster Session

Visual object categorization with indefinite kernels in discriminant analysis framework

S. Kosinov, S. Marchand-Maillet, Univ. de Genève (Switzerland)

This work focuses on the application of indefinite kernels in multimedia processing applications illustrated on the problem of content-based digital image analysis and retrieval. The term "indefinite" here relates to kernel functions associated with non-metric distance measures that are known in many applications to better capture perceptual similarity defining relations among higher level semantic concepts. This paper describes a kernel extension of distance-based discriminant analysis method whose formulation remains convex irrespective of the definiteness property of the underlying kernel. The presented method deploys indefinite kernels rendered as unrestricted linear combinations of hyperkernels to approach the problem of visual object categorization. The presented approach has been implemented as an iterative routine for minimization of a regularized discriminative criterion, each iteration of which involves solving a 2-stage convex quadratic minimization problem. The proposed method of indefinite kernel distance-based discriminant analysis has been tested on the task of visual object categorization demonstrating significant improvement relative to the baseline technique, as well as encouraging overall performance among alternative discriminant analysis methods considered.

6073-01, Session 1

Blind summarization: content adaptive video summarization using time-series analysis

A. Divakaran, R. Radhakrishnan, K. A. Peker, Mitsubishi Electric Research Labs.

Severe complexity constraints on consumer electronic devices motivate us to investigate video summarization techniques that are able to apply a common hardware setup to multiple content genres. We present a time-series analysis based video summarization technique that provides a general core to which we are able to add small content-specific extensions for each genre. The proposed time-series analysis technique consists of unsupervised clustering of samples taken through sliding windows from the time series of features obtained from the content. We classify content into two broad categories, scripted content such as news, and unscripted content such as sports. The summarization problem then reduces to finding either finding semantic boundaries of the scripted content or detecting highlights in the unscripted content. We thoroughly examine the trade-off between content-neutral and content-specific processing for effective summarization for a number of genres, and find that our core technique enables us to minimize the complexity of the content-specific processing and to postpone it to the final stage. We achieve the best results with unscripted content such as sports and surveillance video in terms of quality of summaries and minimizing content-specific processing. For other genres such as drama, we find that more content-specific processing is required.

6073-02, Session 1

Multilevel analysis of sports video sequences

J. Han, D. Farin, P. H. N. de With, Technische Univ. Eindhoven (Netherlands)

We propose a fully automatic and flexible framework for analysis and summarization of tennis broadcast video sequences, using visual features and specific game-context knowledge. Our framework can analyze a tennis video sequence at three levels, which provides a broad range of different analysis results. The proposed framework includes novel pixel-level and object-level tennis video processing algorithms, such as a moving-player detection taking both the color and the court (playing-field) information into account, and a player-position tracking algorithm based on a 3-D camera model. Additionally, we employ scene-level models for detecting events, like service, base-line rally and net-approach, based on a number of real-world visual features. The system can summarize three forms of information: (1) all court-view playing frames in a game, (2) the moving trajectory and real-speed of each player, as well as relative position between the player and the court, (3) the semantic event segments in a game. The proposed framework is flexible in choosing the level of analysis that is desired. It is effective because the framework makes use of several visual cues obtained from the real-world domain to model important events like service, thereby increasing the accuracy of the scene-level analysis. The paper presents attractive experimental results highlighting the system efficiency and analysis capabilities.

We have seen that the player segmentation and tracking steps are the most time-consuming part of our system. This can be reduced significantly by eliminating the background reconstruction for every processed frame. In the near future, we will include audio-analysis functions into our sports content-analysis system. Also, the system may be extended to analyze other sport types, like volleyball, badminton and basketball, since several techniques, such as court detection, camera calibration, player segmentation and high-level analysis, are generally applicable.

6073-03, Session 1

Automated editing of medical training video via content analysis

A. C. Kokaram, The Univ. of Dublin, Trinity College (Ireland); K. Andrews, Univ. of the West Indies (Trinidad and Tobago); D. Ring, The Univ. of Dublin, Trinity College (Ireland); C. Lee, Royal College of Surgeons in Ireland (Ireland)

Physicians in the early part of their training inevitably undertake a course in Anatomy. Unfortunately, the amount of training medical students have with real bodies has decreased. This is further exacerbated with the increasing gap between numbers of medical students and resources available. Medical faculties worldwide are increasingly turning to video training sessions as a complement to practical sessions. This paper presents a number of automated content access and enhancement tools which have been designed to alleviate the difficulty of editing these sessions. The system is being deployed at the Royal College of Surgeons in Ireland.

6073-04, Session 2

Statistical model and error analysis of a proposed audio fingerprinting algorithm

E. P. McCarthy, F. Balado, N. J. Hurley, G. C. M. Silvestre, Univ. College Dublin (Ireland)

In this paper we present a statistical analysis of a particular audio fingerprinting method proposed by Haitsma et al. Due to the excellent robustness and synchronisation properties of this particular fingerprinting method, we would like to examine its performance for varying values of the parameters involved in the computation and ascertain its capabilities. For this reason, we pursue a statistical model of the fingerprint (also known as a hash, message digest or label). Initially we follow the work of a previous attempt made by Doets and Lagendijk to obtain such a statistical model. By reformulating the representation of the fingerprint as a quadratic form, we present a model in which the parameters derived by Doets and Lagendijk may be obtained more easily. Furthermore, our model allows further insight into certain aspects of the behaviour of the fingerprinting algorithm not previously examined. Using our model, we then analyse the probability of error (P_e) of the hash. We identify two particular error scenarios and obtain an expression for the probability of error in each case. We present three methods of varying accuracy to approximate P_e following Gaussian noise addition to the signal of interest. We then analyse the probability of error following desynchronisation of the signal at the input of the hashing system and provide an approximation to P_e for different parameters of the algorithm under varying degrees of desynchronisation.

6073-05, Session 2

An application of weighted transducers to music information retrieval

D. Basaldella, N. Orio, Univ. degli Studi di Padova (Italy)

This paper presents a methodology for retrieving music documents using a query by example paradigm. The basic idea is that a collection of music documents can be indexed by the set of melodic contours. In this context, a contour is defined as a sequence of notes in a music document, described by their pitch and duration. Retrieval is carried out using an approximate matching between query and document contours, which is based on the use of Weighted Transducers. Each contour in the document collection is modeled by different transducers, which are used to compute the similarity between the query contours and the models in the collection. The individual contributions to the computation of the similarity between the query contours and the documents models are combined according a weighting scheme inspired by the TF-IDF

measure for text document retrieval. The methodology has been evaluated on a small collection of music documents and with a set of audio queries. Experimental results highlighted that contour representation of music allow us to build an archive of models whose size is sublinear on the number of music documents in the collection. The results in terms of retrieval effectiveness are encouraging.

6073-06, Session 2

Video scene retrieval with symbol sequence based on integrated audio and visual features

K. Morisawa, N. Nitta, N. Babaguchi, Osaka Univ. (Japan)

In this paper, we propose a method to retrieve semantically similar scenes to a query video from large scale video databases at high speed.

Our method uses the audio features and the color histogram as the visual feature because the audio signal is closely related with the semantic content of videos and the color is an extensively used feature for content-based image retrieval systems.

The feature vectors are extracted from video segments called packets and clustered in the feature vector space and transformed into symbols that represent the cluster IDs.

Consequently, a video is expressed as a symbol sequence based on audio and visual features.

Quick retrieval of similar scenes can be realized by symbol sequence matching.

We conduct some experiments using audio, visual, and both features, and examine the effect of each feature on videos of various genres.

6073-07, Session 2

Físchlár-DiamondTouch: collaborative video searching on a table

A. F. Smeaton, H. Lee, C. Foley, S. McGivney, C. Gurrin, Dublin City Univ. (Ireland)

In this paper we present the system we have developed for our participation in the annual TRECVID benchmarking activity.

More specifically the Físchlár-DT system was developed for participation in the interactive search task of TRECVID 2005. Our back-end search engine uses a combination of a text search which operates over the automatic speech recognised text, and an image search which uses low-level image features matched against video keyframes. The two novel aspects of our work are the fact that we are evaluating collaborative, team-based search among pairs of users working together, and that we are using a novel touch-sensitive tabletop interface and interaction device known as the DiamondTouch to support this collaborative search. The paper summarises the backend search systems as well as presenting the interface we have developed, in detail.

6073-08, Session 3

Mind the gap: another look at the problem of the semantic gap in image retrieval

J. S. Hare, P. H. Lewis, Univ. of Southampton (United Kingdom); P. Enser, C. Sandom, Univ. of Brighton (United Kingdom)

This paper attempts to review and characterise the problem of the semantic gap in image retrieval and the attempts being made to bridge it. In particular, we draw from our own experience in user queries, automatic annotation and ontological techniques. The first section of the paper describes a characterisation of the semantic

gap as a hierarchy between the raw media and full semantic understanding of the media's content. The second section discusses real users' queries with respect to the semantic gap. The final sections of the paper describe our own experience in attempting to bridge the semantic gap. In particular we discuss our work on auto-annotation and semantic-space models of image retrieval in order to bridge the gap from the bottom up, and the use of ontologies, which capture more semantics than keyword object labels alone, as a technique for bridging the gap from the top down.

6073-09, Session 3

Evaluation of strategies for multiple sphere queries with local image descriptors

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Here, we are interested in the fast retrieval, in a large collection of points in high-dimensional space, of points close to a set of m query points (a multiple query). It has been argued that beyond a rather small dimension ($d > 10$) for such queries, sequentially scanning the collection of points is faster than crossing a tree structure indexing the collection (the so-called curse of dimensionality phenomenon). Our first contribution is to experimentally assess whether the curse of dimensionality is reached with various points distributions. We compare the performance of a single sphere query when the collection is indexed by a tree structure (an SR-tree in our experiments) to that of a sequential scan. The second objective of this paper is to propose and evaluate several algorithms for multiple queries in a collection of points indexed by a tree structure. We compare the performance of these algorithms to that of a naïve one consisting in sequentially running the m queries. This study is applied to content-based image retrieval where images are described by local descriptors based on points of interest. Such descriptors involve a relatively small dimension (8 to 30) justifying that the collection of points be indexed by a tree structure; similarity search with local descriptors implies is usually time expensive, justifying our proposal.

6073-10, Session 3

PARIS: a MPEG-7 spatial and temporal referenced personal photograph library

P. Kuo, M. Ito, T. Aoki, H. Yasuda, The Univ. of Tokyo (Japan)

The proliferation of image devices such as digital video camera, digital camera and mobile phone camera enable individuals to capture continuous shots for life events with almost no additional cost. Consequently, consumers began to accumulate hundreds of photographs when travel to new locations or during special events. We argue that people make more photographs while they visit some new locations or during special events. And hence spatial and temporal attributes of personal digital photographs could contain the most relevant context information. Personal photograph collections have very different characteristics compare with traditional commercial stock image collections, which were normally used for image retrieval researches. Hence, organizing, archiving, and retrieving personal photograph collections also require different approaches.

PARIS (Personal Archiving and Retrieving Image System) is an experiment personal photograph library, which includes more than 80,000 of consumer photographs accumulated within a duration of approximately five years, metadata based on our proposed MPEG-7 annotation architecture, Dozen Dimensional Digital Content (DDDC), and a relational database structure. The DDDC architecture is specially designed for facilitating the managing, browsing and retrieving of personal digital photograph collections. In annotating process, we also utilize a proposed Spatial and Temporal Ontology

(STO) designed based on the general characteristic of personal photograph collections.

While previous researches had tried to enable semi-automatic event segmentation based on the recorded time tags from most recent image devices, our research emphasizes a novel approach which utilizes integrated spatial and temporal information. Extended from the StructuredAnnotation Basic Tool of MPEG-7 Multimedia Description Schemes (MDS), we propose a semantic description tool of multimedia content. The proposed content description tool annotates multimedia data with twelve main attributes regarding its semantic representation. The twelve attributes include answers of who, what, when, where, why and how (5W1H) the digital content was produced as well as the respective direction, distance and duration (3D) information. We define digital multimedia contents including image, video and music embedded with the proposed semantic attributes as Dozen Dimensional Digital Content (DDDC).

Investigation on the experiment library shows that there is a strong association between the image context and its respective spatial and temporal clues. Based on this assumption, we experimentally started with specific Domain Ontology of popular tourist stops such as the city of Paris, Tokyo and New York based on their respective spatial and temporal attributes. A more detailed explanation of our proposed Spatial and Temporal Ontology concept can be found in the full paper.

PARIS system is constructed in conjunction with AVR project, Advanced Video Retrieval, a Japan Government funded three year project. While the AVR project explores novel methodologies for multimedia content retrieval including video, audio and image, PARIS system targets on personal photograph collection retrieval in particular. We will also illustrate the AVR architecture in the full paper.

6073-11, Session 3

2+2=5: painting by numbers

C. C. Venters, Univ. of Manchester (United Kingdom); R. J. Hartley, Manchester Metropolitan Univ. (United Kingdom); W. T. Hewitt, Univ. of Manchester (United Kingdom)

Is query by visual example an intuitive method for visual query formulation or merely a prototype framework for visual information retrieval research that cannot support the rich variety of visual search strategies required for effective image retrieval? This paper reports the results of an investigation that aimed to explore the usability of the query by paint method in supporting a range of information problems. While the results show that there was no significant difference, $p > 0.001$, on all four measures of usability, query by paint was considered by this sample not to support visual query expression. It was also observed that the usability of the query method combined with the mental model of the information problem affected both visual query expression and retrieval results. This has important implications for the efficacy and utility of content-based image retrieval as a whole and there is an increasing need to examine the usefulness of query methods and retrieval features in context.

6073-12, Session 4

Structuring continuous video recordings of everyday life using time-constrained clustering

W. Lin, A. G. Hauptmann, Carnegie Mellon Univ.

As personal wearable devices become more powerful and ubiquitous, soon everyone will be capable to continuously record video of everyday life. The archive of continuous recordings needs to be segmented into manageable units so that they can be efficiently browsed and indexed by any video retrieval systems. Many researchers approach the problem in two-pass methods:

segmenting the continuous recordings into chunks, followed by clustering chunks. In this paper we propose a novel one-pass algorithm to accomplish both tasks at the same time by imposing time constraints on the K-Means clustering algorithm. We evaluate the proposed algorithm on 62.5 hours of continuous recordings, and the experiment results show that time-constrained clustering algorithm substantially outperforms the unconstrained version.

6073-13, Session 4

Practical life log video indexing based on content and context

D. Tancharoen, T. Yamasaki, K. Aizawa, The Univ. of Tokyo (Japan)

Today, multimedia information has gained an important role in daily life and people can use imaging devices to capture their visual experiences. In this paper, we present our personal Life Log system to record personal experiences in form of wearable video and environmental data; in addition, an efficient retrieval system is demonstrated to recall the desirable media. We summarize the practical video indexing techniques based on Life Log content and context to detect talking scenes by audio/visual cues and semantic key frames from GPS data. Voice annotation is also demonstrated as a practical indexing method. Moreover, we apply body media sensors to record continuous life style and use body media data to index the meaningful key frames. In the experiments, we demonstrated various video indexing results which provide their semantic contents and showed Life Log visualizations to examine personal life experiences effectively.

6073-14, Session 4

Multimedia for mobile users: image-enhanced navigation

S. Gautam, G. Sarkis, E. Tjandranegara, E. Zekowitz, Y. Lu, E. J. Delp III, Purdue Univ.

As mobile systems (such as laptops and mobile telephones) continue growing, navigation assistance and location-based services are becoming increasingly important. Existing technology allow mobile users to access Internet services (e.g. email and web surfing), simple multimedia services (e.g. music and video clips), and make telephone calls. However, the potential of advanced multimedia services has not been fully developed, especially multimedia for navigation or location based services.

At Purdue University, we are developing an image database, known as LAID, in which every image is annotated with its location, compass heading, acquisition time, and weather conditions. LAID can be used to study several types of navigation problems: A mobile user can take an image and transmit the image to the LAID sever. The server compares the image with the images stored in the database to determine where the user is located. We refer to this as the "forward" navigation problem. The second type of problem is to provide a "virtual tour on demand." A user inputs a starting and an ending addresses and LAID retrieves the images along a route that connects the two addresses. This is a generalization of route planning. Our database currently contains over 20000 images and covers approximately 25% of the city of West Lafayette, Indiana.

6073-15, Session 5

Semantic classification of business images

B. Erol, J. J. Hull, Ricoh Innovations, Inc.

Digital cameras are becoming increasingly common for capturing information in business settings. In this paper, we describe a novel method for classifying images into the following semantic classes: document, whiteboard, business card, slide, and regular images. Our method is based on combining low-level image features, such as text color, layout, and handwriting features with high-level OCR

output analysis. Several Support Vector Machine Classifiers are combined for multi-class classification of input images. The system yields 95% accuracy in classification.

6073-16, Session 5

Region labeling using a point-based coherence criterion

H. Houissa, N. Boujemaa, INRIA Rocquencourt (France)

Query By Visual Example (QBVE) has been widely exploited in image retrieval. Global visual similarity as well as points of interest matching have proven their efficiency when example image/region is available. If starting image is missing, the Query By Visual Thesaurus (QBVT) paradigm offsets it by allowing the user to compose his mental query image through visual patches summarizing the region database. In this paper, we propose to enrich the paradigm of mental image search by constructing a reliable visual thesaurus of the regions provided by a new coherence criterion. Our criterion encapsulates the local distribution of detected points of interest within a region. It leads to semantic labelling of regions into homogenous and textured categories using points spatial topology. Our point-based criterion has been validated on a generic image database combining homogenous regions as well as irregularly and fully textured patterns.

6073-17, Session 5

BlobContours: adapting Blobworld for supervised color- and texture-based image segmentation

T. Vogel, D. N. Quyen, J. Dittmann, Otto-von-Guericke-Univ. Magdeburg (Germany)

Extracting features is the first and one of the most crucial steps in recent image retrieval process. While color and texture features of digital images can be extracted rather easily, shape features and layout features depend on reliable image segmentation. Unsupervised image segmentation, often used in image analysis, works on merely syntactical basis. To obtain high-level objects, which is desirable in image retrieval, human assistance is needed. Supervised image segmentations schemes can improve the reliability of segmentation and segmentation refinement. In this paper we propose an interactive image segmentation technique that combines the reliability of a human expert with the precision of automated image segmentation. The iterative procedure can be considered a variation on the Blobworld algorithm introduced by Carson et al. from EECS Department, University of California, Berkeley. Starting with an initial segmentation as provided by the Blobworld framework, our algorithm, namely BlobContours, gradually updates it by recalculating every blob, based on the original features and the updated number of Gaussians. Since the original algorithm has hardly been designed for interactive processing we had to consider additional requirements for realizing a supervised segmentation scheme on the basis of Blobworld.

6073-18, Session 6

Subjective assessment of consumer video summarization

C. Forlines, K. A. Paker, A. Divakaran, Mitsubishi Electric Research Labs.

The immediate availability of a vast amount of multimedia content has created a growing need for improvements in the field of content analysis and summarization. While researchers have been rapidly making contributions and improvements to the field, we must never forget that content analysis and summarization themselves are not the user's goals. Users' primary interests fall into one of two

categories; they normally either want to be entertained or want to be informed (or both). Summarization is therefore just another tool for improving the entertainment value or the information gathering value of the video watching experience. In this paper, we first explore the relationship between the viewer, the interface, and the summarization algorithms. Through an understanding of the user's goals and concerns, we present means for measuring the success of the summarization tools. Guidelines for the successful use of summarization in consumer video devices are also discussed.

6073-19, Session 6

Evaluation of video summarization systems

C. M. Taskiran, Motorola, Inc.

Compact representations of video data, or video summaries, greatly enhances efficient video browsing. However, rigorous evaluation of video summaries generated by automatic summarization systems is a complicated process. In this paper we examine the summary evaluation problem. Text summarization is the oldest and most successful summarization domain. In this paper, we show some parallels between these to domains and introduce methods and terminology. Finally, we present results for a comprehensive evaluation summary that we have performed.

6073-20, Session 6

Subjective evaluation criterion for selecting affective features and modeling highlights

L. Xing, H. Yu, Q. Huang, Graduate School of the Chinese Academy of Sciences (China); Q. Ye, Chinese Academy of Sciences (China); A. Divakaran, Mitsubishi Electric Research Labs.

In this paper, we propose a subjective evaluation criterion which is a guide for selecting affective features and modeling highlights. Firstly, the database of highlights ground truth is established, and both the randomness of the data set and preparation of the subjects are considered. Secondly, commonly used affective features including visual, audio and editing features are extracted to express the highlights. Thirdly, subjective evaluation criterion is proposed base on the analysis of the average error method and pairwise comparisons method, especially the rationality of this criterion in our specific application is explained clearly according to the three detailed issues. Finally, evaluation experiments are designed on tennis and table tennis as examples. Based on the experiments, we conclude that: 1) the commonly used affective features are correlated; 2) the effective combination of affective features is MPEG-7 motion vector average, cheer duration, excited speech duration and event duration; 3) the highlights model is approximately linear. It proves that previous works on affective features and linear highlights model are effective. Furthermore, 82.0% (79.3%) affective accuracy is obtained fully automatically by computer which is a marvelous highlights ranking result. This result shows the subjective evaluation criterion is well designed for selecting affective features and modeling highlights.

6073-21, Session 6

Evaluation and user studies with respect to video summarization and browsing

M. G. Christel, Carnegie Mellon Univ.

The Informedia group at Carnegie Mellon University has since 1994 been developing and evaluating surrogates, summary interfaces, and visualizations for accessing digital video collections containing thousands of documents, millions of shots, and terabytes of data. This paper surveys the Informedia user studies that have taken place through the years, reporting on how these studies can provide a user pull complementing the technology push as automated video processing advances. The merits of discount usability techniques

for iterative improvement and evaluation are presented, as well as the structure of formal empirical investigations with end users that have ecological validity while addressing the human computer interaction metrics of efficiency, effectiveness, and satisfaction. The difficulties in evaluating video summarization and browsing interfaces are discussed. Lessons learned from Informedia user studies are reported with respect to video summarization and browsing, ranging from the simplest portrayal of a single thumbnail to represent video stories, to collections of thumbnails in storyboards, to playable video skims, to video collages with multiple synchronized information perspectives.

6073-22, Session 7

Semantic feature extraction with multidimensional hidden Markov model

J. Jiten, B. Meriardo, B. Huet, Eurécom Institute (France)

Conventional block-based classification is based on the labeling of individual blocks of an image, disregarding any adjacency information. When analyzing a small region of an image, it is sometimes difficult even for a person to tell what the image is about. Hence, the drawback of context-free use of visual features is recognized up front.

This paper studies a context-dependant classifier based on a two dimensional Hidden Markov Model. In particular we explore how the balance between structural information and content description affect the precision in a semantic feature extraction scenario. We train a set of semantic classes using the development video archive annotated by the TRECVID 2005 participants. To extract semantic features the classes with maximum a posteriori probability are searched jointly for all blocks. In the conclusion we present how the performance varies with block size and number of Gaussians per mixture.

6073-23, Session 7

Rotation and translation invariant feature extraction using angular projection in frequency domain

B. Lee, M. Kim, Information and Communications Univ. (South Korea)

This paper presents a new approach to translation and rotation invariant texture feature extraction for image texture retrieval. For the rotation invariant feature extraction, we invent angular projection along angular frequency in Polar coordinate system. The translation and rotation invariant feature vector for representing texture images is constructed by the averaged magnitude and the standard deviations of the magnitude of the Fourier transform spectrum obtained by the proposed angular projection. In order to easily implement the angular projection, the Radon transform is employed to obtain the Fourier transform spectrum of images in the Polar coordinate system. Then, angular projection is applied to extract the feature vector. The paper present the experimental results to show the robustness against the image rotation and the discriminatory capability for different texture images using MPEG-7 data set. The experiment result shows that the proposed rotation and translation invariant feature vector is effective in retrieval performance for the texture images with homogeneous, isotropic and local directionality.

6073-24, Session 7

Invariant region descriptors for robust shot segmentation

A. Arasanathan, N. Canagarajah, Univ. of Bristol (United Kingdom)

The identification of shots is an important task in the content based analysis of video sequences. Accurate shot detection is essential to

enable meaningful high level video database operations like indexing, annotation, retrieval and semantic description. Regardless of the vast number of approaches in the literature, a robust cut detection algorithm, which works with all kind of video sequences, is still a challenging problem. In this paper, a highly accurate shot cut detection method is presented. The algorithm is based on the concept of local invariant region descriptors which is a novel approach. Compared to previous approaches the proposed method is highly robust to camera and object motions and can withstand severe illumination changes and spatial editing. The validity of the method is established first by testing with different kinds of video sequences, and then by demonstrating superior performance compared to existing methods. Furthermore the approach can be extended to an automatic video annotation and retrieval system as invariant region descriptors gives promising results in applications like content based retrieval, wide baseline stereo and object recognition and localization in recent years.

6073-25, Session 8

A video processing method for convenient mobile reading of printed barcodes with camera phones

C. H. Bäckström, C. Södergård, VTT Information Technology (Finland); S. Udd, UPC Consulting Ltd. (Finland)

Efficient communication requires an appropriate choice and combination of media. The print media has succeeded to attract audiences also in our electronic age because of its high usability. However, the limitations of print are self evident. By finding ways of combining printed and electronic information into so called hybrid media, the strengths of both media can be obtained. In hybrid media, paper functions as an interface to the web, integrating printed products into the connected digital world. This is a "reinvention" of printed matter making it into a more communicative technology. Hybrid media means that printed products can be updated in real time. Multimedia clips, personalization and e-shopping can be added as a part of the interactive medium.

The concept of enhancing print with interactive features has been around for years. However, the technology has been so far too restricting - people don't want to be tied in front of their PC's reading newspapers. Our solution is communicative and totally mobile. A code on paper or electronic media constitutes the link to mobility.

By appropriate selection of image analysis methods it is possible to implement a 2D barcode decoding application using a mobile platform. The algorithms are optimized for speed, performance and other properties. A real time software solution is considered feasible on a mobile platform. The robustness of the proposed solution is deemed to be satisfactory for everyday use. The solution provides independence of shadows, rotation and perspective distortion. The software extends the use of camera cell phone, transforming it to an information terminal at no additional cost.

6073-26, Session 8

Flexible surveillance system architecture for prototyping video content analysis algorithms

R. Wijnhoven, Bosch Security Systems B.V. (Netherlands); E. G. T. Jaspers, P. H. N. de With, LogicaCMG (Netherlands)

Many proposed video content analysis algorithms for surveillance applications are very computationally intensive, which limits the integration in a total system, running on one processing unit (e.g. PC). To build flexible prototyping systems of low cost, a distributed system with scalable processing power is therefore required. Requirements for surveillance systems are discussed, considering

two example applications. The first is the face-recognition case, where object tracking results are used in the detection step. The second application is the resolution enhancement using a static camera and a pan-tilt-zoom camera. From these requirements, specifications for a prototyping architecture are derived. An implementation of the proposed architecture is presented, enabling mapping of multiple software modules onto a number of processing units (PCs). The architecture enables fast prototyping of new algorithms for complex surveillance applications without considering resource constraints.

6073-27, Session 8

Motion-based parsing for video from observational psychology

A. C. Kokaram, E. Doyle, D. Lennon, L. Joyeux, R. Fuller, The Univ. of Dublin, Trinity College (Ireland)

In Psychology it is common to conduct studies involving the observation of humans undertaking some task. The sessions are typically recorded on video and used for subjective visual analysis. The subjective analysis is tedious and time consuming, not only because much useless video material is recorded but also because subjective measures of human behaviour are not necessarily repeatable. This paper presents tools using content based video analysis that allow automated parsing of video from one such study involving Dyslexia. The tools rely on implicit measures of human motion that can be generalised to other applications in the domain of human observation. Results comparing quantitative assessment of human

6073-28, Session 9

Occlusion costing for multimedia object layout in a constrained window

S. Widdowson, Hewlett Packard Labs.

We propose a novel method for applying image analysis techniques, such as saliency map generation and face detection, to the creation of compelling image layouts. The layouts are designed to maximize the use of available real estate by permitting images to partially occlude one another or extend beyond the boundaries of the window, while retaining the majority of visual interest within the photo and deliberately avoiding objectionable visual incongruities. Optimal layouts are chosen from a candidate set through the calculation of a cost function called the occlusion cost. The basic form of the occlusion cost is applied to candidate layout sets where the sizes of the images are fixed with respect to the window. The area-compensated form of the occlusion cost permits a more general solution by relaxing the fixed-size constraint, and allowing each image to scale with respect to both the frame and the other images. Finally, a number of results for laying out one or two images within a frame are presented.

6073-30, Session 9

Using CART to segment road images

R. L. Davies, Intel Corp.; R. W. Lienhart, Univ. Augsburg (Germany)

The 2005 DARPA Grand Challenge is a 132 mile race through the desert with autonomous robotic vehicles. Lasers mounted on the car roof provide a map of the road up to 20 meters ahead of the car but the car needs to see further in order to go fast enough to win the race. Computer vision can extend that map of the road ahead but desert road is notoriously similar to the surrounding desert. A sample of desert road within 20 meters of the car is provided by the lasers and projected into the 2D image frame from the video camera mounted on top of the car. The contribution of the computer vision subsystem is to determine if the colors and textures beyond the first 20 meters are similar to the sample from the lasers. The CART algorithm (Classification and Regression Trees) provided a machine learning boost to carefully measure that similarity while at the same time measuring when that road could not be distinguished from surrounding desert. The computer vision subsystem provides a simple decision to the planner: whether to go 25 or 35 mph. The Stanford Grand Challenge team won the race by 11 minutes.

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6074-01, Session 1

New APIs for mobile graphics

K. A. Pulli, Nokia

No abstract available

6074-02, Session 2

A novel fast inter-prediction mode decision for H.264/AVC

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Video communication over wireless links using handheld devices is a challenging task. There are two fundamental constraints in video coding for mobile wireless transmission: low bit rate transmission and limited computational capacity. Nowadays, H.264/AVC offers a significant improvement of coding efficiency compared with other video coding standards such as H.263, MPEG-4. However, much more complexity is brought into its scheme due to newly adopted algorithms such as quarter-pixel motion compensation, variable block size motion estimation/compensation, loop filter and context-based adaptive binary arithmetic coding (CABAC), etc. Among these techniques, the full exhaustive search of all modes in motion estimation and mode decision by using Rate Distortion Optimization (RDO) contributes a lot to the complexity.

RDO is one of the essential parts of the whole encoder to achieve the much better coding performance in terms of minimizing compressed video data bits and maximizing coding quality. RDO for inter-prediction mode decision is used to select the best one among all the possible modes (skip, 16x16, 16x8, 8x16, P8x8 (including 8x8, 8x4, 4x8, 4x4), Intra4x4 and Intra16x16). The general equation of Lagrangian RDO can be expressed as $J(\text{mode}) = D + (\text{Lagrangian multiplier}) \cdot R$, where $J(\text{mode})$ is the Rate-Distortion cost (RD cost); D is the distortion between the original macroblock and the reconstructed macroblock located in the current coded frame; and R reflects the number of bits associated with choosing the mode and macroblock quantizer value, Q_p , including the bits for the macroblock header, the motion vector(s) and all the DCT residue blocks.

For the sake of avoiding the full exhaustive search of all modes in inter prediction mode decision of H.264/AVC, we use the fast mode decision to decide whether the current searching mode is the best in advance. If it is the best one, the remaining modes will never be searched any more, so the video coding time saves and the corresponding computation is reduced. Meanwhile, we establish a searching order of priority based on a priori knowledge about the modes distribution in the encoded frame, by which the mode with higher percentage will be tested earlier. Our experimental results show that about 50% of the modes are skip mode; more than 10% are 16x16 mode; the occurrence of the remaining modes has such an order: 16x8, 8x16, P8x8 (including 8x8, 8x4, 4x8, 4x4), Intra4x4, Intra16x16. Thus, in our proposed scheme, the skip mode is the initial guess, and the order of other modes is as follows: 16x16, 16x8, 8x16, P8x8 (including 8x8, 8x4, 4x8, 4x4), Intra4x4, Intra16x16.

In our study, we find that there is a high correlation between the RD cost of macroblocks in the current P frame and that of their co-located macroblocks in the previous P frame. The average RD cost ratio of current P frame to previous P frame approximates to a fixed value, which is around 1.0. Based on the above observation, we propose to employ the co-located macroblock's RD cost as a judgement to select the best mode in the current macroblock being encoded and to terminate the mode decision as early as possible. In addition, we find that the average RD cost of the skip mode is much less than that of the other four modes (16x16, 16x8, 8x16, and P8x8 (including 8x8, 8x4, 4x8, 4x4)), so we could set a lower threshold in

the case of selecting skip mode additionally. This circumstance may happen when the best mode of the current macroblock is skip while the co-located macroblock in the previous P frame is other modes.

Let T be the co-located macroblock's RD cost in previous P frame; a be the lower threshold factor for skip mode which can stop the mode selection as early as possible; b be the range reference factor for all modes which is used to decide whether $J(\text{mode})$ is near to T ; c be the fluctuation of b . Our fast mode decision algorithm consists of two steps. Step1: Check skip mode; If $J(\text{skip})$ is lower than aT or in the range $((b-c)T, (b+c)T)$, set skip mode as the best mode and then stop. Step2: Check the modes in the order of $\{16x16, 16x8, 8x16, \text{and } P8x8 \text{ (including } 8x8, 8x4, 4x8, 4x4), \text{Intra4x4 and Intra16x16}\}$; Once the RD cost of one mode is in the range $((b-c)T, (b+c)T)$, then set the corresponding mode as the best mode and stop. We set the initial value of factors a, b, c to 0.70, 1.0, 0.05 respectively and update them according to the previous RD cost ratio dynamically.

In order to verify our proposed approach, we conduct a number of experiments. Simulation results show that our approach can reduce 20% to 50% encoding time on all the test sequences, with a negligible PSNR loss less than 0.1 dB and bit rate increase no more than 2%, which demonstrate clearly that our proposed approach is very effective. In this paper, we only exploit the temporal correlation of the RD cost to do the mode decision and get a good result. As a future work, we would try to induce the spatial correlation of the RD cost into this scheme.

6074-03, Session 3

Concealment driven bit rate reduction using the H.264 video coding standard

S. T. Beesley, A. J. Armstrong, C. Grecos, D. J. Parish, Loughborough Univ. (United Kingdom)

With the continual increase in both popularity and power of portable multimedia devices, it is often desirable to stream video across telephone networks using modern encoding standards, even when the transmission network has only limited bandwidth available. This paper demonstrates an alternative use of the passive error concealment algorithm that is currently used in the H.264 video coding standard. As each macroblock is encoded a concealed version is also generated in the same way that a decoder would conceal an erroneous macroblock. Occasionally the concealed version is mathematically closer to the original source than the normally reconstructed version, in these cases the macroblock is flagged as containing no data and is not included in the bit stream. The decoder then uses the already present weighted pixel value averaging concealment technique to reconstruct the flagged macroblocks as it renders the picture. The proposed method has been tested over a wide variety of test sequences at various sizes and qualities; the outcome of the research is that for almost identical mathematical and visual metric results, a significant reduction in the bit stream size can be achieved, in some cases this saving can be as much as 5%.

6074-04, Session 3

Image embedded coding with edge preservation based on local variance analysis for mobile applications

G. Luo, D. Osypiw, Buckinghamshire Chilterns Univ. College (United Kingdom)

Transmitting digital images via mobile device is often subject to bandwidth which are incompatible with high data rates. Embedded coding for progressive image transmission has recently gained popularity in image compression community. However, current progressive wavelet-based image coders tend to send information

on the lowest-frequency wavelet coefficients first. At very low bit rates, images compressed are therefore dominated by low frequency information, where high frequency components belonging to edges are lost leading to blurring the signal features. This paper presents a new image coder employing edge preservation based on local variance analysis to improve the visual appearance and recognizability of compressed images. The analysis and compression is performed by dividing an image into blocks. Fast lifting wavelet transform is developed with the advantages of being computationally efficient and boundary effects minimized by changing wavelet shape for handling filtering near the boundaries. A modified SPIHT algorithm with more bits used to encode the wavelet coefficients and transmitting fewer bits in the sorting pass for performance improvement, is implemented to reduce the correlation of the coefficients at scalable bit rates. Local variance estimation and edge strength measurement can effectively determine the best bit allocation for each block to preserve the local features by assigning more bits for blocks containing more edges with higher variance and edge strength. Experimental results demonstrate that the method performs well both visually and in terms of MSE and PSNR. The proposed image coder provides a potential solution with parallel computation and less memory requirements for mobile applications.

6074-05, Session 3

Image coding using adaptive resizing in the block-DCT domain

J. J. Koivusaari, J. H. Takala, M. Gabbouj, Tampere Univ. of Technology (Finland)

In this paper, we propose an image coding scheme using adaptive resizing algorithm to obtain more compact coefficient representation in the block-DCT domain. Standard coding systems, e.g. JPEG baseline, utilize the block-DCT transform to reduce spatial correlation and to represent the image information with a small number of visually significant transform coefficients. Because the neighboring coefficient blocks may include only a few low frequency coefficients, we can use downsizing operation to combine the information of two neighboring blocks into a single block.

Fast and elegant image resizing methods operating in transform domain have been introduced previously. In this paper, we introduce a way to use these algorithms to reduce the number of coefficient blocks that need to be encoded. At the encoder, the downsizing operation should be performed delicately to gain compression efficiency. The information of neighboring blocks can be efficiently combined if the blocks do not contain significant high frequency components and if the blocks share similar properties. The results include objective quality comparison against current image coding standards in terms of PSNR versus compression efficiency.

6074-06, Session 3

Spatial scalability of multiple ROIs in scalable video coding

T. M. Bae, T. C. Thang, D. Y. Kim, Y. M. Ro, Information and Communications Univ. (South Korea); J. Kim, Electronics and Telecommunications Research Institute (South Korea)

Currently, MPEG and ITU-T are jointly making a standard scalable video codec that is based on Motion Compensated Temporal Filtering (MCTF) and H.264. The objectives of this scalable video codec are generating temporal, spatial, and quality scalable coded stream, therefore users can be provided QoS guaranteed streaming services independent of video consuming device in heterogeneous network environment. But, even in the restriction of resolution or display size, user wants to see what he/she wants to see with enough large resolution. Defining Region of Interest (ROI) in the picture and providing only ROI containing video stream would be

good solution to the user in that situation. Therefore, we assume the case when there exist more than one ROI in the picture, and each ROI can be decoded independently with spatial, temporal, and quality scalabilities. To accomplish the objective, we used FMO (Flexible Macroblock Ordering) in the H.264 to describe ROIs. But FMO is not enough for independent decoding of multiple ROIs. The first problem is related with slice group boundary in independent decoding of ROI. Second problem is related with overlapping between ROIs. In this paper, we present solutions to address these difficulties.

6074-07, Session 4

Implementing energy efficient embedded multimedia

O. J. Silvén, Univ. of Oulu (Finland)

Multimedia processing in battery powered mobile communication devices is pushing their computing power requirements to the level of desktop computers. At the same time the energy dissipation limit stays at 3W that is the practical maximum to prevent the devices from becoming too hot to handle. In addition, several hours of active usage time should be provided on battery power.

During the last ten years the active usage times of mobile communication devices have remained essentially the same regardless of big energy efficiency improvements at silicon level. The reasons can be traced to the design paradigms that are not explicitly targeted to creating energy efficient systems but to facilitate implementing complex software solutions by large teams. Consequently, the hardware and software architectures, including the operating system principles, are the same for both mainframe computer system and current mobile phones.

In this paper, we consider the observed developments against the needs of video processing in mobile communication devices and propose means of implementing energy efficient video codecs both in hardware and software. Monolithic video acceleration is the most attractive solution, while software is becoming increasingly difficult to implement in an energy efficient manner.

6074-08, Session 5

A study of low-complexity tools for semantic classification of mobile images and video

A. Mariappan, M. Igarta, Purdue Univ.; C. M. Taskiran, B. Gandhi, Motorola, Inc.; E. J. Delp III, Purdue Univ.

With the proliferation of cameras in handheld devices that allows users to capture still images and videos, providing users with software tools to efficiently manage multimedia content has become essential. In many cases users desire to organize their personal media content using high-level semantic labels. However, automatic extraction of such semantic labels is currently very hard to achieve. Furthermore, the algorithms that have been proposed for such labeling are generally not suitable for hand-held devices due to computational constraints. To solve this problem, we have focused on developing low-complexity algorithms to derive low-level semantic labels, such as "indoor/outdoor", "face/not face", and "motion/not motion", from images and video. These low-level labels can then be used to derive higher-level semantic labels for the media, e.g., outdoor and motion labels may indicate the sports label. In this paper we will describe the results of our semantic label extraction experiments on a test collection consisting of 400 images and a database of nearly 60 minutes of 3gpp video.

6074-09, Session 5

Audio-based queries for video retrieval over Java enabled mobile devices

I. Ahmad, Nokia Corp. (Finland); F. A. Cheikh, S. Kiranyaz, M. Gabbouj, Tampere Univ. of Technology (Finland)

In this paper we propose a generic framework for robust and efficient retrieval of audiovisual media based on the audio content. This framework is implemented in a client-server architecture where the client application is developed in Java so as to be operational for any Java enabled mobile device whereas the server application is implemented for the PC platform. Client application adapts to the characteristics of mobile devices: screen size, commands and media formats. The entire framework is designed to take advantage of the high-level segmentation and classification of audio content to improve speed and accuracy of audio-based media retrieval. Therefore, the primary objective of this framework is to provide a robust and adaptive basis for performing efficient retrieval operations according to audio type (speech, music, fuzzy and silence). In order to further improve the retrieval speed a key-frame model is applied during the indexing phase. Finally, the proposed framework is designed in a flexible and dynamic way which allows the use of various low-level audio features extraction techniques in run time. Experimental results approve that such a content-based retrieval scheme can be used from mobile devices to search and retrieve video items efficiently over wireless networks.

6074-11, Session 6

Parallel implementation of MPEG-2 video decoder

A. Sarkar, North Carolina State Univ.; K. Saha, S. Maiti, STMicroelectronics Pvt. Ltd. (India)

The demand for low cost real-time MPEG decoding is growing in multimedia applications. This paper discusses a hardware-software co-design for MPEG-2 Video decoding and describes an efficient parallel implementation of the software module. We have advocated the usage of hardware for VLD since it is inherently serial and efficient hardware implementations are available. The software module is a macro-block level parallel implementation of the IDCT and Motion Compensation. The parallel implementation has been achieved by dividing the picture (into two halves for 2-processor implementation and into four quadrants for 4-processor implementation) and assigning the macro-blocks present in each divided portion to a single processor. The processors perform IDCT and Motion Compensation in parallel for the macro-blocks present in their allotted sections. Thus each processor displays a picture frame. This implementation minimizes the data dependency among processors while performing the Motion Compensation since data dependencies occur only at the edges of the divided sections. Load balancing among the processors has also been achieved, as all the processors perform computation on an equal number of macro-blocks. Apart from these, the major advantage is that the time taken to perform the IDCT and Motion Compensation reduces linearly with an increase in number of processors.

6074-12, Session 6

Software-based geometry operations for 3D computer graphics

M. Sima, Univ. of Victoria (Canada); D. Iancu, J. C. Glossner, Sandbridge Technologies, Inc.; M. J. Schulte, S. Mamidi, Univ. of Wisconsin/Madison

In this paper we describe a software fixed-point implementation of the vertex processor functions using the COordinate Rotation Digital Computer (CORDIC) instruction for the Sandbridge multithreaded low power processor. A CORDIC-based solution for vertex

processing exhibits a number of advantages over classical Multiply-and-Accumulate solutions. First, since a single primitive is used to describe the computation, the code can easily be vectorized and/or partitioned into threads, and thus fits the major Sandbridge architectural features. Second, since a CORDIC iteration consists of only a shift operation followed by an addition, the computation may be deeply pipelined. Third, the CORDIC algorithm produces one bit of accuracy per iteration. Thus, all CORDIC-based rotations will have the same latency for a given precision, which allows trade-offs to be made between precision and latency at run-time. Since many 3D graphics computations can be expressed in terms of CORDIC primitives, a CORDIC-based solution is a promising approach. Our preliminary results indicate that the CORDIC-based solution can provide the performance level required by many 3D graphics applications at the cost of a hardware CORDIC unit and a CORDIC instruction.

6074-13, Session 6

MVSP: multithreaded VLIW stream processor

S. Sardashti, H. R. Ghasemi, O. Fatemi, Univ. of Tehran (Iran)

Stream processing is a new trend in computer architecture design which fills the gap between inflexible special-purpose media architectures and programmable architectures with low computational ability for media processing. Stream processors are designed for computationally intensive media applications characterized by high data parallelism and producer-consumer locality with little global data reuse. They try to exploit the locality and concurrency inherent in media applications using stream programming model. Stream programming organizes data as streams and all computations as kernels. Stream processors directly execute applications mapped to this programming model. They contain clusters of functional units and provide a memory hierarchy (bandwidth hierarchy), supporting hundreds of arithmetic units. In this paper, we propose a new stream processor, named MVSP (Multithreaded VLIW Stream Processor). This processor is a programmable stream processor based on Imagine stream processor. MVSP exploits thread level, data level, instruction level parallelisms inherent in media applications. Full simulator of MVSP has been implemented and several media workloads composed of EMBC benchmarks have been applied. The simulation results show the performance and functional unit utilization improvements of around two times in comparison with Imagine processor.

6074-14, Session 6

System-on-chip architecture with media DSP and RISC core for media application

P. Liu, W. Wang, Q. Yao, Zhejiang Univ. (China)

System-on-chips provide single-chip solutions in many embedded applications to meet the applications size and power requirements. Media processing such as real-time compression and decompression of video signal is now expected to be the driving force in the evolution of System-on-chip. The MediaSoC3221A consists of two fully programmable processor cores and integrates digital video encoder. The programmable cores toward a particular class of algorithms: the MediaDSP3200 for RISC/DSP oriented functions and multimedia processing, and the RISC3200 for bit stream processing and control function. Dedicated interface units for DRAM, SDRAM, Flash, SRAM, on screen display and the digital video encoder are connected via a 32-bit system bus with the processor cores. The MediaSoC3221A is fabricated in a 0.18 μ m 6LM standard-cell SMIC CMOS technology, occupies about 20mm², operates at 180MHz. The MediaSoC3221A are used to audio/video decoder for embedded multimedia application.

6074-15, Session 6

IIA: a novel method to optimize media instruction set of embedded processor

K. Chen, Q. Yao, W. Wang, P. Liu, Zhejiang Univ. (China)

To accelerate media processing, many media instructions have been adopted into the instruction set of DSP and RISC processor. In this paper, a novel method, called interaction between instructions and algorithms (IIA), is proposed to optimize media instructions. Based on the analysis of inherent characteristics of video processing algorithms, we propose three useful instructions for manipulation on bit level to speed up variable-length decoding (VLD). Little hardware is added to avoid penalties introduced by unaligned load in SIMD instructions. We also propose data path and memory architecture to support 128-bit word processing. This method is used in the design of a 32-bit Embedded DSP processor, MediaDsp3201. Simulation results show that our method can reduce more than 26% instructions for VLD, 41% for IDCT and 60% for MC.

6074-34, Poster Session

A FGS coding method based on LC multiwavelet transform

W. Liu, South China Normal Univ. (China); Z. Ma, Zhongshan Univ. (China)

Wavelet analysis is a tool of time-frequency analysis after Fourier analysis. It has become one of the most outstanding techniques widely used in fields of image processing. Multiwavelet is the expansion of scalar wavelet, which keeps good traits in both time domain and frequency domain, and which overcomes scalar wavelet defects. Multiwavelet transform has important traits in image processing such as symmetric, orthogonal, smoothness, and short support.

Image coding is an important task for image processing. With the prevalence of broadband communications, more and more attention has been paid to video and image transmitting over networks. Scalable coding and multiple-description coding are main transmission-oriented image and video coding techniques nowadays. In this paper, we made deep research in the application of multiwavelets in scalable coding and proposed a new transmission-oriented image coding method, that is Fine Granularity scalable coding method based on CL multiwavelet transform. The experimental results show that the proposed coding method is effective. It is a valuable work on the application of multiwavelet transform in image coding. Furthermore, we extend our work to field of video signal processing.

6074-35, Poster Session

A context-aware video display scheme for mobile devices

K. Seo, C. Kim, Information and Communications Univ. (South Korea)

A fully automatic and computationally efficient method is proposed for intelligent display of soccer video on small multimedia mobile devices. The rapid progress of the multimedia signal processing has contributed to the extensive use of multimedia devices with small LCD panel. With these flourishing small displays on the mobile devices, the video sequences captured for normal viewing on traditional analog TV or HDTV may give the small-display-viewers uncomfortable experiences in understanding what is happening in a scene. For instance, in a soccer video sequence taken by a long-shot camera technique, the tiny objects (e.g., soccer ball and players) may not be clearly viewed on the small LCD panel. Thus, an intelligent display technique is needed for viewers on small devices. To this end, one of the key technologies is to determine region of

interest, which is a part of the scene that viewers pay more attention to than other regions.

In this paper, we only focus on soccer video display for mobile devices. Instead of taking visual saliency into account, we take domain-specific approach with a constraint of video type. We propose a context-aware soccer video display scheme, which includes three folds: long shot frame detection, ground analysis, and final decision. The experimental results show the propose scheme is capable of context-aware video display on mobile devices.

6074-36, Poster Session

Verification of WIPI-based T-DMB platform for interactive mobile multimedia services

B. Bae, W. Kim, J. Yun, C. Ahn, Electronics and Telecommunications Research Institute (South Korea); K. Sohng, Kyungpook National Univ. (South Korea)

Recently, T-DMB receivers have been developed as a wide range of terminals, including notebook computers, PDAs, and cellular phones. Especially, most of manufacturers focus on the T-DMB receivers combining the cellular phone, which uses the CDMA network in Korea, since the two different devices have the similar features of portability and mobility. That means that the interactive mobile broadcasting services can be possible by being able to use a mobile telecommunication network as a return channel. In this paper, we present the architectures of the interactive T-DMB system and the integrated receiver using the CDMA network. We also propose the layered model of the new platform based on WIPI (Wireless Internet Platform for Interoperability) in the receiver. To verify the proposed platform and the interactive mobile broadcasting services, we implemented the integrated receiver as well as the data broadcasting server and the return channel server. We also implemented T-DMB extended WIPI platform and the integrated browser, which shows A/V and data contents at the same time, on a WIPI emulator. 4 data contents such as quiz show, shopping, stock information, and weather information were used to verify the proposed WIPI-based T-DMB platform. Users can get interactive services or more information about broadcasting through CDMA network by using this platform. This shows the possibilities of new interactive services in the digital broadcasting by utilizing the mobility of T-DMB and CDMA.

6074-37, Poster Session

New TPEG applications based on digital multimedia broadcasting

Y. Jeong, S. Cho, G. Kim, C. Ahn, S. Lee, Electronics and Telecommunications Research Institute (South Korea); W. Kim, Chungnam National Univ. (South Korea)

The DMB allows the consumers to view clear moving pictures in harsh reception conditions and also can provide an economical way of massive multimedia data services up to 1.7Mbps. Therefore, DMB is emerging as an optimal solution to address the several drawbacks of the mobile communication network. The TPEG is a protocol to provide traffic and travel Information (TTI) and it has been applied merely to two application areas. One is to transfer the road traffic status message (RTM) in case of road speed, an accident, weather reporting, and so forth. The other is to convey the public transport information message (PTI) such as schedules and routes of buses, trains, flights, ships, and so forth. Recently, however, new needs of consumer for POI (Point-Of-Interest) and News services become pronounced, that cannot be met through the RTM and PTI. In this paper, we propose new POI and News applications based on TPEG using DMB. To verify the stability of POI and News protocols, we implemented the data server and the DMB/DAB receiver. Through the trial broadcasting using commercial DMB network, it is shown that the proposed protocol operates stably and effectively in the

navigation system. The automation techniques to insert and to update the POI/News information provided by the content provider will be developed in a near future.

6074-39, Poster Session

AROMA: augmented reality on mobile devices API (Java)

S. Edlich, Technische Fachhochschule Berlin (Germany); H. Hörning, R. Hörning, Biting Bit (Germany)

General purpose image processing solutions are widely available in the computing area. But the adoption for the special need of mobile devices is rarely seen. JTWI / JSR-185 compliant cell phones basically need the fastest algorithms with a minimum of memory consumption. The area of augmented reality on cell phones is just emerging due to the widespread availability of digital cameras incorporated in them. The idea using cell phones is to show the reality filmed with the camera on the screen and use it to interact with virtual reality displaying relevant information. The first applications are just emerging (see http://www.ojom.de/g_killer_virus.html) but application areas, device coverage and technical support has to improve.

Technical improvements include A) not only motion but also rotation (like providing float `getAngle(Image img)` as a function) B) identification and tracking of relevant spots (trees to climb on, noses to be changed, friends / enemies, etc.) C) clever overlay algorithms for any augmentation need.

The authors see a huge market for applications build on this technology. Practical examples are existing games like the one mentioned above where viruses get attached to your real world and can (only) be seen on your filming cell phone. But there is room for other applications (like changing your hair dress) and for extreme complex applications like a location based scavenger hunt game. We are confident that news will soon report on real humans moving (GPS tracked and identified over AROMA) through the city, gesticulating and fighting enemies on their cell phone screen.

The challenge is 1) to obtain the pictures as fast as possible (current java cell phones often have a latency of about a second for a complete new image processed), 2) due to this fact: to process fast and efficient (which is quite hard in a Java ME environment) 3) to have a small lib footprint 4) to provide a reasonable API 5) to leverage Java for fast image processing in order to make the API work on plenty of cell phones.

This poster shows the efforts we made in building up the infrastructure for augmented reality image processing but initially structures the requirements and limiting conditions. We show the theoretical foundation of realizing an augmented reality game called Highnoon under Java ME. Two real humans can play the game with their cell phones while standing in front of each other. We also show further application areas for this kind of technology.

6074-40, Poster Session

An effective method and its implementation for splicing in terrestrial DMB

Y. Lee, J. Lee, G. Lee, C. Ahn, S. Lee, Electronics and Telecommunications Research Institute (South Korea); N. Kim, Chungbuk National Univ. (South Korea)

This paper proposes the effective method and its implementation for splicing in terrestrial Digital Multimedia Broadcasting (T-DMB) which can provide multimedia service without any discontinuity of video and audio when inserting commercial program while transmitting main DMB broadcasting program. T-DMB has been developed to provide multimedia service to mobile user at various mobile environments. For this service, T-DMB uses Eureka-147 as

transmission standard and use MPEG-4 Advanced Video Coding (AVC), MPEG-4 Bit Sliced Arithmetic Coding (BSAC), MPEG-2 and MPEG-4 system for media encoding. Also it additionally uses an outer coding technique as well as channel coding technique based on Eureka-147, and can provide high quality mobility to mobile user by applying COFDM transmitting technique. As T-DMB service is launched, some service requirements become necessary that wish to send local programs such as advertisement and specific programs at local broadcasting station while retransmitting broadcasting signal coming from central or other station. But, when switching from one digital signal to the other one in digital broadcasting system, presentation discontinuity of video and audio at the receiver may happen unlike analog broadcasting system. Therefore, the transcoding techniques have been typically used to overcome these limitations at local broadcasting station. However, the general transcoding techniques require expensive transcoding device such as decoder and encoder, and it may cause picture quality distortion. To solve this problem, this paper proposes effective method for splicing in T-DMB.

6074-42, Poster Session

Media digital signal processor core design for multimedia application

P. Liu, G. Yu, W. Cai, Q. Yao, Zhejiang Univ. (China)

An embedded single media processor named MediaDSP3200 core fabricated in a six-layer metal 0.18um CMOS process implementation the RISC instruction set, DSP data processing instruction set and single-instruction-multiple-data (SIMD) multimedia-enhanced instruction set is described. MediaDSP3200 fuses RISC architecture and DSP computation capability thoroughly, which achieves RISC fundamental, DSP extended and single instruction multiple data (SIMD) instruction set with various addressing modes in a unified and customized pipeline stage architecture. These characteristics enhance system digital signal processing performance greatly. The test processor can achieve 32x32-bit multiply-accumulate (MAC) 320 MIPS, and 16x16-bit MAC can achieve 1280MIPS. The test processor dissipates 600mW at 1.8v, 300MHz. The implementation was primarily standard cell logic design style. MediaDSP3200 targets diverse embedded application systems, which need both powerful processing/control capability and low-cost budget, e.g. set-top-boxes, video conferencing, DTV, etc. MediaDSP3200 instruction set architecture, addressing mode, pipeline design, SIMD feature, split-ALU and MAC are described in this paper. Finally, the performance benchmark based on H.264 and MPEG decoder algorithm are given in this paper.

6074-17, Session 7

Multimedia services for next-generation mobile networks

S. J. Wee, D. Penkler, Hewlett-Packard Labs.

Multimedia services such as video on demand or interactive gaming are typically delivered over broadband wireline networks to the living room or desktop computer. In this talk, we describe technology advances in next-generation mobile networks that are making it possible to deliver compelling media services to mobile users. This includes the emergence of a service-enabled network infrastructure capable of delivering and processing high-quality multimedia streams, a scalable and extensible architecture that allows new multimedia services to be deployed over time, and a set of emerging standards that promotes interoperability between infrastructure components and end user devices.

6074-18, Session 8

Wireless steganography

S. S. Agaian, D. Akopian, S. D'Souza, The Univ. of Texas at San Antonio

We propose a new approach to the implementation of steganographic applications. Steganography is traditionally accomplished using the high processing speeds of a desktop or even notebook computer. Recently, new technology has miniaturized high complexity circuitry giving rise to the convenience of portable and complex processing components. Such advancements are clearly demonstrated in the field of wireless communications. Cell phones, as one example, are continuously increasing in the level and quality of services and applications that are offered. With the introduction of mobile platform operating systems, there arises the opportunity to create and develop innovative translations of commonly used processes. We take advantage of this opportunity with the introduction of wireless steganographic algorithms.

Steganography is the art of concealing one form of digital media into another form of digital media designated the cover media. The information intended to be unseen by intermediate parties is considered the steganographic content. Some possible media are to include audio files, video files, text files, and images. In this article, we discuss the scenario of hiding an image within an image. Images come in several memory and display formats. To sustain a level of simplicity, these preliminary programs were constructed to acknowledge the insertion of an 8-bit grayscale image into a 24-bit color bitmap image. The decision to confine the selection of stego images to the intensity domain coincides with the display capabilities of the portable device. Steganography itself is an established field. We strive to increase the versatility of this science by introducing a new platform for the execution of such functionality.

The ability to apply steganography with a mobile device greatly increases the effectiveness of this particular type of covert communication. In addition, this new concept helps to validate the art and aides in the establishment of steganography as a practical approach for transmitting sensitive material. We consider this new idea to be a great contribution to this rapidly growing field.

The development of programs functional on mobile devices is facilitated by the well established and widely accepted operating system known as Symbian.

6074-19, Session 9

Image processing for navigation on a mobile embedded platform

H. Loose, C. Lemke, C. Papazov, Brandenburg Univ. of Applied Sciences (Germany)

This paper deals with intelligent mobile platforms connected to a camera controlled by a small hardware-platform called RCUBE. This platform is able to provide features of a typical actuator-sensor board with various inputs and outputs as well as computing power and image recognition capabilities.

Several intelligent autonomous RCUBE devices can be equipped and programmed to be a participant of a network called BOSPORUS. These components form an intelligent network for gathering sensor and image data, sensor data fusion, navigation and control of mobile platforms.

The RCUBE platform provides a standalone solution for image processing, which will be explained and presented. It plays a major role for several components in a reference implementation of the BOSPORUS system. On the one hand, intelligent cameras will be positioned in the environment, analyzing the events from a fixed point of view and sharing their perceptions with other components in the system. On the other hand, image processing results will contribute to a reliable navigation of a mobile system, which is

crucially important. Fixed landmarks and other objects appropriate for determining the position of a mobile system can be recognized. For navigation other methods are added, i.e. GPS calculations and odometers.

6074-20, Session 9

Image processing for navigation on a mobile embedded platform

T. Preuss, L. Gentsch, M. Rambow, Brandenburg Univ. of Applied Sciences (Germany)

Mobile computing devices such as PDAs or cellular phones may act as "Personal Multimedia Exchanges", but they are limited in their processing power as well as in their connectivity.

In a more dynamic environment, previously applied client/server architectures do not match all requirements, therefore, a communication network is required that enables communication with peers and allows use of the services provided by these peers.

In this paper, a generic approach is presented that connects different kinds of clients with each other and allows them to interact with more powerful devices. This architecture, called Bosphorus, represents a communication framework for dynamic peer-to-peer computing. Each peer offers and uses services in this network and communicates loosely coupled and asynchronously with the others. These features make Bosphorus a service oriented network architecture (SONA).

The Bosphorus system overcomes the problems of building up a consistent ad hoc network infrastructure for communication by installing services in a plug and play manner. Scenarios like image processing for low-end devices like robots or statistical analyses on PDAs can be provided with the system. This enables the implementation of customized services for specific problem domains, e. g. the gathering, storage, processing and relaying of all kinds of data used in multimedia environments.

6074-21, Session 9

The future is 'ambient'

A. R. Lugmayr, Tampere Univ. of Technology (Finland)

The research field of ambient intelligence starts to spread rapidly and first applications for consumer homes are on the way. Ambient intelligence is the logical continuation of research in multimedia. Multimedia has been evolving from integrated presentation in one form (multimedia), to generating a synthetic world (virtual reality), to natural environment is the user-interface (ambient media), and will be evolving towards real/synthetic undistinguishable media (bio-media or bio-multimedia). After the IT bubble was bursting, multimedia was lacking a vision of potential future scenarios and applications. Within this research paper the potentials, applications, and market available solutions of mobile ambient multimedia are studied. The different features of ambient mobile multimedia are manifold and include wearable computers, adaptive software, context awareness, ubiquitous computers, middleware, and wireless networks. The paper especially focuses on algorithms and methods that can be utilized to realize modern mobile ambient systems.

6074-22, Session 9

Embedded video surveillance system for vehicle over WLAN and CDMA1X

L. Ming, Wuhan Univ. (China)

with the recent advancement of mobile wireless technologies such as: wireless LAN and CDMA, it has become viable to create a network-in-motion inside a Vehicle. This paper presents an Embedded Video Surveillance System for vehicle over WLAN and CDMA1X. First, it constructs high speed automobile communication

environment by fusing CDMA1X and WLAN wireless network; In order to fit the bandwidths sharply variety of wireless channel, adaptive video compression algorithms based MPEG4 is utilized to encode the high quality video. Moreover, unique transmission mechanism using media server and media gateway is presented, which can support large scale concurrent users up to 1000. This transmission mechanism uses the buffer on media server to smooth the video transport in wireless channel. Using this architecture of video transmission for Vehicle, the live surveillance video of mobile can be viewed over internet. Furthermore, Control center can be set up anywhere with internet access without being restricted by monitored site locations. This system is supported by Electronic Information Industry Development Fund of 2004.

6074-23, Session 10

Performance analysis of MPEG-21 technologies on mobile devices

S. De Zutter, F. De Keukelaere, C. Poppe, R. Van de Walle, Univ. Gent (Belgium)

This paper gives an introduction on technologies and methodologies to measure performance of MPEG-21 applications in mobile environments. Since resources, such as processing time, available memory, storage, network, and remaining battery time, are very sparse on mobile devices, it is important to optimize technologies to use as little as possible of those resources. Therefore, those performance measurements technologies are applied on a prototype implementation of MPEG-21 Digital Item Declaration and Digital Item Processing. The MPEG-21 standard is currently under development and its goal is providing transparent and augmented use of multimedia resources across a plethora of networks and devices. This prototype, which has been implemented on the J2ME platform, gives information about possible bottlenecks when designing MPEG-21 based applications. The results of the measurements are discussed and used to create a design strategy that can avoid possible memory and processor consumptions when implementing the discussed parts of the MPEG-21 standards on a mobile platform. This paper ends with concluding remarks and guidelines on how to apply our design strategy to describe further optimizations of the implemented prototype.

6074-24, Session 10

TV-anytime and MPEG-21 DIA based ubiquitous content mobility prototype system for multi-users

M. Kim, C. Yang, J. Lim, M. Kim, Information and Communications Univ. (South Korea); S. Park, K. Kim, SAMSUNG Electronics Co., Ltd. (South Korea)

There has been growing number of studies about core technologies for ubiquitous video service. The ubiquitous video service is that users can consume video contents which they want at anytime and anywhere in the form of what users want. For the ubiquitous video service, content mobility, the same concept of session mobility in MPEG-21 DIA, is one of key functions to support ubiquitous video service. In the conventional systems, a user only can seamlessly consume TV contents from a display device terminal to another display device terminal based on information such as a content ID, amount of content consumption, and user ID; however, the content mobility of the conventional systems only support for a single user. Therefore, we propose a ubiquitous content mobility system that a user can consume their preferred contents through many kinds of display device terminals in digital home environment. The proposed ubiquitous content mobility system supports content mobility for multi-users, and utilizes TV-Anytime Metadata and Content Referencing specifications to describe the TV program contents and

MPEG-21 DIA specification to describe the context information of user's environments and terminal characteristics. Based on these standards, a user can seamlessly watch preferred TV program contents through various display devices under the ubiquitous video service environments.

6074-25, Session 10

Multimedia-based construction management and supervision on mobile JTWI devices and the EDF-portal

S. Edlich, Technische Fachhochschule Berlin (Germany); R. Strauch, edv plan GmbH; L. Visengeriyeva, Fachhochschule Brandenburg; D. Reeck, edv plan GmbH

Mobile Devices in construction management (CMA) have rarely been used so far. The work presented is based on research projects to develop a portal (EDF-Portal) to manage mid-sized construction projects. Further research has been done to get a mobile prototype running, which uses this EDF-Portal. After this, more research could be funded since 2004 to evaluate the technical limitations and needs as well as HCI issues for mobile devices in construction management. This paper describes several problems that had to be solved to enable cell phones in CMA projects. In particular the document management, the content reduction for mobile devices, multimedia handling, workflow components, and much more have shown to be quite difficult to handle. In this paper we show the possibilities, limitations and strategies for this kind of mobile software to be implemented, evaluated and forced to be accepted in real construction areas. The results can be easily transferred to any area where management portals can be used via mobile devices although construction management has lots of special law related requirements which strongly influences the interaction with portals.

6074-26, Session 10

A mobile phone-based context-aware video management application

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Modern mobile phones are equipped with cameras and connect to high-speed cellular networks making mobile video sharing readily available to users. We present a video management system that comprises a video server and MobiCon, a mobile phone application, which allows users to capture videos, annotate them with metadata, specify digital rights management (DRM) settings, upload the videos and share them with others. Users can also search via a web interface the stored video database and watch them using different terminals. Our work considers the mobile phone not only as a video consumption device, but as a video production tool. We describe the MobiCon architecture, compare it with related work, provide an overview of the video server, and illustrate a typical user scenario from the point of capture to video sharing to video retrieval. We summarise field trial results conducted in the area of Oulu, Finland, which demonstrate that users can master the application quickly, but are unwilling to perform extensive manual annotations. After the trial, we integrated an extensible annotation web service into the MobiCon architecture which takes advantage of the temporal, spatial, calendar, and other contextual information available at the time of video capture, thus making video annotations more user-friendly.

6074-27, Session 11

MIKE's PET: a participant-based experiment tracking tool for HCI practitioners using mobile devices

D. Mohamedally, City Univ. London (United Kingdom); S. Edlich, Technische Fachhochschule Berlin (Germany); E. Klaus, Fachhochschule Brandenburg (Germany); P. Zaphiris, H. Petrie, City Univ. London (United Kingdom)

Knowledge Elicitation (KE) methods are an integral part of Human Computer Interaction (HCI) practices. They are a key aspect to the synthesis of psychology empirical methods with requirements engineering, User Centred Design (UCD) and user evaluations. Examples of these methods include prototyping, focus groups, interviews, surveys and direct video observation. The MIKE project (Mobile Interactive Knowledge Elicitation) at the Centre for HCI Design, City University London, UK provides mobile cyberscience capabilities for HCI practitioners conducting such research while at stakeholder locations. This paper reports on the design and development of a new MIKE based tool, named PET, a Participant-based Experiment Tracking tool for HCI practitioners using Java-based (J2ME) mobile devices. PET integrates its user tracking techniques with the development of the second generation implementation of the CONKER (COllaborative Non-linear Knowledge Elicitation Repository) Web Service. We thus report further on CONKER v2.0's new capabilities developed to enable tighter collaboration and empirical data management between HCI practitioners, considering their UCD needs. The visualisation, tracking and recording of HCI participant-based datasets via PET is explored with close connectivity with the CONKER v2.0 Web Service, in order to provide mobile-web cyberscience for remote and local HCI practitioners.

6074-28, Session 11

Maintenance support: case study for a multimodal mobile interface

G. Fuchs, D. Reichart, H. Schumann, P. Forbrig, Univ. Rostock (Germany)

Maintaining and repairing complex technical facilities such as generating plants requires comprehensive knowledge on subsystems, operational and safety procedures by the technician. Upgrades to the facility may mean that knowledge about these becomes outdated, raising the need for documentation on-site. Today's commonplace availability of mobile devices motivates the use of digital, interactive manuals over printed ones. Such applications should provide state-of-the-art visualization and interaction techniques tailored for specific tasks, while at the same time allow flexible deployment of these components on a multitude of (mobile) hardware platforms. This includes the integration of multimodal interaction facilities like speech recognition into the user interface. To meet these demands, we propose a model-based approach that combines task, object and dialog models to specify platform-independent user interfaces. New concepts like relating tasks to domain objects and dialog views allow us to generate abstract canonical prototypes. Another focus is on the necessary adaptation of visualization techniques to the platform capabilities to remain effective and adequate, requiring tight coupling of the underlying model, the visualization, and alternative input/output modes. The above aspects have been addressed in a prototype for air-condition unit maintenance, presented on the CeBIT 2005 fair.

6074-29, Session 11

Breaking the news on mobile TV: user requirements of a popular mobile content

H. O. Knoche, Univ. College London; A. Sasse, Univ. College London (United Kingdom)

Focus groups have identified news as the most popular mobile content. News content consists of three different media types: video, audio and text. The quality of all these are important to the perceived video quality on mobile devices. When following news content at low resolutions participants complained about the loss of detail especially for text legibility. If we do not simply recode TV content "as is" for mobile consumption but assure that the text used e.g. in ticker, logos, inserts etc. is legible the perceived acceptability of video quality can be increased. This could be achieved by either changes in layout and/or separate delivery and rendering of text at the receiver. With sufficiently sized text video encoding bitrates of 160kbit/s resulted in video quality acceptability reaching asymptote for all resolutions from 120x90 to 320x240. Furthermore, participants felt strongly about details that help identifying objects as well as facial details. Lip-reading aides speech perception and the mouth, eyes, and eyebrows all contribute to the decoding of facial expressions. Mobile TV producers have to make sure that small screens, low resolutions, the employed shot types and the used encoding bitrates still adequately render these features of depicted people to the user.

6074-30, Session 11

Multimodal audio guide for museums and exhibitions

S. Gebbensleben, J. Dittmann, Otto-von-Guericke Univ. (Germany)

In our paper we introduce a new audio guide concept for exploring buildings, realms and exhibitions. Actual proposed solutions work in most cases with pre-defined devices, which users have to buy or lend. These guides go often along with technical installations and user training for device handling. Furthermore the activation of descriptions related to the objects is mainly based on additional components like infrared, radio frequency or GPS technology.

Beside the required installation of these components an automatic activation only is possible.

Therefore in some approaches guides are directly controlled by entering of object numbers to navigate.

Motivated by these main disadvantages we introduce a new concept based on the visitor's mobile phone. The advantages are twofold: firstly the guide can be used in each place without any purchase and extensive installation of additional components. Secondly the visitors can experience the exhibition on individual tours only by uploading the guide at a single point of entry. Furthermore the user is familiar with his phone and can interact with his device easily. Our technical concept makes use of two general ideas for activation: the number based activation and digital audio watermarking. The main new idea about this approach is the usage of the visitor's mobile phone, the navigation through the exhibition using virtual maps on the display of the mobile phone and the direct input of the appropriate number. For automatic activation digital audio watermarking is introduced by playing appropriate watermarked sound closed to objects. The phone detects the embedded information and starts the related commentary.

6074-31, Session 11

Human sound detection on experience movies

S. Shimura, Y. Hirano, S. Kajita, K. Mase, Nagoya Univ. (Japan)

In this paper, we will describe an indexing method of video lifelog using sounds generated by human actions. The miniaturization of information-processing devices has enabled us to constantly record experience movies recently. However, these include many useless parts for a user. It is important to automatically extract only useful experiences from whole records. If an easy tool to add indices to important experiences is provided, users can mark these ones. Considering a users' load, it is undesirable for users to wear devices other than a microphone and a video camera that are needed to record experiences. Therefore, we propose a method that users can add indices using sounds which can be generated by using a part of users' body. We have especially analyzed typical sounds like hand clapping and finger clicking sounds that users can generate themselves. A detection method of two index-sounds has been developed. We have performed an experiment to confirm the recall ratio and relevance ratio of two index-sounds. A wearable system was worn by a subject and experiences were recorded for ten days (about 100 hours). The proposed detection method has been applied to recorded data, and two index-sounds have been detected with the recall ratio 88.0% and the relevance ratio 83.3%.

Tuesday-Thursday 17-19 January 2006

**Part of Proceedings of SPIE Vol. 6075 Optical Security and Counterfeit Deterrence
Techniques VI**

6075-40, Poster Session

**Recording the optical identification marks
on CDs**

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To protect distribution of unlicensed CDs, they offer to use various methods. Some of them are aimed at prevention of copying CDs, while the other ones pursue the purpose to inform users about true CD manufacturer, i.e., to provide an indicator of license character inherent to these CDs offered for sale. A possible solution of the CD identification task lies in making special marks recorded using laser radiation directly on CD surface. The ways to write these marks on should meet two main requirements, namely: the marks should be hardly imitated and make no considerable effect on information recorded onto CDs. Recording the identification marks in zones free of information can be currently realized at any modern laser recording station and cannot serve as an effective method to reveal counterfeiting.

The task to record identification marks in CD information zone is more hard-to-realize one. We studied and compared various methods of recording these identification marks. In doing so, it was ascertained that the most promising are the methods based on artificial changing the pit width while keeping the pit and land lengths unchanged. Besides, it seems also reasonable to record holograms by using the dot-matrix technology, the grooves of the holograms being mainly oriented at right angles to information tracks. The changes in the pit width can be realized by various methods including also the supplementary modulation of the laser radiation intensity in the course of recording information onto the master-disc. Synchronous with changing the laser radiation intensity, one should correct the recording pulse duration. Recording the identification marks by using the laser beam intensity modulation without any corrections in the pit length results in a fast growth of the error number with increasing the identification mark diffraction efficiency. In our case, the depth of protective hologram elements did not exceed $1/8...1/10$ of the pit depth necessary to code information. Both of the applied methods to record identification marks can be used in CDs and DVDs. One promising method more is that based on placing the elements of identification marks between CD information tracks. However, this method is more suitable for CD carriers, as DVD ones possess the distance between tracks too small (approximately 0.2 micron) to place there identification marks with a high diffraction efficiency.

The performed experimental investigations have shown that a sufficiently high diffraction efficiency of holographic identification marks made using the dot-matrix technology results in the increased level of corrected errors up to $20...30$ BLER/C. If the diffraction efficiency is decreased, recording these holographic marks can be practically provided at some constant level of corrected errors - $3...5$ BLER/C. Recording the identification marks by using modulation of the pit width within the range 0.35 to 0.7 micron allowed to register identification marks with the high diffraction efficiency. Changes in the pit width resulted only in changing the playback signal amplitude and have no effects on the corrected error level.

It is noteworthy that the most perspective direction in CD identification technology is creation of combined marks possessing both visually-readable images and machine-readable elements.

6075-41, Poster Session

**Concealed images in design of security
devices and methods of their
authentication**

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In the present paper two various ways of formation of the concealed images in DOVIDs are analysed.

The first way is on a placing of elements, filled by diffractive grating with grating pitch $200-400$ nm. Such elements can be observed at the very large angle of light diffraction (for $300-400$ nm period gratings), or in zero-order (for of $200-300$ nm period gratings), which essentially differs from observation conditions of DOVID's image at the "-1" order.

We investigate optimum methods of formation diffractive images: using e-beam lithography - with grating pitch in range $300-400$ nm, and optical holography - in range $260-300$ nm.

The second way is in placing into DOVID's structure of Concealed Laser-Readable Image (CLRI). It provides second-line inspection with portable laser-reading device. While CLRI is read it forms in both (+/- 1) orders of diffraction two identical statically or animated images.

Represents significant interest a synthesis of CGH restoring image only in one diffractive order or two different images in +1 and -1 orders of diffraction. For realization of this task, we have carried researches of methods of holograms' synthesis based on principles of Gilbert-optics. Based on these methods of the synthesis, the latent elements form on screen CLRI various images in the +1 and -1 orders of diffraction of laser radiation.

Samples DOVIDs with realization of the first and second ways of formation of the latent images are resulted.

6075-42, Poster Session

**Use of metameric filters for future
interference security images structures**

B. Baloukas, L. Martinu, École Polytechnique de Montréal (Canada)

The rise of criminal and terrorist activity as well as the progress in reprographic technology has strongly stimulated the need for new and enhanced security features to be incorporated in financial and identity documents. In the present work, we describe innovative approaches and properties that can be added to the already popular thin film Optically Variable Devices (OVD) used on banknotes around the world for their color-shifting effect.

We will show two practical examples of OVDs, namely (i) a pair of metameric filters offering a hidden image effect as a function of the angle of observation as well as a specific spectral property permitting automatic note readability, and (ii) multi-material filters offering a side-dependent color shift. In the first part, we specifically describe the design approach of these new devices. We present their sensitivity to deposition errors especially in the case of metameric filters, where slight thickness variations have a significant effect on the obtained colors. Since color depends on the source of illumination, a multiple illuminant analysis is also done. The performance of prototype samples prepared by dual ion beam sputtering (DIBS) will be described. This system being very versatile

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due to its second ion source (ion assist), we will also discuss the mechanical properties and stability of these filters with respect to their potential use on polymer substrates.

6075-01, Session 1

Feed back from the public for better banknote design

H. A. M. de Heij, De Nederlandsche Bank (Netherlands)

User input in banknote design is essential for better banknotes. Central banks are taking more-and-more initiatives to enter the field of consumer or market research on the public awareness of banknotes. Consumer input may be collected in different ways: with periodic surveys, with focus groups, in depth interviews and other ways. Several types of research have been used on the new euro notes; an overview will be presented. Key of the presentation are the three measurements done by De Nederlandsche Bank in 2002, 2003 and 2005 on the public's appreciation and knowledge of the euro banknotes. These Dutch measurements will be contrasted against the findings of former guilder notes and also to the findings of other recent consumer research done by the US Treasury (2002), Bank of Canada (2003) and European Central Bank (2004). A unique time line will be published demonstrating the public's knowledge of security features in the Netherlands over the years 1983 - 2005. Other subjects are:

- favourite security features of the public,
- most and least appreciated euro banknote,
- average knowledge of the public (security features, design and text elements),
- split in low and high denominations,
- emotions of banknotes (new measurement),
- public confidence in banknotes (new measurement),
- theme selection of banknotes.

The influence of public feed back in banknote designs is still limited but will certainly be noticed in the near future.

6075-02, Session 1

Robust and reliable banknote authentication and print flaw detection with opto-acoustical sensor fusion methods

V. Lohweg, Fachhochschule Lippe und Höxter (Germany); J. G. Schaeede, KBA-GIORI S.A. (Switzerland); T. Türke, KBA-Bielefeld (Germany)

The authenticity checking and inspection of bank notes is a highly labour intensive process where traditionally every note on every sheet is inspected manually. However with the advent of more and more sophisticated security features, both visible and invisible, and the requirement of cost reduction in the printing process, it is clear that automation is required. As more and more print techniques and new security features will be established, total quality security, authenticity and bank note printing must be assured. Therefore, this factor necessitates amplification of a sensorial concept in general. We propose a concept for both authenticity checking and inspection methods for pattern recognition and classification for securities and banknotes which is based on the concepts of sensor fusion and fuzzy interpretation of data measures. In the approach different methods of authenticity analysis and print flaw detection are combined which can be used for vending or sorting machines as well as for printing machines. Usually only the existence or appearance of colours and their textures are checked by cameras. Our method combines the visible camera images with IR-spectral sensitive sensors and acoustical and other measurements like temperature and pressure of printing machines.

6075-03, Session 1

The implication of direct laser engraved intaglio plates on bank note security

H. Deinhammer, Österreichische Banknoten- und Sicherheitsdruck (Austria)

Intaglio printing remained the key security element in banknote printing until today, providing the characteristic feel and tactility recognised by the public. Traditionally, platemaking for this very specific process was done by an electroforming process that involved multiple production steps and manual retouching. We have developed a machine to manufacture these printing plates by direct laser engraving into a metallic substrate. The first machine has recently been put into live banknote production at our premises.

We describe the changeover to this novel technology and give a thorough comparison of our findings on print-quality, plate stability and the workflow in direct comparison with conventional platemaking.

Results include

- Mechanical stress-tests of the new plate material before and after printing,
- Measurements of plate elongation during the printing
- SEM investigations on line-quality and surface topography and
- Whitelight interferometric 3D profiling of the engraved structures.

We conclude with actual data on engraving time and platemaking lead-times and an overview of the design possibilities using this new approach.

6075-04, Session 2

The circulation simulator method for evaluating bank note and optical feature durability

W. J. Bartz, Crane & Co., Inc.

Effective long-term authentication of optical security features on bank notes requires a sound substrate that can withstand the rigors of circulation. Crane & Co. has developed a test method that simulates the deterioration observed in actual circulated bank notes: soiling, creasing, tearing, edge tatteredness and limpness. The method relies on the physical degradation of note specimens that are weighted on each corner and tumbled in a medium of glass beads, metal discs and synthetic soil. Durability is judged by how well a note retains its initial optical and physical properties after being subjected to the conditions of the Circulation Simulator. Much of our early research was directed at improving the paper substrate, and evaluating surface treatments that resist soiling since excessive soiling is often the primary reason bank notes are removed from circulation. Recent work has examined the correlation between Circulation Simulator results and the properties of actual bank notes culled from circulation. We also are using the Circulation Simulator method to qualitatively evaluate the potential durability and effectiveness of optical security features such as electrotypes, watermarks, windowed threads, foils and inks. This presentation will provide a description of the test method and a detailed overview of these most recent results.

6075-05, Session 2

Visual and optical evaluation of bank notes in circulation

S. E. Church, M. P. Lacelle, T. Garanzotis, Bank of Canada (Canada)

A method for comparing quality of bank notes in circulation based on both a subjective visual sorting technique and on quantitative wear evaluations is described and applied to circulated Canadian

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bank notes. The sample notes, which were part of a \$5 circulation trial, issued over a 4-6 week period, had been in circulation for roughly 6 months. Notes were first sorted visually into four defined substrate categories (No Edge Wear, Corner Folds, Minimal Edge Wear and Edge Wear) and four surface wear categories (Soil Levels 1, 2, 3, and 4). Samples of each category were tested at Crane and Co. using a range of physical and optical techniques: air resistance, air permeability, stiffness deflection, double folds, gray scale, gray scale, brightness, perimeter length, and top/bottom mean and maximum deviations. The visual sorting showed that neither soiling nor ink loss are the major wear problems for bank notes in Canada. However, the substrate does become tattered and worn. The mechanical and optical wear tests show that most of the parameters change logically as the soil level increases. The changes for other parameters are less clear as a function of wear categories, but are relatively consistent in distinguishing between the No Edge Wear and Edge Wear. Impact of wear on security features will also be described.

6075-06, Session 2

The mechanisms of human recognition as a guideline for security feature development

J. G. Schaede, KBA-GIORI S.A. (Switzerland)

Security features for automated processing and / or forensic identification of bank notes have proven to reliably recognize and select counterfeit bank notes in circulation. As a result of this development the decisive first line of defense is the public, where either the criminal fraternities or opportunity counterfeiters try to place their antisocial products.

Educating the public in sophisticated, still well recognizable, security features has proven to be of limited success. The public regularly trusts the protective efforts of the government by proper bank note security and law enforcement to a degree, which leads to low awareness of the full range of available public features. Further it is human nature - not only in seasoned age - to forget.

Therefore those security features, which fit into the range of subconscious recognition and habitual knowledge, are those of major importance in application and development.

Evolution has formed the human recognition channels in a slightly different environment than our civilized world. The basic functionality of these channels are made such, that with the limited information available and in a short time we are able to create an internal image of our environment even of elements, which are only visible in traces (i.e. conclusions from foot print on the animal to hunt) This very basic capacity of the human brain (for example as described in :R. Grüsser Medienökologie Berlin, Mainz 1994) which are addressed as "pars pro toto" functionality of human recognition has to be considered, when we try to understand how human beings perceive bank notes and recognize value and authenticity. Recent research (Treinen : Perception of bank notes 2003) allow conclusions on these perception mechanisms, which include the use of habitual knowledge.

This paper tries to raise some questions how the human recognition, its well-developed functionality and how these through evolution-acquired capabilities may considerably influence the improvement of public security features in bank notes.

6075-07, Session 3

Qualification of security printing features

S. J. Simske, Hewlett-Packard Labs; J. S. Aronoff, Hewlett-Packard Labs.; J. Arnabat, Hewlett-Packard Co. (Spain)

This paper describes the statistical and hardware processes involved in qualifying two related printing features for their deployment in product (e.g. document and package) security. The first is a multi-colored tiling feature that can also be combined with

microtext to provide additional forms of security protection. The color information is authenticated automatically with a variety of handheld, desktop and production scanners. The microtext is authenticated either following magnification or manually by a field inspector.

The second security feature can also be tile-based. It involves the use of two inks that provide the same visual color, but differ in their transparency to infrared (IR) wavelengths. One of the inks is effectively transparent to IR wavelengths, allowing emitted IR light to pass through. The other ink is effectively opaque to IR wavelengths. These inks allow the printing of a seemingly uniform, or spot, color over a (truly) uniform IR emitting ink layer. The combination converts a uniform covert ink and a spot color to a variable data region capable of encoding identification sequences with high density. Also, it allows the extension of variable data printing for security to ostensibly static printed regions, affording greater security protection while meeting branding and marketing specifications.

6075-08, Session 3

Potentiality of holographic technique in fragile watermarking

G. Schirripa Spagnolo, Univ. degli Studi di Roma Tre (Italy)

Fragile watermark is designed to detect slight changes to the watermarked image with high probability. In the security community, an integrity service is unambiguously defined as one, which insures that the sent and received data are identical. This binary definition can also be applicable to images; however it is too strict and not well adapted to this type of digital document. Indeed, in real life situations, images will be transformed. Their pixel values will therefore be modified but not the actual semantic meaning of the image. In order to provide an authentication service for still images, it is important to distinguish between malicious manipulations, which consist of changing the content of the original image such as captions or faces, and manipulations related to the use of an image, such as format conversion, compression, filtering, and so on. Unfortunately this distinction is not always clear; it partly depends on the type of image and its use.

Scope of this paper is to present potentiality of Holographic technique in fragile watermarking for digital image authentication of medical or military images. Furthermore, we propose asymmetric cryptography as subset of Holographic Watermarking so that the integrity and ownership of the image can be verified using a public key.

6075-09, Session 3

Secure graphical data storage by full-spectrum image coding

H. Oltmans, Consultant (Netherlands)

Full Spectrum coding is a method of providing a picture with a machine readable code image. The transparency and robustness of the code can be influenced by the embedding parameters, according to the intended application (e.g. robust or fragile marking).

The code image contains hidden information, identifying the document in some way. In principle, it can be any binary pattern or grey-scale picture. Alternatively, it may be desirable to encode (binary) data, e.g. ID numbers or (biometric) templates. Such data should be transformed into a code image suitable for the proposed kind of embedding. In the presented implementation, the code image contains a binary block structure, similar to a 2-dimensional (bar) code. Even in the presence of noise, this code can be extracted from the magnitude-spectrum of the captured image by iterated down-sampling.

Full Spectrum is well-suited for application to printed documents. It survives graphical processes (halftone screening, printing / digitizing) and the reconstructed code image is invariant to shifting

and robust to cropping. A technique is presented to perform registration for rotation and scaling of the captured image with respect to the original. The approach is to embed a marking signal based on perfect-correlation sequences in the radial-polar representation of the code image. In this domain, the rotation angle and (under certain conditions) the scale factor, can be determined by linear cross-correlation. Additionally, techniques are proposed to obtain resistance to more general distortions.

6075-10, Session 3

Sub-pixel analysis to support graphic security after scanning at low resolution

R. A. Cordery, Pitney Bowes; S. K. Decker, Digimarc Corp.; B. Haas, Pitney Bowes; H. Gou, Univ. of Maryland/College Park

Whether in the domain of audio, video or finance, our world tends to become increasingly digital. However, for diverse reasons, the transition from analog to digital is often much extended in time, carefully proceeding step by step (steps which sometimes seem to never complete). One such step is the conversion of information on analog media to digital information. We focus in this paper on the conversion (scanning) of printed documents to digital images.

Analog media have the advantage over digital channels that they can harbor much imperceptible information that can be used for fraud detection and forensic purposes. But this secondary information usually fails to be extracted during the conversion step. This is particularly relevant since the Check-21 act (Check Clearing for the 21st Century act) became effective in 2004 and allows images of checks to be handled by banks as a usual paper check.

We use here this situation of check scanning as our primary benchmark for graphic security features after scanning. In a first section we will present a quick review of the most common graphic security features currently found on checks, with their specific purpose, qualities and disadvantages, and we demonstrate their poor survivability after scanning in the average scanning conditions expected from the Check-21 Act.

In a second section, we present a novel method of measurement of distances between and rotations of line elements in a scanned image: Based on an appropriate print model, we determine expected distances, periodicity, sharpness and print quality of known characters, symbols and other graphic elements in a document image to refine direct measurements to an accuracy beyond the size of a scanning pixel.

Finally, in the last section, we apply our method to fraud detection of documents after grey-scale scanning at average resolution. We show in particular that alterations on legitimate checks or copies of checks can be successfully detected by measuring with sub-pixel accuracy the irregularities inherently introduced by the illegitimate process.

6075-11, Session 3

New applications of modulated digital images in document security

R. Lee, P. W. Leech, L. D. McCarthy, G. F. Swiegers, Commonwealth Scientific & Industrial Research Organisation (Australia)

In the 2004 conference in this series, we described the selective masking, or modulation, of digital images as a means of creating documents and transparent media containing overt or covert images. In the present work we describe and demonstrate various new and refined applications of such Modulated Digital Images in document security applications. In particular, we show how multiple hidden images can be concealed as half-tone printing within branded and consumer products, or as concealed watermarks for identity- and authenticity-verification. Such hidden images may contain a variety of novel features that hinder unauthorized copying,

including concealed microprinting-, animation-, colour-, and various fade-effects. Overt, optically-variable images of similar type may be created using suitable printing and embossing methods. We also report new techniques in which a combination of electron beam and greytone lithography, as well as wet chemical etching are used to create multiple hidden images in embossable form. We further report the development of an optically variable technology in which an electron-beam-originated master dye is used to emboss a series of dithered images, each of which consists of distinctly-sloped micropisms, into polymer substrates. Physical examples of the so-called Biometric OVD, which was previously described in concept, are demonstrated.

6075-13, Session 4

The role of optics in secure credentials

T. L. Lichtenstein, LaserCard Corp.

LaserCard Corporation has pioneered the development of a highly-tamper resistant optical data storage medium that can incorporate multiple security features to greatly enhance the counterfeit resistance of ID documents. Some of the highest profile secure ID card applications - the US green card being a prime example - have contributed to LaserCard's unequalled reputation in forensic circles as the most secure card technology available today.

This security is based upon LaserCard's WORM (Write Once Read Many) non erasable recording medium. A combination of laser ablation and sophisticated microlithography techniques produce very high resolution (12,000 dpi) features that cannot be replicated by conventional printing processes. Custom secure data encoding formats, diffractive patterns, personalized optical variable devices, and fine line security patterns - such as guilloche, micro images and text - represent a layered approach that satisfy the most stringent overt, covert and forensic inspection requirements.

This unique combination of visual and digital security ensures that optical memory provides a bridge from today's reality (where 95% of ID documents are inspected visually) to the automated inspection environments planned for tomorrow.

This paper will review these features, highlighting the fact that there is no known example of LaserCard optical memory security having been compromised.

6075-14, Session 4

Practical use of lens structures in ID documents

J. van den Berg, SDU Identification (Netherlands)

Polymer ID-documents mostly are made of plastic foils which are laminated to one massive card by applying heat and pressure. During this lamination process, some structures can be transferred from the metal laminating plate to the card surface. These structures can be shaped in the form of a lens. Both are possible, positive as well as negative lens structures, for example in the form of lines or (micro) text. Also lens arrays of cylinder lenses can be made.

The lens structures can be combined with the security design which is printed on the document, resulting in optically variable effects of moiré patterns. Also these lens structures can be combined with laser engraving during personalization of the document. In this way it is even possible to personalize the document with a stereo photo, the so called stereogram. The tactility of the structures on the ID-document, combined with the optical effects, makes these structures a very strong first line security feature. This kind of security features are completely integrated into the card body and combined with the personalization, which make them hard to manipulate by counterfeiters.

Because of the fact that the human eye can handle images with a lot of noise, the optical quality of the lenses as well as the focal point seems to be less important.

6075-15, Session 4

Three-dimensional floating images as overt security features

D. S. Dunn, T. L. Potts, L. E. Lorimor, J. M. Jonza, R. L. Smithson, S. P. Maki, 3M Co.

3M has developed a proprietary laser process for creating three-dimensional images that appear to float above and/or below the plane of a substrate containing an array of microlenses. During the imaging process the laser records a microscopic image of the desired three-dimensional pattern in the material located at the focal point of each microlens in the array. The images exhibit motion parallax comparable to that seen from holograms and are easily visible in a wide range of ambient lighting conditions. The images are therefore similar, but not identical, to integral images, first proposed in 1908 by Lippmann. The fidelity of these floating images requires maintaining exact registration between the microlens array and the corresponding microimage array. In addition, the use of an ablative laser process for the production of the microimages enables the production of microimage features smaller than the diffraction limit (approximately 50,000 dpi). The images are therefore very difficult to simulate, counterfeit, or modify and are highly desirable as an overt security feature. 3M has scaled up the floating image process to produce images in Confirm-- Retroreflective Security Laminate to authenticate passports and driver's licenses and in retroreflective license plate sheeting as the Ensure-- Virtual Security Thread to authenticate vehicle registration. This allows addition of features to a secure document that are easily verifiable, using only the human eye, by a large and widely dispersed population to create an identity document that is easily identified as genuine.

6075-16, Session 4

Development of the random-retardation-encoding anti-counterfeiting technology

W. Huang, C. Tsai, T. Chen, M. Kuan, C. Wen, Industrial Technology Research Institute (Taiwan)

In our daily life, anti-counterfeit issue is very important in many domains. In order to conceal the authentication pattern in a manner not to be directly visible and difficult to falsify, we designed and fabricated an authentication pattern in an optical retardation film. In the experiments, the authentication pattern was divided into two parts with different random retardation distribution. The two parts of random retardation pattern were fabricated on two separate films. One of them can be used as the authentication tag, and the other is used for the identification of the authentication tag. Because the resolution of the random retardation pattern can be made very high, it's very hard to counterfeit the authentication tag without knowing the original design pattern. In addition, the transparency property of the retardation film makes it easy to be integrated with other anti-counterfeiting method, e.g. it can be laminated on a hologram without destroying the visual performance of the hologram while the authentication function of the retardation film is still maintained.

In this paper, we use the reactive liquid crystal as the material of the retardation film. UV and thermal processes in Nitrogen environment are adopted to fabricate retardation pattern of micro scale. Good performance in the concealing and recognition of the authentication pattern was also established.

6075-37, Session 4

Black fluorescent ink and applications

J. Auslander, R. A. Cordery, Pitney Bowes

We initially developed BFI inks, that are visually black and red-fluorescent, for use in postal indicia applications. In processing a mail piece, the postal service needs high readability of the 2D bar code in the indicium for both providing services and for verification

of postage payment. The fluorescence of the indicium is used to signal the presence of an indicium on the envelope which allows the envelope to be oriented and indicates the mode of postage payment.

The ink compositions are such that quenching of the fluorescence is largely inhibited, and competition among the various dye components for ultraviolet is avoided. The resulting images exhibit bright fluorescence in spite of their black visual appearance. There seems to be no commercial incentive to produce visually dark fluorescent inks for general use in graphics. Therefore, these inks could remain unique and only available for specific security applications.

Fluorescent ink jet printable inks that produce images that are machine readable in diffuse reflectance have applications beyond mail. An image printed with BFI ink can be viewed under white light and ultraviolet light. The dual readability, in diffuse reflection and in fluorescence, enabled by this ink can be used for security and information hiding. In this paper we present applications of BFI enabled by dual readability.

These inks render a visible dark image and fluorescent bright image that are exactly coincident and constitute positive-negative image pairs. This image coincidence can be verified both visually and by machine-reading, providing a means of detecting imitations. Typical imitations may use common black printing against a fluorescent background or black printing overprinted with a fluorescent material.

Information-based verification of cryptographically protected printed information allows verification of data integrity, authentication of the source of the data and consistency of the data with associated data. Yet, such comparison does not reveal whether the print is original or a copy. The application of the present ink immediately reveals duplicates.

A verifier detects copies of a security marking by acquiring an image of the security marking in the visible wavelength range under of visible light illumination and acquiring a second image of the security marking from the fluorescent emission under ultraviolet illumination. The two images are then compared to detect copies of the security marking. The relative sizes of the two image segments will provide a detectable difference in fluorescent image sharpness. These machine-readable fluorescent inks thus provide a protective measure against undetectable copying and simulation of valuable documents.

BFI ink can be combined with regular black ink for information hiding. Because the regular black ink and BFI ink are visibly very similar, the hidden fluorescent image is not discernible under ambient light. Under UV light it the fluorescent image stands out with a high contrast ratio.

Methods for printing documents with fragile watermarks that can be authenticated automatically (not by forensic means) are also described.

6075-17, Session 5

Advanced verification methods for OVI(r) security ink

P. G. Coombs, Flex Products/JDS Uniphase Corp.; S. F. McCaffery, JDS Uniphase Corp.; T. Markantes, Flex Products/JDS Uniphase Corp.

OVI(r) security ink, incorporating OVP(r) security pigment microflakes, enjoys a history of highly-effective document protection. This security feature provides not only first-line recognition by the person on the street, but also facilitates machine-readability. This paper explores the evolution of OVI reader technology from proof-of-concept to miniaturization.

Three different instruments have been built to advance the technology of OVI machine verification. A bench-top unit has been constructed which allows users to automatically verify a multitude of different banknotes and OVI images. In addition, high speed

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modules were fabricated and tested in a state of the art banknote sorting machine. Both units demonstrate the ability of modern optical components to illuminate and collect light reflected from the interference platelets within OVI ink. Electronic hardware and software convert and process the optical information in milliseconds to accurately determine the authenticity of the security feature.

Most recently, OVI ink verification hardware has been miniaturized and simplified providing yet another platform for counterfeit protection. This latest device provides a tool for store clerks and bank tellers to unambiguously determine the validity of banknotes in the time period it takes the cash drawer to be opened.

6075-18, Session 5

Overt security features through digital printing

R. A. Einhorn, M. J. Hampden-Smith, S. Haubrich, J. Shah, R. Bhatia, N. Hardman, R. Kornbrekke, Cabot Corp.

Digital printing technology is seen as a significant counterfeiting threat. It is not uncommon to hear of someone trying to counterfeit security documents on their home computer using a low cost ink jet printer. The quality of the ink-jetted counterfeit is typically very poor and is spotted almost immediately, but it is still a threat. But not all digital printing is the same and given digital printing's capabilities to incorporate variable data and imagery a closer look at possible uses of digital technologies to create new security has been conducted. Specifically the use of industrial, high performance digital printing technology has been modified to create new overt features. Not only is the printing technology not readily available, the inks used to create the features are specifically designed for these printers and to NOT work in small-office, home-office printers. The particles used in these inks are made by a unique process and are also designed only for these types of inks and have limited commercial availability. Combining a unique printing process, limited-access materials made by unique manufacturing techniques, and the actual design of the features makes these digital, variable-data features viable security features.

6075-19, Session 5

Novel particulate production processes to create unique security materials

M. J. Hampden-Smith, T. Kudas, S. Haubrich, M. Oljaca, R. A. Einhorn, Cabot Corp.

Security features are often created using unique, expensive, difficult and sometimes obsolete technologies. Intaglio printing and optically variable pigments are examples of unique and expensive processes used in security printing. A new method to produce security particles has been developed to large-scale capability. This process, called spray pyrolysis, is not only unique and difficult to replicate, its use also results in unique particles with unique features that cannot easily be replicated by the conventional processes used today. In addition, the particles made by spray pyrolysis are typically spherical, have smaller particle size and a tighter size distribution. These features aid in the reproducible printing / coating of these materials. This presentation will describe the spray pyrolysis and several examples of the security features possible.

6075-20, Session 5

Combining overt and covert anti-counterfeiting technologies for securities

T. Uematsu, National Printing Bureau of Japan (Japan)

National Printing Bureau of Japan has developed overt and covert anti-counterfeiting technologies. We present new technologies to prevent counterfeiting by combining three kinds of security features,

such as "Metallic View", "Microstructural Lines involving Luminescence" and "Imageswitch".

Metallic View: This is an optically variable feature using offset printing inks. The differences in gloss between mirror and diffused reflection from the combination of ordinal and metallic offset printing inks give rise to the optically variable features. Consequently, different images observed at a given prospect angle can be embedded into the printing matter.

Microstructural Lines involving Luminescence: This is an anti-copy technique using microstructural security lines with luminescent inks. These lines comprising from tri-branched and divided lines show clearer hidden image compared to that of other anti-copy lines, and furthermore, when they are exposed under the ultra violet light, a clear hidden image emerges.

Imageswitch: "Imageswitch" is our newly developed covert security solution regarding security documents with secure unique information. It provides ID security documents with gradational hidden image under infrared rays. The security feature is based on its highly sophisticated and domestically designed software to generate characteristic screen. The major advantage of this technique lies in the ability to output ID security documents with purchasing facilities and materials.

6075-21, Session 5

Bacteriorhodopsin-based multilevel optical security features

N. A. Hampp, M. Neebe, I. Yang, Philipps-Univ. Marburg (Germany)

Bacteriorhodopsin (BR) is a crystalline photochromic protein which shows an astonishing stability towards chemical and thermal degradation. This material is used in a variety of applications which have been developed, among them photochromic color changes, optical data storage and molecular traceability of the material. Integration of all three security levels in a document will be shown. One year long lasting field test have proven the stability of the system in daily use. First applications of polarization encoded data storage and data encryption have been realized successfully. The development of BR-based security features will be reviewed and newer developments will be presented, among them individualized computer generated holograms and the development of ink-jet inks. The data storage capabilities of the biomaterial BR have been further developed and now visual detectable as well as visual non-detectable storage processes are available. The molecular mechanisms of the data storage process will be presented.

6075-22, Session 5

Optical security in ink: an industry standard that continues to evolve

M. Schmid, SICPA SA (Switzerland)

The level of security against counterfeiting and forgery that is provided by optically variable ink has led to this technology becoming the industry reference for the protection of value documents. For this ink to be secure, it must obviously differentiate itself from inks used for purely decorative purposes. Hence, the inks used for protecting value documents have intense, saturated colours that lie within a specified and restricted colour range, a very wide colour travel, and can be identified with the naked eye or specific optical filters. These characteristics are achieved with sophisticated technologies that result in pronounced optical interference effects. For instance, vacuum deposition techniques are used to produce interference pigment flakes that create the distinctive colours and wide colour travel. Another technology, based on liquid crystal pigments, displays rare and specific characteristics under a polarising filter. Ink chemistry and formulation provide the foundation of the security feature. This foundation is then combined with different printing and industrial techniques to create even high

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security. Building on the proven basis of intense, saturated colours and wide colour travel, optically variable inks offer the flexibility to combine the creativity of graphic artists with the know-how of security printers and breakthroughs in printing technology to create ever more secure features that can be easily and readily authenticated by the public.

6075-23, Session 6

Current use and efficacy of optical security devices

I. M. Lancaster, Reconnaissance International Ltd. (United Kingdom) and International Hologram Manufacturing Association (United Kingdom)

The paper will comprise two parts, the first establishing the framework for the second.

In the first part a taxonomy of authentication and inspection will be proposed. This will examine the function of each part of the authentication continuum which spans overt, semi-covert, covert and forensic features. The paper will then focus on the role and function of overt optical features, which includes printed designs, labels, colour-shifting inks and OSDs. The final section of this first part will concentrate on OSDs and their part in authentication and protection of documents and products. Especially their role as a visible feature in reassuring the public that a given item is genuine.

Then the paper will examine the current use of OSDs worldwide, giving examples of government-issued documents, fiduciary documents and branded or OEM products which use a hologram or similar optical device to enable the genuine article to be differentiated from fake items. After a brief history to show the growth in usage worldwide we will give case-studies which will show that OSDs continue to be an effective means of detecting fakes. These case studies will include a review of the Meditag(tm) project in Malaysia, which is effectively an experiment in the use of an OSD within a coherent national strategy to prevent fake medicines from reaching the public.

The paper will confront the issue of counterfeit OSDs and the threat they pose to their continued use, which is based on misconceptions of their function. Designers and producers of OSDs have contributed to these misconceptions by failing to recognise that a passable product does not have to be a 100% accurate copy, and thus misleading users and issuers. The conclusion of the paper will refer to the taxonomy of part one in providing a conceptual framework for the use of OSDs.

6075-24, Session 6

The security enhancement of diffractive optically variable image devices

A. Argoitia, R. W. Phillips, Flex Products/JDSU

It is well known that Diffractive Optically Variable Image Devices (DOVIDs) can be copied, duplicated or simulated by the counterfeiters. Some customers consider that such devices are no longer secure and will not use them to protect their product. To avoid counterfeiting, DOVIDs are being made more complicated with the introduction of a large number of images simultaneously, where the recognition by the customers is strongly compromised. Future trends appear to favor multiple technologies in one device that while allowing the consumer to readily identify and remember the device. One approach calls for a combination of the diffractive foil interference found in DOVIDs with thin film interference to create new security devices called SecureShift™ ChromaGrams. A second approach calls for a combination of diffractive and thin film interference in the form of pigments combined with magnetic fields during the printing process to create another new security device called a "PrintaGram"

Each type of enhanced DOVIDs will be discussed in terms of its optical performance, manufacturability, its counterfeit deterrence, and its application.

6075-25, Session 6

The Aztec structure: an improved replicable security device

J. J. Cowan, Aztec Systems, Inc.

Holograms that are predominantly in use today as visually identifiable security devices can generally be divided into two categories: either surface relief rainbow holograms or reflection type volume holograms. The Aztec structure is a special surface relief device that combines aspects of both of these types. It has unique identifying characteristics, with provision for great difficulty in counterfeiting, which make it more secure. Its fabrication by holographic means requires techniques of both surface and volume holograms, thus is technically more difficult to make than either separately. The structure is deeper than the standard surface relief hologram, and its profile has the characteristic of several well defined steps, such that, when viewed on edge, resemble a stepped pyramid. Thus, replication of the Aztec structure requires special high resolution techniques to faithfully record the submicron features of the stepped profile, and thus is more difficult to manufacture. The visual characteristics of the Aztec structure are similar to the volume hologram, in that single colors, rather than rainbow colors, can be viewed. Also, a combination of single colors can be encoded into a single master, yielding unique visual effects.

6075-26, Session 6

Combination of optically variable diffractive and multilayer interference structures: a new class of security devices

V. I. Girnyk, Optronics, Ltd. (Ukraine); R. W. Phillips, JDSU-Flex Products Group; E. V. Braginets, Optronics, Ltd. (Ukraine) and National Kiev Taras Schevchenko Univ. (Ukraine)

Modern progress in the field of nanotechnologies allows us to generate precision diffractive and interference microstructures which provide the recording of OVD with unusual optical effects and at the same time are very difficult to forge. On the other hand, progress in the field of Interference Security Image Structures (ISISs) creation opens the way for creation of new protective element - Chromagram, which is harmonious combination of all the best DOVIDs and ISISs features.

In our researches, for DOVID we use Polygram(tm) - is about exquisite design based on high resolution (10,000,000 pixels per square inch). Our researches have shown, that the diffractive DOVIDs structures and interferential structures ISIS are better spatially divided, using for ISIS demetalized Polygram(tm) parts. For successful usage of the ISISs in Chromagram we researched the physical properties of ISIS as independent, interactive elements of diffractive and interferential structures. Color shifting effects in thin films are based on multi-dielectric low-high pairs or on Fabry Perot designs. Fabry Perot designs, however, allow intense colors at low layer count. These designs involve at least one reflector (R) and at least one or more dielectric spacer layers (D) with one or more semi-transmitting, semi-reflecting layers (A). Three layers designs of the type A/D/A or A/D/R and five layer designs of the type A/D/A/D/R can be made as a foil. Symmetrical designs of the type A/D/A, A/D/R/D/A and A/D/A/D/R/D/A/D/A can be formulated into optical pigments for use in color shifting inks.

6075-27, Session 7

Novel optically variable color devices

M. Stalder, F. Seils, Rolic Technologies Ltd. (Switzerland)

The recently introduced ROLICURE(tm) PEARL is a novel optically variable device (OVD) ideally suited for security applications. It may hold high resolution images, (micro-) text or graphical designs. Upon tilt or rotation high contrast positive/negative flips are observed. The optical effect of these devices is based on a proprietary technology of Rolic and includes light scattering at patterned anisotropic microstructures. Since these microstructures are non-periodic no rainbow colors are generated, making these devices easy to authenticate and clearly distinguishable from standard holograms.

In this paper, we describe how to modify the optical appearance of our - a priori - colorless ROLICURE(tm) PEARL feature by addition of distinct color-shift thus further increasing its level of protection and meeting design requirements. This is accomplished by optical interference at additional dielectric and metallic layers in combination with the ROLICURE(tm) PEARL scattering microstructure. Various configurations are conceivable and have been realised in our labs. Depending on the nature of its dielectric layers red, green and blue colors are obtained and respective photospectra will be presented. While the optical appearance remains attractively bright, excellent color saturation is achievable. Independently from the color-shift which originates from changes of the optical path length under various viewing angles, the contrast inversion of the image is still present and is visualized when the device is tilted or rotated. In general, images of these security devices are easily recognizable within wide viewing angles without need of a point light source.

6075-28, Session 7

Diffraction Moiré features for optically variable devices

A. Schilling, W. R. Tompkin, R. Staub, OVD Kinegram AG (Switzerland); R. D. Hersch, S. Chosson, I. Amidror, École Polytechnique Fédérale de Lausanne (Switzerland)

We present diffractive second-line security features based on the moiré phenomenon designed for use in Optically Variable Devices (OVDs).

We first present line-based, 1-D animated moiré patterns within diffractive OVDs. These covert features are verified using a printed, high-resolution screen, which causes the covert information to become visible. When the screen is translated, the covert information appears to move dynamically. This diffractive, animated moiré feature is integrated into OVDs with visual first-line security features.

We present diffractive OVDs where moiré features are integrated into graytone images. Such an integration has the advantage that the area, where the second-line security effect is contained, can be used for a attractive first-line effect. Additionally, one creates a link between the first and second security levels, which enhances the security of the OVD. The integrated diffractive moiré features are verified with a 2-D microlens array through which the OVD is viewed.

Finally, we demonstrate a diffractive moiré-feature, where the 2-D microlens verifier is used in a fixed combination with the information layer, which consists of diffractive microstructures. Such a diffractive moiré-feature convinces through the unique visual impression that it creates where projected images appear to move and transform as the OVD is tilted.

6075-29, Session 7

Combination of e-beam and optical holography on micro- and macro-levels of OVD

E. V. Braginets, V. I. Girnyk, Optronics, Ltd. (Ukraine) and National Taras Shevchenko Univ. (Ukraine); B. Holmes, De La Rue International Ltd. (United Kingdom)

Combigram - technology, based on combination of optical hologram's aesthetic appeal advantages at macro level and a powerful selection of protective features of e-beam holograms.

At the beginning creation process was consist of combining the foreground - e-beam holography with the background - optical holography and using the non-organic chalcogenide registry mediums. This combination, in principle, enabled Combigram's production, but was not perfect technologically. Low sensitivity of the HGS resist to the e-beam exposure, made it difficult to record the 3D CGH holograms and any large numbers of digital information, which limited the ability of the e-beam holography.

The research work continues on to the development and creation of the Combigrams recording methods, on to the organic resists with information capacity of 10 000 000 per square inch, in time that is technically affordable. Methods that provide the positional precision between the optical and electronic parts up to +/-0,2 mm were designed. Optimal structure of resist plates was researched. These researches allowed to determine the exposure energy (20 mC/cm²) for e-beam holography, and optimal development conditions. Methods of the gain-frequency characteristic correction, which provide the recording density up to 3500 lines/mm, were created. Combigram samples with these parameters are provided.

6075-30, Session 8

Choosing the correct forensic marker(s) in currency, document, and product protection

J. J. Plimmer, Product & Image Security Foundation (United Kingdom)

The use of forensic markers as authenticity agents in document and product provenance protection is gaining increased acceptance. There is now a wide choice to be made from a variety of technologies available from a number of suppliers. What criteria should be employed to aid the selection of the most appropriate technology?

There are presently six competing categories of technology:

- Organic Molecular Markers
- Inorganic Molecular Markers
- Miniature Nameplates
- Radioactive Tracers
- NanoTechnologies
- Nano-Coatings

Applications include:

- Tags to authenticate items (products)
- Tags to authenticate materials (papers, inks and boards)
- Tags to authenticate data (toner and other non impact data applications)
- Tags that provide discrete (instant) authentication with hand held devices
- Tags that can only be identified under laboratory conditions
- Tags that provide continuous authentication in machine sortation systems
- Tags that can be embedded in liquid products
- Tags that can be embedded in powder or granular products
- Tags that can be 'engineered' to specific client profiles

6075-31, Session 8

Overview and analysis of intellectual property in security embossed holography

N. O. Reingand, D. Hunt, Landon IP, Inc.

The paper provides a brief overview of worldwide Intellectual Property centered around Embossed Hologram for security. Worldwide IP was selected by means of comprehensive search of patents and published applications. It includes a review of thousands of patent documents granted or published by USPTO, EPO, JPO, and WIPO from January 1971 to November 2005. EAST database in United States Patent Office building Search room was used to perform this search. Micropatent and Delphion databases and processing tools were applied for the data evaluation and analysis. Almost two thousands of patents were processes and evaluated.

The patents retrieval itself is not a complicated process, however combined with statistical processing features offered by modern software, it allows to make an interesting observations and conclusions on the existing trends and development perspectives, to unveil the companies aggressively penetrating the market or, on opposite side, to guess on departments/companies closure basing on the information on shriveled patent application flow.

The goal of this paper is provide more sophisticated study. The patents are categorized into three major invention types: product design, manufacturing method, and applications; and then further splitted into subcategories within each large category. These results show the technical areas crowded with patents and some others forgotten by inventors, which open the door for start-ups. Top assignees' patents distribution over the technical categories show the areas considered the most progressive and investment rewarding from the point of view of large companies.

Analysis of the patent landscape is significantly helpful in developing strategic plans for:

- Research and development (R&D) programs
- Business alliances
- Licensing strategies
- Mergers and acquisitions (M&A) strategies.

6075-32, Session 8

Life recognition based on color variations in fingerprint images of live and artificial fingers

K. Tai, M. Kurita, I. Fujieda, Ritsumeikan Univ. (Japan)

Higher security is desired for unattended fingerprint identification systems. In a series of fingerprint images obtained during an input action, the color and the area of the fingerprint are correlated and this fact can be utilized for life recognition. We have proposed several criteria, some of which check the variations in the chromaticity coordinate x and the luminance Y and others check the areas surrounded by the trajectories of x , Y and A/Y in the plots of these values versus the fingerprint area A . To see how these criteria work, we fabricated several replicas that imitated the color and elasticity of a live finger. Here, a fingerprint sensor based on scattered-light detection was used. With the threshold values set previously for rejecting one particular replica, some other replicas occasionally passed as live fingers. We redefined the threshold values so that all the input-trials with all the replicas were properly rejected. When we tested the input-trials by more than 30 participants with these stricter criteria, the index $+x$ (the difference in the chromaticity coordinate x during an input-action) gave the highest acceptance ratio of 82.9%. Design considerations for sensor hardware and recognition criteria are discussed for improving the performance.

6075-33, Session 8

RFID identity theft and countermeasures

A. Herrigel, Up-Great AG (Switzerland)

Different government organizations and ICAO have published in the last two years a growing number of specifications and deployment guidelines for RFID based biometric passports. Some authors have questioned the approach since they conclude that a higher security level of the travel documents results in a privacy loss of the machine reader travel document owner. Unauthorized third parties may exploit this privacy loss and jeopardize the security of the biometric passports. This paper first reviews the security architecture of biometric passports specified by ICAO. An attack enabling RFID identity theft for a later misuse is then presented. Specific countermeasures against this attack are described. It is shown that robust high capacity digital watermarking can be applied as a very effective mean against RFID identity theft. The solution requires only minimal modifications of the passport manufacturing process and is an enhancement of already proposed solutions. It is shown that the approach may also be applied as a backup solution (damaged RFID chip) to verify with asymmetric cryptographic techniques the authenticity and the integrity of the passport data.

6075-34, Session 9

On the use of mobile imaging devices for the validation of first and second line security features

T. F. Rodriguez, M. Weaver III, Digimarc Corp.

The proliferation of mobile imaging devices combined with Moore's law has yielded a class of devices that are capable of imaging and/or validating many First and Second Line security features. Availability of these devices at little or no cost due to economic models and commoditization of constituent technologies will result in a broad infrastructure of devices capable of identifying fraud and counterfeiting.

The presence of these devices will influence all aspects of design, production and usage models for value documents, as both a validation tool and as a mechanism for attack. To maximize the value as a validation tool, a better understanding is needed as to the technical abilities of these devices and which security features and design approaches favor them.

As a first step in this direction, the authors investigate the use of a specific imaging equipped cellular telephone and PDA as a validation tools for identity documents. The goal being to assess the viability of the device as a mechanism to identify photo swapping, image alteration, data alteration and counterfeiting. To accomplish this, security printing techniques such as Digital Watermarking and micro-printing are leveraged along with the presence of an Optically Variable Device.

6075-35, Session 9

Facets of color laser marking in high secure ID documents

F. Kappe, M. Schumacher, ORGA Systems enabling services GmbH (Germany); K. Schäfer, M. Hillebrand, M. Hennemeyer-Schwenkner, D. Fischer, Orga Systems GmbH (Germany)

Our new true color laser personalization system (CYMart--) for ID cards and documents doesn't suffer from producing only black and white images as it is known from state of the art personalization systems, which use Nd-YAG lasers. These well-established black and white laser-marking systems are treasured so much because the marking is created inside the material. Therefore, it is protected from

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counterfeiting and tampering. In exact the same manner CYMart-- features an embedded image.

CYMart-- is based on a three-wavelength laser system, one for each primary color (red green and blue). A deflection system is used to direct the focused beams onto the document. The wavelength sensitive color forming process generates true color images comprised of a combination of the 3 primary colors. The color of any image element can be determined by the intensity of each laser beam.

Unlike conventional laser marking with CYMart we are able to mark square shaped dots. So far due to the gaussian beam of the laser source the marking was done with circular beam shape, which have a non-uniform intensity profile. However, this profile results in inhomogeneous gray level of each marked dot. By introducing an aspherical phase plate into the laser beam we have the opportunity to manipulate the light and realize square shaped dot, which have a uniform intensity profile. This enables us to mark an area with seamless transitions and without any color deviation.

6075-36, Session 9

Protection of data carriers using secure optical codes

J. A. Peters, A. Schilling, R. Staub, W. R. Tompkin, OVD Kinegram AG (Switzerland)

Smartcard technology, combined with biometric-enabled access control systems, are required for many high-security government ID card programs. However, recent field trials with some of the most secure biometric systems have indicated that smartcards are still vulnerable to well equipped and highly motivated counterfeiters. In this paper, we present the Secure Memory Technology which not only provides a first-level visual verification procedure, but also reinforces the existing chip-based security measures. This security concept involves the use of securely-coded data (stored in an optically variable device) which communicates with hashed information stored in the chip memory via a smartcard reader device.

The paper first analyses the potential attacks on chip-based ID documents, such as the electronic passport, and then describes the approaches to enhancing the document security using the Secure Memory Technology. Various methods for personalizing and verifying the secure codes are discussed. Finally, the functionality and reliability according to a specific application requirement are evaluated.

6075-38, Session B

Optically variable threads and polarization effects

F. Kretschmar, Louisenthal GmbH (Germany)

Optically variable threads are well known for banknotes. Louisenthal will report on a new generation of add-on features for unmistakable authentication.

6075-39, Session B

Public education by Central Banks on the Internet

R. L. van Renesse, VanRenesse Consulting (Netherlands)

The Internet is the most powerful medium of information today and has enormous potential in conveying information as still images, video clips and applets. An investigation was carried out of the information provided by 133 Central Banks on public security features of their currency. Many Central Banks provide no

information at all, some only provide written information and some indeed provide illustrations. It appears that even the illustrated information provided by Central Banks often lacks the most elementary requirements: obviousness, clarity and adequate visual representation of the intended effects. As a result, the information made available by issuing authorities on the internet remains largely ineffective and - on occasion - assumes silly proportions.

Part of Proceedings of SPIE Vol. 6076 Digital Publishing

6076-01, Session 1

E-books and the challenge of preservation

F. Romano, Rochester Institute of Technology

The introduction of the so-called e-book—that is, a book that can be read on the screen of a computer, PDA, cell phone, or any electronic device—has brought with it new challenges for access and preservation. This paper discusses the relevant issues and provides a historical background on the evolution of the electronic book.

(please see attachment)

6076-02, Session 1

User centered design of the digital book: why looking backward can help us move forward

J. C. Wallis, Univ. of California/Los Angeles

What is emerging from the digital book revolution is a state of technology that has brought new affordances to the book, such as search, hyperlinking, personalization, dynamic content, 24/7 access, automated indexing and summarizing, aggregated content, and new modes of reading and access. These could solve some of the issues users have with the static content of traditional bound volumes. But technology so far has staunchly ignored the tried and true technologies of books, such as infinite resolution, high contrast, low glare, haptic navigation, typographic niceties, and the rights of first sale to borrow, lend, or resell a work. By exploring a survey of literature, reviews, and user tests, I intend to address the point of how the current concept of the digital book is an inappropriate tool for the user and the task of reading, and as a result not been enthusiastically embraced by the market. The collected evidence indicates that it is impossible to forget our past in our quest for the future, and that technology can help us to unite the disparate realities of analog and digital to create a truly digital book.

6076-03, Session 1

Interactive publications: creation and usage

G. R. Thoma, G. Ford, M. Chung, K. Vasudevan, S. K. Antani, National Library of Medicine

As envisioned here, an “interactive publication” has similarities to multimedia documents that have been in existence for a decade or more, but possesses specific differentiating characteristics. It is a self-contained document, either as a single file with media files embedded within it, or as a “folder” containing tightly linked media files. With an interactive publication the reader may reuse the media content for analysis and presentation, and to check the underlying data and possibly derive alternative conclusions. We have created prototype publications containing paginated text and several media types encountered in the biomedical literature: 3D animations of anatomic structures; graphs, charts and tabular data; cell development images (video sequences); and clinical images such as CT, MRI and ultrasound in the DICOM format. This paper presents: a tool to convert static tables or graphs into interactive entities, authoring procedures followed to create prototypes, and outlines future work including meeting the challenge of network distribution for these large files.

6076-05, Session 1

Personalized direct marketing using digital publishing

L. K. Cheeniyil, J. K. Prabhakaran, Hewlett-Packard Co. (India)

In today's cost-conscious business climate, marketing and customer service decision makers are increasingly concerned with how to increase customer response and retention rates. Companies spend large amounts of money on Customer Relationship Management (CRM) solutions and data acquisition but they don't know how to use the information stored in these systems to improve the effectiveness of their direct marketing campaigns.

By leveraging the customer information they already have, companies can create personalized, printed direct mail programs that generate high response rates, greater returns, and stronger customer loyalty, while gaining a significant edge over their competitors. To reach the promised land of one-to-one direct marketing (personalized direct marketing - PDM), companies need an end-to-end solution for creating, managing, printing, and distributing personalized direct mail “on demand.” Having access to digital printing is just one piece of the solution. A more complete approach includes leveraging personalization technology into a useful direct marketing tool that provides true one-to-one marketing, allowing variable images and text in a personalized direct mail.

This paper describes a typical Digital Publishing Solution comprising of components namely the front-end e-service and back end Print Service Providers (PSP). The e-service helps in creating, customizing, previewing and managing variable data print jobs and the PSP fulfills these print jobs. The e-service can integrate with an existing CRM system, for creation and distribution of marketing collateral in a highly personalized fashion.

6076-06, Session 1

Automated campaign system

G. L. Vondran, H. Chao, X. Lin, P. Joshi, D. Beyer, C. B. Atkins, P. Obrador, Hewlett-Packard Co.

To run a targeted campaign involves coordination and management across numerous organizations and complex process flows. Everything from performing market analytics on customer databases, acquiring content and photographs, composing the materials to the sponsoring corporate branding standards, material production and fulfillment, and analysing the results, all processes are currently performed by experienced highly trained staff. Presented is a developed solution that not only brings together technologies that automate each process, but also automates the entire flow so that a novice user could easily run a successful campaign from their desktop. This paper presents the technologies, structure, and process flows used to bring this system together. Highlighted will be how the complexity of running a targeted campaign is hidden under-the-hood of the system, while providing the benefits of a professionally managed campaign.

6076-07, Session 2

Is the nature of a document changing

J. C. King, S. Towers, Adobe Systems, Inc.

Documents have

6076-08, Session 2

Expression of document structure in automatic layout

S. J. Harrington, Xerox Corp.; R. Price Jones, J. F. Naveda, Rochester Institute of Technology; N. Thakkar, IBM Corp.

With the dynamic generation of documents and their presentation on various output devices, it is valuable to automatically adjust their layout and style. Measures for layout desirability have typically focused on document aesthetics (making the document look good). But other values are also important. This paper explores measures for the effectiveness with which style and layout convey the document's logical structure. This primarily contributes to the document's ease of use. The measures described are the group identity, separability and distinguishability of elements. These measures are defined as combinations of simpler, properties that are practical to calculate.

6076-09, Session 2

Evaluating interface aesthetics: measure of symmetry

H. Balinsky, Hewlett-Packard Ltd. (United Kingdom)

Symmetry is one of the most fundamental principles in a design. The choice between symmetry and asymmetry affects the layout and feeling of a design. A symmetrical page gives a feeling of permanence and stability, while informal balance creates interest. The aim of this paper is to solve the problem of an automatic detection of axial and radial symmetry or lack of it in published documents. Previous approaches to this problem gave only a necessary condition for symmetry. We present a necessary and sufficient criterion for automatic symmetry detection and also introduce a Euclidean-type distance from any layout to the closest symmetrical one. We present mathematical proof that the measure of symmetry we introduce is exact and accurate. It coincides with intuition and can be effectively calculated. Moreover, any other symmetry criterion will be a derivative of this measure.

6076-10, Session 2

Automatic color scheme picker for document templates based on image analysis and dual problem

P. Obrador, Hewlett-Packard Labs.

This paper presents two complementary methods to help in the area of document creation where the document includes color templates (banners, clipart, logos, etc.) as well as picture photographs.

The problems that are being addressed are:

- given a photograph that a document needs to be built around, extract a good palette of colors that harmonize with the selected photograph, which may be used to generate the color template;

The images are segmented with a color based morphological approach, which identifies regions with a dominant color.

Based on the morphology of such "color" regions, and the other color objects in the template the scheme will pick a set of possible color harmonies (affine, complementary, split complementary, triadic) for such color elements within the document based on the combined morphology image-document. If the image is changed in the future the color scheme could be changed automatically.

- given a document color template, identify from a collection of images the best set that will harmonize with it.

The document color template is analyzed in the same way as above, and the results are used to query an image database in order to pick a set of images that will harmonize the best with such a color scheme.

6076-11, Session 3

Ringling artifact measurement for JPEG images

X. Feng, J. P. Allebach, Purdue Univ.

Ringling artifact is one of the most disturbing artifacts in JPEG images. Typically, it appears to be the visible noisy vicinity around major edges. In this paper, we propose a no-reference method to measure the perceptibility of the ringling artifact for JPEG images. When viewing an image, people gain knowledge such as the color and the texture of different objects on the image. If the noisy regions surrounding an edge are supposed to be part of a smooth object, the contrast of their texture with the rest of the object will cause the perception of the ringling artifact. Therefore, we first perform a global analysis to classify the smooth regions in an image into different objects according to their colors and region activities. Then we assign each potential ringling region an appropriate proxy object. Finally, we calculate a local ringling feature for each edge pixel based on the contrast between the noise levels of the local ringling regions and their corresponding proxy objects. Thus we obtain a map indicating the visibility of local ringling artifacts. Our approach attempts to mimic the way people perceive ringling artifacts and provides a meaningful feature value to describe the visibility of the artifacts. Our preliminary results show that it is promising.

6076-12, Session 3

A hybrid intelligence approach to artifact recognition in digital publishing

F. Vega, H. J. Santos-Villalobos, Univ. de Puerto Rico Mayagüez

The system presented integrates rule-based and case-based reasoning for artifact recognition in Digital Publishing. In Variable Data Printing (VDP) human proofing could result prohibitive since a job could contain millions of different instances that may contain two types of artifacts: 1) evident defects, like a text overflow or overlapping 2) style-dependent artifacts, subtle defects that show as inconsistencies with regard to the original job design. We designed a Knowledge-Based Artifact Recognition tool for document segmentation, layout understanding, artifact detection, and document design quality assessment. Document evaluation is constrained by reference to one instance of the VDP job proofed by a human expert against the remaining instances. Fundamental rules of document design are used in the rule-based component for document segmentation and layout understanding. Ambiguities in the design principles not covered by the rule-based system are analyzed by case-based reasoning, using the Nearest Neighbor Algorithm, where features from previous jobs are used to detect artifacts and inconsistencies within the document layout. We used a subset of XSL-FO and assembled a set of 44 document samples. The system detected all the job layout changes, while obtaining an overall average accuracy of 84.56%, with the highest accuracy of 92.82%, for overlapping and the lowest, 66.7%, for the lack-of-white-space.

6076-13, Session 3

Nearest-neighbor and bilinear resampling factor estimation to detect blockiness or blurriness of an image

A. Suwendi, J. P. Allebach, Purdue Univ.

Conventional, but widely-used, interpolation methods such as nearest-neighbor and bilinear interpolation generate characteristic image artifacts, namely, blockiness for nearest-neighbor and blurriness for bilinear interpolation. In this paper we present interpolation detection and resampling factor estimation algorithms for both interpolation methods. These algorithms are centered on

the fact that nearest-neighbor interpolation produces an observable pattern of peaks in the first-order difference image while bilinear interpolation produces it in the second-order difference image. The ability to detect which, if any, of the two interpolation methods has been applied and the knowledge of resampling factors used would then enable us to predict the extent of blockiness or blurriness in an image.

Interpolated images may also undergo post processing such as JPEG compression, sharpening, or watermarking. In this paper, we also evaluated the robustness of our detection algorithms to common post processing algorithms. We found that the nearest neighbor interpolation detection algorithm is relatively robust; however, the bilinear interpolation detection algorithm is not that robust. Bilinear interpolation pattern is much more sensitive to post processing algorithms. As a result, a tradeoff between false alarms and robustness is necessary. For our intended application i.e. document preflight tool, we optimized it for false alarms suppression.

6076-14, Session 3

Analytical model of skew effect in digital press characterization

M. Qiao, J. P. Allebach, Purdue Univ.

In this paper we propose an analytical model of the skew effect in digital press characterization. Digital press characterization gives critical information based on which one can predict how a certain layout, images, and text will be rendered by the press on a particular substrate. Modulation Transfer Function (MTF) analysis characterizes the digital press of interest using MTF test patches designed with different spatial frequencies, tone levels, angles, and colors. These patches are printed and then scanned. However, at high spatial frequencies, a small mis-registration in the scanned image can produce large distortion. Skew is a common image mis-registration introduced in the image analysis processes due to the imperfect alignment between the scan target media and the scanning device. The conventional method of de-skewing by rotating the scanned image is not desirable because of the small skew angle and the introduction of interpolation errors. We present a strategy for rejecting skewed images based on the skew angle and the error tolerance so that they can be rescanned and also a simple procedure to correct the skew effect based on our analytical model.

6076-15, Session 3

Detection and location of very small print defects in real time for high-speed digital printing

G. W. Braudaway, IBM Corp.

This paper addresses the variations and adaptations of processes needed for verifying print quality in real time for high-speed digital printers. The term high-speed is here defined to be more than 750 printed pages per minute. The processes used for print verification are based on very high speed image processing technology applied to scanned images of the printed pages. Print verification is done by scanning the printed copies on the obverse and reverse web sides thereby forming two streams of digitized images. Digitized images from each scanned image stream are then spatially aligned page by page, line by line and pixel by pixel with digitized images from a corresponding source streams. The accuracy of alignment needed to compensate for the poor dimensional stability of paper creates a need for additional sophistication in image alignment. The source and scanned images are compared to find pixel sequences that are different. The intent is to identify all differences, either missing-black or unexpected-black, that are larger than a 0.01 inch (0.25 mm) square. These differences may represent unacceptable defects in the printed copies.

6076-16, Session 4

New economy, new strategy: digital technology innovations and applications

N. Raman, Hewlett-Packard Labs.

A new global economy demands new business models. "Medium is the message" (Marshall McLuhan, understanding Media, 1964) and digital publishing is poised to invent technologies to enable these new business models through appropriate use of multimedia.

Reading a story in a book, listening to it on the radio or seeing it as a movie are all valuable yet different experiences. With the advancement in digital technologies and innovations in publishing, effective communication is about matching the experience to the user need. To deliver on this promise we must:

1. Maximize human potential for creativity: Allow for individual creativity while minimizing the tedium of dealing with technology. Publishing or content management systems will be architected to easily store, find and automatically select, or mix and match content from various sources to deliver information that is most appropriate for the desired experience.
2. Minimize device dependency: Mobile device such as PDAs or cell phones are becoming smaller, have limited displaying area and limited bandwidth, but offer interactivity, a new value. Intelligence can reside in the transmitting device e.g. information delivery can focus on the region of interest on the page instead of the whole page for limited displays.
3. Simplify the Experience: Data conversion, integration, and communication models will emulate human information processing models to be effective. To tell a multimedia story in print, video analysis to select semantically meaningful key frames can deliver the experience simply and automatically.

Multi-media enrich human experience and redefines literature yet today it creates more complexity. Winning innovations will satisfy the demands for simplicity, manageability, and adaptability.

6076-17, Session 4

How small should a document thumbnail be?

K. Berkner, Ricoh Innovations, Inc.

Viewing document images on small devices is still a challenge today. When showing selected high resolution data for reading, a page overview is generally lost. If a page overview is desired, typically a low resolution version of the image - a thumbnail view - is provided. The size of a thumbnail is set by the application. Whereas readability of text in thumbnails is almost always lost, document layout information may or may not be preserved.

This paper derives models for controlling the preservation of document layout information in thumbnails by determining the size of a thumbnail depending on the layout content of the document. The downsampling factor for a document image will depend on its layout information. After scaling, layout units will be visually separable by the viewer. The link between scaling factors and document layout information is created through novel models, White Space Graphs (WSG) and White Space Trees (WST), enabling control over enhancement and suppression of document layout structures during scaling. Using WSG or WST, a minimal scaling factor can be derived that assures visual separability of a controlled set of layout units after scaling. The result is a content-dependent thumbnail size.

6076-18, Session 4**Image object adaptation in variable data printing**

J. Fan, Hewlett-Packard Labs.; H. Chao, Hewlett-Packard Co.

In variable data printing (VDP), it is desirable to automatically fit an arbitrary shaped image object into an arbitrarily shaped copy hole or template with maximized use of the available space. In this paper, we describe a practical image processing method that segments out the object and determines the scale and translation for the optimal fitting.

For our application, an arbitrary shaped object is placed on a uniformed color background in a JPEG compressed image file. The compression artifacts around the object boundary area complicate object segmentation. In order to identify object boundary precisely, we developed an orientation-dependent adaptive thresholding method, which significantly improve the boundary accuracy. In the first step, we identify the background pixels using zero thresholding. Connectivity analysis is then performed to remove very small blobs. Mathematical morphological operations are applied to background pixels in order to smooth the border. In the second step, object boundaries are refined using the proposed orientation-dependent adaptive thresholding. In determining the optimal scale and translation, we used an image-based iterative search algorithm that step through a set of scaling factors in descending order until a complete fit is found. Under each scale, all possible translations are tested. The exit scale along with the mass center of the feasible translations under the scale is then used for the object placement.

6076-20, Session 5**Laying out the future of final-form digital documents**

D. F. Brailsford, Univ. of Nottingham (United Kingdom)

It is now just over 20 years since Adobe's PostScript created a new era in digital documents. PostScript allows most details of rendering to be hidden within the imaging device itself, while providing a rich set of primitives enabling document engineers to think of final-form document rendering as being just a sophisticated exercise in computer graphics.

The refinement of the PostScript model into PDF has been amazingly successful in creating a near-universal interchange format for complex and graphically rich digital documents but the PDF format itself is neither easy to create nor to amend. In the meantime a whole new world of digital documents has sprung up centred around XML-based technologies. The most widespread example is XHTML (with optional CSS styling) but more recently we have seen Scalable Vector Graphics (SVG) emerge as an XML-based, low-level, rendering language with PostScript-compatible rendering semantics.

This paper surveys graphically-rich final-form rendering technologies and asks how flexible they can be in allowing adjustments to be made to final appearance without the need for regenerating a whole page or an entire document. Particular attention is focused on the relative merits of SVG and PDF and on the desirability, in any document layout language, of being able to manipulate the graphic properties of document components at a level of granularity smaller than an entire page.

6076-21, Session 5**Intelligent content fitting for digital publishing**

X. Lin, Hewlett-Packard Co.

One recurring problem in Variable Data Printing (VDP) is that the existing contents cannot satisfy the VDP task as-is. So there is a strong need for content fitting technologies to support high-value

digital publishing applications, in which text and image are the two major types of contents. This paper presents meta-Autocrop framework for image fitting and TextFlex technology for text fitting. The meta-Autocrop framework supports multiple modes: fixed aspect-ratio mode, advice mode, and verification mode. The TextFlex technology supports non-rectangular text wrapping and paragraph-based line breaking. We also demonstrate how these content fitting technologies are utilized in the overall automated composition and layout system.

6076-22, Session 5**A total-fit page-breaking algorithm with user-defined adjustment strategies**

A. Di Iorio, L. Furini, F. Vitali, Univ. degli Studi di Bologna (Italy)

Page breaking algorithms are responsible for the task of splitting the content of a document (text, images, footnotes, ...) into pages, respecting a set of rules stating where page breaks are allowed and where they should be avoided.

In doing this, these algorithms should also guarantee that the content placed into each page fits the available area without leaving any unexpected space, but this desirable feature is not implemented in existing pagination applications, forcing users to manually adjust some properties (such as word spacing, letter spacing, etc.) to locally valid values page by page.

We describe an algorithm that, on the contrary, works automatically and globally on the whole document, building a set of page breaks that require a minimal set of adjustments in order to fill perfectly the available space. Users can guide the algorithm by setting a list of properties that can be modified; the list also specifies the priority order in the adjustment of these properties.

The algorithm has been implemented into Apache FOP; the list of properties and the request for an optimized set of page breaks are set directly into the input files as extensions to the XSL-FO standard.

6076-23, Session 5**Extensible layout in functional documents**

J. Lumley, R. Gimson, O. Rees, Hewlett-Packard Ltd. (United Kingdom)

Highly customised variable-data documents make automatic layout of the resulting publication hard. Architectures for defining and processing such documents can benefit if the repertoire of layout methods available can be extended smoothly and easily to accommodate new styles of customisation. The Document Description Framework incorporates a model for declarative document layout and processing where documents are treated as functional programs. A canonical XML tree contains nodes describing layout instructions which will modify and combine their children component parts to build sections of the final presentation. Leaf components such as images, vector graphic fragments and text blocks are 'rendered' to make consistent graphical atoms. These parts are then processed by layout agents described and parameterised by their parent nodes, and which can range from simple layouts like translations, flows, encapsulations and tables through to highly complex arrangements such as constraint-solution or pagination. The result then becomes a 'molecule' for processing at a higher level of the layout tree. A variable and reference mechanism is included for resolving rendering interdependency and supporting component reuse. Addition of new layout types involves definition of a new combinator node and attachment of a suitable agent.

6076-24, Session 6

Production digital printing: making the leap from emerging to everyday

C. Valiquette, Caslon & Co.

Since its emergence in 1993, color digital printing has undergone several important transformations, both technologically and from a business value proposition standpoint. This paper will give a broad overview of the current state of the production digital printing industry and the issues that drive adoption of this relatively new technology. Inkjet and electrostatic processing techniques will be discussed briefly, along with which of these technologies have been embraced by the major vendors. Business applications, market trends and value propositions driving the adoption of digital print as a communications medium will be summarized. Finally, we will review the workflow components and processes required to actually produce a digital print project, along with a brief overview of Personalized Print Markup Language (PPML) and Job Definition Format (JDF), the industry standards that are driving interoperability between devices.

6076-25, Session 6

WARP (workflow for automated and rapid publishing): a framework for end-to-end automated digital publishing workflows

P. Joshi, Hewlett-Packard Co.

Publishing industry is experiencing a major paradigm shift with the advent of digital publishing technologies. A large number of components in the publishing and print production workflow are transformed in this shift. However, the process as a whole requires a great deal of human intervention for decision making and for resolving exceptions during job execution. Furthermore, a majority of the best-of-breed applications for publishing and print production are intrinsically designed and developed to be driven by humans. Thus, the human-intensive nature of the current prepress process accounts for a very significant amount of the overhead costs in fulfillment of jobs on press. It is a challenge to automate the functionality of applications built with the model of human driven execution. Another challenge is to orchestrate various components in the publishing and print production pipeline such that they work in a seamless manner to enable the system to perform automatic detection of potential failures and take corrective actions in a proactive manner. Thus, there is a great need for a coherent and unifying workflow architecture that streamlines the process and automates it as a whole in order to create an end-to-end digital automated print production workflow that does not involve any human intervention. This paper describes an architecture and building blocks that lay the foundation for a plurality of automated print production workflows.

6076-26, Session 6

A scheduling framework applied to digital publishing workflows

W. Rivera, W. L'Ozano, Univ. de Puerto Rico Mayagüez

In this paper we discuss the advances in developing a dynamic scheduling technique suitable for automating digital publishing workflows. Traditionally scheduling in digital publishing has been limited to timing criteria. From our point of view, the scheduling process in digital publishing needs a new approach based on metrics targeting quality of service. In order to achieve such a scheduling methodology we have concentrated our research efforts in developing a scheduling algorithm that takes into account contingency (unexpected events) and priority fluctuations (changes in job priorities). Such a scheduling algorithm is a modification of the

Maximum Urgent First (MUF) algorithm. The new algorithm, referred to as DP-MUF, gives high priority to jobs with low probability of failing according to criteria defined in artifact recognition and workflow modeling and allows diverse scheduling policies. A fundamental component of the modified MUF algorithm is the definition of a set of quality of service metrics. Such a set of metrics are defined to address questions such as how to account for complex issues of availability of resources, how to choose among different options for completing a job based on cost/time to completion/quality of results, and how to deal with missing deadlines and overtime. The experimental results show the suitability and efficiency of the scheduling framework in a print shop environment.

6076-27, Session 6

Desktop binding: a novel approach to booklet making hardware

S. W. Trovinger, Hewlett-Packard Co.

In the realm of desktop printing, many advances have been made with regard to image quality, a shift from monochrome to six or more colors, photo quality output, faster throughput, lower printer cost, and smaller form factor. Many of these vectors have seen orders of magnitude improvements, with the exception of one; virtually all printers still present finished output as a loose pile of paper; the focus has been on the individual page, not on documents.

Discussed here is a technology that enables true desktop publishing - the creation of printed and bound hardcopy output from desktop devices, without the issues associated with commercial bindery hardware. Hewlett Packard Laboratories has invented a technology that uses novel mechanical operations to deliver saddle stitch booklet-making solutions appropriate to low cost desktop printing technologies.

The novelty of this technology comes from performing finishing operations on a sheet-by-sheet basis. This differs from conventional methods where the entire stack of pages is processed as a single unit. Booklet making operations involve precision sheet positioning and low force tools to trim and fold. The sheet wise method allows finishing operations to be done with low cost tools and low forces.

6076-28, Session 6

Color variance in PDF-based production workflows

M. P. Riordan, Rochester Institute of Technology

Based on the production practices of a representative sampling of graphic arts professionals, a series of tests were conducted to determine the potential color variance incurred during specific production-based PDF workflows. The impact of key production variables—including the use of ICC profiles, methods and settings used for PDF distillation, and printer/RIP color management handling for PDF rendering—were examined for RGB, CMYK and select spot colors to determine the potential magnitude of color variation under normal production conditions. The results of the study, quantified via paired comparison and delta E, showed that, while color variance could be kept to a minimum using very specific workflow configurations, significant color variation was incurred in many of the common workflow configurations representative of the production environments observed from the sample population. Further, even compliance to PDF-X1a and PDF-X3 specifications allowed for unwanted variation depending on specific production activities that preceded or followed the creation of the PDF-X file.

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6077-01, Session 1

Superresolution of text from nonideal video

X. Li, West Virginia Univ.

Texts represent an important class of information in our daily lives. This paper studies the problem of super-resolution (SR) of texts, namely reconstructing high-resolution texts from low-resolution video captured by handheld cameras. Such type of video is called \$nonideal\$ due to uncontrolled imaging condition, unknown point spread function and inevitable distortion caused by compression algorithms. Motivated by the different consideration in SR from mosaicing, we investigate the error accumulation in homography-based registration of multi-view images. We advocate the nonuniform interpolation approach towards SR that can achieve resolution scalability at a low computational cost and study the issues of phase consistency and uncertainty that are difficult to be addressed under the conventional framework of treating SR as an inverse problem. We also present a nonlinear diffusion aided blind deconvolution technique for simultaneous suppression of compression artifacts and enhancement of textual information. The performance of the proposed SR-of-texts technique is demonstrated by extensive experiments with challenging real-world sequences.

6077-02, Session 1

Registration of aliased images for super-resolution imaging

P. Vandewalle, L. M. Sbaiz, S. E. Süsstrunk, École Polytechnique Fédérale de Lausanne (Switzerland); M. Vetterli, École Polytechnique Fédérale de Lausanne (Switzerland) and Univ. of California/Berkeley

Super-resolution imaging techniques reconstruct a high resolution image from a set of low resolution images that are taken from almost the same point of view. The problem can be subdivided into two main parts: an image registration part where the different input images are aligned with each other, and a reconstruction part, where the high resolution image is reconstructed from the aligned images.

In this paper, we mainly consider the first step: image registration. We present three frequency domain methods to accurately align a set of undersampled images. First, we describe a registration method for images that have an aliasing-free part in their spectrum. The images are then registered using that aliasing-free part. Next, we present two subspace methods to register completely aliased images. Arbitrary undersampling factors are possible with these methods, but they have an increased computational complexity. In all three methods, we only consider planar shifts. We also show the results of these three algorithms in simulations and practical experiments.

6077-03, Session 1

A practical approach to superresolution

S. Farsiu, Univ. of California/Santa Cruz; M. Elad, Technion - Israel Institute of Technology (Israel); P. Milanfar, Univ. of California/Santa Cruz

Super-Resolution (SR) methods are developed through the years to go beyond the achievable resolution limit of imaging devices by acquiring and fusing several low-resolution (LR) images of the same scene, producing a high-resolution (HR) image. The early works on SR, although occasionally mathematically optimal for particular models of data and noise, produced poor results when applied to real images. In this paper, we discuss two of the main issues related to designing a practical SR system, namely reconstruction accuracy and computational efficiency. Reconstruction accuracy refers to the problem of designing a robust SR method applicable to images from different imaging systems. We study a general framework for optimal

reconstruction of images from grayscale, color, or color filtered cameras. The performance of our proposed method is boosted by using powerful priors and is robust to both measurement (e.g. CCD readout noise) and system noise (e.g. motion estimation error). Noting that the motion estimation is often considered a bottleneck in terms of SR performance, we introduce the concept of “constrained motions” for enhancing the quality of super-resolved images. We show that using such constraints will enhance the quality of the motion estimation and therefore results in more accurate reconstruction of the HR images. We also justify some practical assumptions that greatly reduce the computational complexity and memory requirements of the proposed methods. We use efficient approximation of the Kalman-Filter and adopt a dynamic point of view to the SR problem. Novel methods for addressing these issues are accompanied by experimental results on real data.

6077-04, Session 1

Jitter camera: a superresolution video camera

M. Ben-Ezra, Siemens Corporate Research; A. Zomet, S. K. Nayar, Columbia Univ.

Super-Resolution is a computational method for obtaining high-resolution images from multiple low resolution images. For super-resolution to be effective, the low resolution images must be mutually displaced. These displacements are typically obtained by moving the camera. However, a moving camera introduces motion blur, which limits the quality of super-resolution results.

We analyze this effect and show that motion blur has a substantial degrading effect on the performance of super-resolution; to address this, we propose camera designs that enable super-resolution without introducing motion blur. We describe the implementation of our super-resolution video camera called the “Jitter-Camera” and our adaptive super-resolution algorithm that handles complex dynamic scenes in a robust fashion.

We show that the video resolution produced by the “Jitter-Camera” is notably enhanced for stationary or slowly moving objects, while it is improved slightly or left unchanged for objects with fast and complex motions. The end result is a video that has a significantly higher resolution than the captured one.

6077-05, Session 1

Face recognition with independent component based superresolution

O. G. Sezer, Sabanci Univ. (Turkey); Y. Altunbasak, Georgia Institute of Technology; A. Ercil, Sabanci Univ. (Turkey)

Performance of current face recognition algorithms reduces significantly when they are applied to low-resolution face images. To handle this problem, super-resolution techniques can be applied either in the pixel domain or in the face subspace. Since face images are high dimensional data which are mostly redundant for the face recognition task, feature extraction methods that reduce the dimension of the data are becoming standard for face analysis. Hence, applying super-resolution in this feature domain, in other words in face subspace, rather than in pixel domain, brings many advantages in computation together with robustness against noise and motion estimation errors. Therefore, we propose new super-resolution algorithms using Bayesian estimation and projection onto convex sets methods in feature domain and present a comparative analysis of the proposed algorithms and those already in the literature.

6077-07, Session 1

Robust superresolution based on pixel-level selectivity

Z. A. Ivanovski, L. Panovski, Ss Cyril and Methodius Univ. (Macedonia); L. J. Karam, Arizona State Univ.

In this paper, a new technique for robust super-resolution (SR) from compressed video is presented. The proposed method exploits the differences between low resolution images at the pixel level, in order to determine the usability of every pixel in the low resolution images for SR enhancement. Only the pixels, from the low resolution images, that are determined to be usable, are included in the L_2 norm minimization procedure. The results obtained with real video sequences demonstrate superior quality of the resulting enhanced image in the presence of outliers and same quality without outliers when compared to existing L_2 norm minimization techniques. At the same time, the proposed scheme produces sharper images as compared to L_1 norm minimization techniques.

6077-08, Session 1

Resolution enhancement of low-quality videos using a high-resolution frame

T. Q. Pham, L. J. van Vliet, Technische Univ. Delft (Netherlands); K. Schutte, TNO-FEL (Netherlands)

This paper proposes an example-based Super-Resolution (SR) algorithm of compressed videos in Discrete Cosine Transform (DCT) domain. Input to the system is a Low-Resolution (LR) compressed video together with a High-Resolution (HR) still image captured by the same device. Using a training set of corresponding LR-HR pairs of image patches from the HR still image, high-frequency details are transferred from the HR source to the LR video. Different from traditional spatial-based algorithms (e.g. Freeman2002), the DCT-based algorithm uses quantized DCT coefficients for LR content matching. $N \times N$ HR patches ($N=4,8$) are synthesized from corresponding 8×8 LR coded blocks in a raster-scan order. Due to heavy quantization, only the 10 most significant AC DCT coefficients are used for matching. $2N-1$ HR overlapping pixels are also used in the search vector to ensure boundary consistency of the synthesized blocks. The algorithm does not require a full decompression because each 8×8 coded block is either taken from the input bit stream or is composited from 4 adjacent DCT blocks. Without zooming, the algorithm improves picture definition by removing the quantization degradation. When used with a zoom factor of 2, the algorithm offers an effective scheme for SR of low-quality compressed videos.

6077-25, Session 1

Toward new a compression standard using superresolution techniques

R. Molina, Univ. de Granada (Spain); A. K. Katsaggelos, Northwestern Univ.; L. Alvarez, J. Mateos, Univ. de Granada (Spain)

The term super-resolution is typically used in the literature to describe the process of obtaining a high resolution image or a sequence of high resolution images from a set of low resolution observations. This term has been applied primarily to spatial and temporal resolution enhancement. However, intentional pre-processing and downsampling can be applied during encoding and super-resolution techniques to upsample the image can be applied during decoding when video compression is the main objective. In this paper we consider the following three video compression models. The first one simply compresses the sequence using any of the available standard compression methods, the second one pre-processes (without downsampling) the image sequence before compression, so that post-processing (without upsampling) is applied to the compressed sequence. The third model includes downsampling in the pre-

processing stage and the application of a super resolution technique during decoding. In this paper we describe these three models but concentrate on the application of super-resolution techniques as a way to post-process and upsample a compressed video sequences. Experimental results are provided on a wide range of bitrates for two very important applications: format conversion between different platforms and scalable video coding.

6077-09, Session 2

Predictive fast motion/disparity search for multiview video coding

P. Lai, A. Ortega, Univ. of Southern California

In this paper, we consider the problem of complexity reduction in motion/disparity estimation for multiview video coding. We propose predictive fast search algorithms that, after either the motion field or the disparity field has been estimated, obtain with low complexity a good set of candidate vectors for the other field. The proposed scheme performs predictive motion search from view to view after the disparity field has been estimated (denote as DtM, Disparity then Motion) and predictive disparity search from one time instant to another time after the motion field has been estimated (MtD, Motion then Disparity). We also propose an efficient search pattern that starts with the candidate vectors from the proposed algorithms. Two sets of simulation results, one on the original images and one using a coding approach based on H.264/AVC, are provided in this paper. The results show a very significant reduction in coding complexity with slight coding efficiency degradation as compared to the full search in both motion and disparity estimations. The key to the performance of the proposed algorithm is that most reliable estimation should be performed first, so that the fast predictive search on the second field can make use of good candidate vectors. Since motion estimation generally provides better block matching than disparity estimation, MtD generates higher coding efficiency than DtM.

6077-10, Session 2

Complexity scalable motion estimation for H.264/AVC

C. Kim, Univ. of Southern California; J. Xin, A. Vetro, Mitsubishi Electric Research Labs.; C. C. J. Kuo, Univ. of Southern California

A new complexity-scalable framework for motion estimation is proposed to efficiently reduce the motion-complexity of encoding process, with focus on long term memory motion-compensated prediction of the H.264 video coding standard in this work. The objective is to provide a complexity scalable scheme for the given motion estimation algorithm such that it reduces the encoding complexity to the desired level with insignificant penalty in rate-distortion performance. In principle, the proposed algorithm adaptively allocates available motion-complexity budget to macroblock based on estimated impact towards overall rate-distortion (RD) performance subject to the given encoding time limit. To estimate macroblock-wise tradeoff between RD coding gain (J) and motion-complexity (C), the correlation of J-C curve between current macroblock and collocated macroblock in previous frame is exploited to predict initial motion-complexity budget of current macroblock. The initial budget is adaptively assigned to each blocksize and block-partition successively and motion-complexity budget is updated at the end of every encoding unit for remaining ones. Based on experiment, proposed slope based allocation is better than uniform motion-complexity allocation scheme in terms of RDC tradeoff. It is demonstrated by experimental results that the proposed algorithm can reduce the H.264 motion estimation complexity to the desired level with little degradation in the rate-distortion performance.

6077-11, Session 2

Depth map compression for unstructured lumigraph rendering

U. Fecker, A. Guenegues, I. Scholz, A. Kaup, Friedrich-Alexander- Univ. Erlangen-Nürnberg (Germany)

Image-based rendering techniques require capturing an object or scene from many viewpoints. Often, depth maps are used in addition to the original images for rendering new views for novel viewpoints not coinciding with one of the original camera positions. Due to the high amount of data, efficient compression is necessary. When the data is stored or transmitted, it is not only desirable to compress the image data but also the depth information. In this paper, the case of sequences recorded with a single, hand-held camera is investigated. These sequences are used for unstructured lumigraph rendering. In addition, the case of multi-view video sequences is analyzed. For both cases, depth maps are compressed using H.264/AVC, and the achievable data rates are studied. For the case of unstructured lumigraph rendering, the effect of depth map compression on the quality of rendered images is analyzed in a second step.

6077-12, Session 2

Shape adaptive integer transform for coding arbitrarily shaped objects in H264/AVC

X. Li, E. A. Edirisinghe, H. E. Bez, Loughborough Univ. (United Kingdom)

A novel Shape Adaptive Integer Transform (SA-IT) is proposed, which can be effectively used in future for enabling arbitrary shaped object coding in H.264. The use of shape-adaptive transforms is a popular approach for coding arbitrarily shaped objects in image/video coding due to their adaptability at object edges and low complexity. In this respect shape adaptive DCT (SA-DCT) and shape adaptive DWT (SA-DWT) have been proposed in previous literature. The Integer Transform (IT), a derivative of the 4x4 DCT, has been adopted in the latest H.264/AVC standard for coding image blocks in residual data (texture). The associated integer arithmetic guarantees fast and accurate coding/decoding. Though Integer Transforms are a derivative of 4x4 DCTs, in H.264, to maintain integer arithmetic capability, the post-and pre-scaling factors of transform process are integrated into the forward and inverse quantiser stages respectively for reducing the total number of multiplications and avoiding the loss of accuracy. Thus SA-IT considerably differs from SA-DCT and calls for novel design and implementation considerations based on combining those merits of both SA-DCT and IT. We provide theoretical proofs and support them with experimental justifications.

6077-13, Session 2

Optimal bit allocation for hybrid scalable/multiple-description video transmission over wireless channels

M. Bansal, M. K. Jubran, L. P. Kondi, SUNY/Univ. at Buffalo

In this paper, we consider the problem of optimal bit allocation for wireless video transmission over fading channels. We use a newly developed hybrid scalable/multiple-description codec that combines the functionality of both scalable and multiple-description codecs. It produces a base layer and multiple-description enhancement layers. Any of the enhancement layers can be decoded (in a non-hierarchical manner) with the base layer to improve the reconstructed video quality. Two different channel coding schemes (Rate-Compatible Punctured Convolutional (RCPC)/Cyclic Redundancy Check (CRC) coding and, product code Reed Solomon RS)+RCPC/CRC coding) are used for unequal error protection of the layered bitstream. Optimal allocation of the bitrate between source and channel coding is performed for discrete sets of source coding rates and channel coding rates.

Experimental results are presented for a wide range of channel conditions. Also, comparisons with classical scalable coding show the effectiveness of using hybrid scalable/multiple-description coding for wireless transmission.

6077-14, Session 2

Space-time multiple description video coding

D. Wang, N. Canagarajah, D. Bull, Univ. of Bristol (United Kingdom)

This paper develops a combined space-time multiple description video coding (ST-MDVC) scheme and corresponding error concealment methods in order to adapt to error prone packet networks, especially for multiple channels. It generates four descriptions, instead of two in most other MDVC schemes, with much lower redundancy than others. The three-loop slice group MDVC approach of [8] is used to achieve spatial description splitting. MDVC is very suitable for multiple channel environments, and especially able to maintain acceptable quality when some of these channels fail completely, i.e. in an on-off MDC environment, without experiencing any drifting problem. Our MDC scheme coupled with the proposed concealment approaches proved to be suitable not only for the on-off MDC environment case (data from one channel fully lost), but also for the case where only some packets are lost from one or more channels. Several steps to achieve high performance concealments are done with the received packets. Results show the promising performance with very low redundancy for both the balanced and unbalanced channel cases. Generating four descriptions make it more adapted to multi-path scenarios.

6077-15, Session 2

Improving sequential decoding of CABAC encoded data via objective adjustment of the complexity-efficiency trade-off

S. Ben-Jamaa, M. Kieffer, P. Duhamel, Univ. Paris XI (France) and Ctr. National de la Recherche Scientifique (France)

In this paper, we present an improved sequential decoding technique for

CABAC encoded data. Redundancy present after the binarization step is exploited and no extra redundancy is added. The proposed sequential decoders handle adaptive probabilities and context modeling. An hypothesis test allowing to adjust the decoding complexity according to the desired performances is elaborated. Simulation results show that our method outperforms those using classical sequential algorithms.

6077-16, Session 2

New intra-luma prediction mode in H.264/AVC using collocated weighted chroma pixel value

I. Cho, J. Lee, W. Lee, D. Jeong, Inha Univ. (South Korea)

Intra prediction in H.264/AVC uses 9 modes in 4x4 luma block, 4 in 16x16 luma and 8x8 chroma blocks. For the better coding efficiency, intra prediction modes utilize similarity of current macroblock with pre-encoded neighboring macroblocks and directionality of image in pixel domain. However coding efficiency in intra-coded frame is much lower compared to that of inter slice since the intra prediction modes use only limited neighboring macro blocks and then to obtain good matched reference block image using intra prediction may be more difficult than inter prediction. Therefore for higher coding efficiency, it is very important to get good matched prediction block in a given environment. In this paper, we propose additional intra luma prediction mode using collocated chroma pixels and weight values. The proposed method utilizes collocated chroma macroblocks as reference image for more efficient intra luma prediction. After chroma components of current macroblock are intra-predicted from neighboring macroblocks, luma

components are predicted as multiplication of predicted chroma component values and some weighted value. This weighted value is calculated from luma and chroma values nearest neighboring reconstructed pixels. We identified that the proposed method improves coding efficiency of intra prediction by maximum 0.7dB from experiment.

6077-56, Poster Session

Coupled nonlinear-diffusion color image sharpening based on the chromaticity-brightness model

T. Saito, R. Nosaka, T. Komatsu, Kanagawa Univ. (Japan)

Previously we have presented a selective image sharpening method based on the coupled nonlinear diffusion process composed of a nonlinear diffusion term, a fidelity term and an isotropic peaking term, and it can sharpen only blurred edges without increasing the noise visibility. Our previously presented prototypal color-image sharpening methods based on the coupled nonlinear-diffusion process have been formulated on the linear color models, namely, the channel-by-channel model and the 3D vectorial model. Our prototypal methods can sharpen blurred color step edges, but they do not necessarily enhance contrasts of signal variations in complex texture image regions so well as in simple step-edge regions. To remedy the drawback, this paper extends our coupled nonlinear-diffusion color-image sharpening method to the nonlinear non-flat color model, namely, the chromaticity-brightness model, which is known to be closely relating to human color perception. We modify our time-evolution PDE's for the non-flat space of the chromaticity vector and present its digital implementations. Through experimental simulations, we compare our new color-image sharpening method based on the chromaticity-brightness model with our prototypal color-image sharpening methods based on the linear color models.

6077-57, Poster Session

Parallel implementation of arbitrary-shaped MPEG-4 decoder for multiprocessor systems

M. Pastrnak, P. H. N. de With, LogicaCMG (Netherlands) and Technische Univ. Eindhoven (Netherlands); S. Stuijk, J. van Meerbergen, Technische Univ. Eindhoven (Netherlands)

MPEG-4 is the first standard that combines synthetic objects, like 2D/3D graphics objects, with natural rectangular and non-rectangular video objects. This paper addresses the optimization of such complex multimedia algorithms for implementation on multiprocessor platforms. It is shown that when choosing the correct granularity of processing for enhanced parallelism, a substantial improvement in processing efficiency can be obtained. We chose a multiprocessor System-on-Chip (SoC) setup that satisfies the requirements on the overall computation capacity. We propose the optimization of the non-rectangular MPEG-4 video decoding to more efficiently use the multiprocessor architecture. First, we present a modification of the Repetitive Padding to increase the pipelining at block level. We identified the part of the padding algorithm that can be executed in parallel with the DCT-coefficient decoding and modified the original algorithm. Second, we introduce a synchronization mechanism that allows the processing for the Extended Padding and postprocessing filters at block level. The first optimization results in about 58% decrease of the original Repetitive-Padding task computational requirements. By introducing data-level parallelism between the separated color components (Y, Cr, Cb), the computational savings are about 72% on the average. Moreover, the proposed optimizations marginalize the processing latency from frame size to slice order-of-magnitude.

6077-58, Poster Session

A framework for fast mode decision in the H.264 video coding standard

M. Y. Yang, C. Grecos, Loughborough Univ. (United Kingdom)

We propose a novel framework for fast mode decision in the simple and main profiles of the H264 video coding standard. Our framework consists of a specific combination of algorithms, each achieving computational savings while retaining Rate Distortion (RD) performance very similar to the standard. In particular, we utilise a set of skip mode conditions for P and B slices, two heuristics that reduce the cardinality of the inter mode set to be examined, inter/intra mode prediction and the monotonicity property of the Rate Distortion cost functions. We achieve content dependent savings in run times between 5.8 and 90.1% as compared to H264. Compared to other work that was used as input to the standard, our scheme is faster by 9-23% for very similar RD performance. The proposed framework can be used wholly or partially for computational speed-ups, it is independent of the motion search method used and is applicable in both the rate controlled and non rate controlled cases.

6077-59, Poster Session

Interpolation of still images using the decay and persistence properties of discrete wavelet transform coefficients

W. Kwak, R. Park, J. Lee, Sogang Univ. (South Korea)

According to advances in digital image processing techniques, interest in high-quality still images has been increased. This paper proposes an effective discrete wavelet transform (DWT)-based algorithm that efficiently interpolates a high-resolution (HR) still image from a low-resolution (LR) one. The decay and persistence properties of DWT coefficients are utilized for HR image reconstruction. DWT coefficients are initially estimated based on the decay of the Lipschitz exponential and the similarity of DWT coefficients across resolution scales is used for coarse estimation. For optimal fine estimation the mean squared error is iteratively minimized. The proposed DWT-based interpolation algorithm yields better performance than the conventional methods in terms of the peak signal to noise ratio and subjective image quality.

6077-60, Poster Session

Optimum computational resource allocation and energy minimization for video encoding on portable devices

Z. He, Univ. of Missouri/Columbia

We consider a portable video device which captures and compresses video data. The compressed bit stream is either stored in an on-board storage device or transmitted to a remote user through wireless channels. The storage space or the amount of energy and channel bandwidth available for data transmission determines the total number of bits that the video encoder can generate. Besides this bit resource constraint, the portable video device also operates under data processing energy constraint. This is because video compression is computationally intensive and energy-consuming. One of the central challenging issues in portable video communication system design is how to maximize the operational lifetime. In this work, we will investigate the following research problem: given a portable device, which has a certain amount of power supply E and the maximum number of bits it can store or transmit is R , and the required video quality level is D , what is the maximum operational lifetime of this portable device, and how to allocate the bit and energy resources to achieve this maximum lifetime? To address this problem, we design an energy-scalable video encoder and study its power-rate-distortion (P-R-D) behavior. We theoretically study the optimum bit and energy resource allocation and analyze the energy saving performance. Our

results show that for typical consumer electronic videos, using the proposed P-R-D video encoding technology, the operational lifetime of the portable device can be doubled or even tripled. This has a significant impact in energy-efficient portable video communication system design.

6077-61, Poster Session

Optimal video sensing strategy and performance analysis for wireless video sensors

Z. He, Univ. of Missouri/Columbia

Wireless video sensor networks have been envisioned for a wide variety of important applications. In this work, we investigate the following research problem: given a mobile video sensor with an initial resource configuration, what is the maximum video quality it can provide, and what is the best video encoding and streaming strategy to achieve this performance? To address this problem, we study the energy consumption of each sensor node in video compression and wireless data transmission. We statistically model the node mobility and study its impact on wireless video transmission. We develop a task-oriented performance metric to measure the video sensing performance of the sensor node. We develop an optimal resource allocation and scheduling scheme for the video sensor to maximize the performance metric. The results provide an important step stone for our future performance study of wireless video sensor networks.

6077-62, Poster Session

Shot boundary detection using scale invariant feature matching

M. Park, R. Park, S. W. Lee, Sogang Univ. (South Korea)

This paper presents a shot boundary detection (SBD) method that finds boundaries between shots using the changes in visual content elements such as objects, actors, and background. Our work presented in this paper is based on the property that the features do not change significantly within a shot whereas they change substantially across a shot boundary. Noticing this characteristic of shot boundaries, we propose a SBD algorithm using the scale- and rotation-invariant local image descriptors. To obtain information of the content elements, we employ the scale invariant feature transform (SIFT) that has been commonly used in object recognition. The number of matched points is large within the same shot whereas zero or the small number of matched points is detected at the shot boundary because all the elements in the previous shot change abruptly in the next shot. Thus we can determine the existence of shot boundaries by the number of matched points. We identify two types of shot boundaries (hard-cut and gradual-transition such as tiling, panning, and fade in/out) with an adjustable frame distance between consecutive frames. Experimental results with four test videos show the effectiveness of the proposed SBD algorithm using scale invariant feature matching.

6077-63, Poster Session

Extracting focused object from low depth-of-field image sequences

J. Park, C. Kim, Information and Communications Univ. (South Korea)

The paper proposes a novel unsupervised video object segmentation algorithm for image sequences with low depth-of-field (DOF), which is a popular photographic technique enabling to represent the intention of photographer by giving a clear focus only on an object-of-interest (OOI). The proposed algorithm largely consists of two modules. The first module automatically extracts OOIs from the first frame by separating sharply focused OOIs from other out-of-focused foreground or background objects. The second module tracks OOIs for the rest of the video sequence, aimed at running the system in real-time, or at least,

semi-real-time. The experimental results indicate that the proposed algorithm provides an effective tool, which can be a basis of applications, such as video analysis for virtual reality, immersive video system, photo-realistic video scene generation and video indexing systems.

6077-64, Poster Session

Adaptive de-blocking filter for low bit rate applications

X. Jin, G. Zhu, Huazhong Univ. of Science and Technology (China)

In block-based video compression technology, blocking artifacts are obvious because of the luminance and chrominance discontinuities which are caused by block-based discrete cosine transform (DCT) and motion compensation. As a kind of solution, an in-loop filter has been successfully used in H.264 adapting to quantization parameter and video content. In this paper, blocking artifacts distribution properties are analyzed carefully to reflect the blocking effect more accurately in the low bit rate applications. Two important parameters, named blocking severity and pixel variation, are defined to describe the boundary strength and the gradient of the samples across the edge respectively. Through series of statistical data retrieval and analysis for these parameters using multiple representative video sequences, a novel blocking artifacts distribution model is concluded. Based on this distribution model, an improved filter is proposed to H.264 with novel strength determination rule and different alpha model. Comparing with H.264 anchor results, the proposed de-blocking filter shows better performance especially in subjective aspect, which could be widely used in low bit rate applications.

6077-65, Poster Session

Fast intra-mode decision algorithm of H.264/AVC

W. Lee, J. Lee, I. Cho, D. Jeong, Inha Univ. (South Korea)

Intra prediction coding is one of the many coding-efficiency oriented tools of H.264/AVC, but it requires high computational complexity. Many fast intra coding algorithms have been proposed to reduce the computational complexity of intra prediction, but most of them have been focused on the mode decision methods themselves. In this paper, we propose a fast algorithm in which new intra modes are substituted for certain of the conventional intra modes, so that the number of intra modes can be reduced. The proposed intra modes, namely the weighted mean and median modes, can effectively represent the directions of a block in a frame. The simulation results showed that the proposed method could reduce the encoding time of the overall sequence by about 11 % and that of the I-frames by about 28%, without any noticeable degradation of the coding efficiency.

6077-66, Poster Session

A splitting algorithm for touched particle based on distance map and particle shape information

W. Wang, Chongqing Univ. of Posts and Telecommunications (China)

image analysis of crushed aggregates, in most cases, after binarization of a grey scale image, the resulting binary image is not satisfactory, because particles touch or overlap each other. Many commercial image analysis systems lack this automatic procedure, and the operator has to do this manually in an interactive system. Hence, it is a need to construct an algorithm for automatically splitting touching or overlapping particles in a binary image. This paper presents how to split touching particles. The algorithm mainly consists of two sub-algorithms; they are splitting based on concavities of boundaries and splitting based on object skeleton histogram. It first traces particle boundaries based on discontinuities, then splits touching parts of

particles based on shape information, where no gray information can be used, by using morphological mathematics method (e.g. distance map) combining particle shape information (information is classified by using fuzzy mathematics). After that, the algorithm split the remaining touching parts by using the information of concavities of particle boundaries. The algorithm can automatically delineate particles not only on a simple image (a few particles touching) and also on a complex image (many particles touching together). The algorithm has been tested in a laboratory; it works well for various particle images.

6077-67, Poster Session

Geo-registration of aerial images by feature matching

Z. Wu, H. Qian, M. Zhu, Zhejiang Univ. (China)

We propose a new featured-based geo-registration technique for aerial images that helps nearly real-time calibrate and update the telemetry data and sensor model on flight. Firstly

by using the available telemetry information, we bring both images into a common projection space. Second, we use the distribution of local geometric properties to guess the initial rotation and translation parameters. After the coarse alignment, the Harris operator is adopted to produce the initial feature points set, while the corresponding feature points set in the target image can be established through normalized correlation in local neighborhood of the selected points' position. Finally after the matched feature point sets are well constructed, the transform parameters can be solved by least square error estimation. The experiment shows our algorithm can effectively reduce the error in telemetry data caused by various noises.

6077-68, Poster Session

A new segmentation approach using Gaussian color model and temporal information

M. Karaman, L. Goldmann, T. Sikora, Technische Univ. Berlin (Germany)

A new segmentation approach usable for fixed or motion compensated camera is described. Instead of the often used color spaces such as RGB, YCbCr, and HSI we operate with the invariant Gaussian color model proposed by Geusebroek and temporal information which eliminates unsteady regions surrounded by the moving objects. The Gaussian color model has never been used in video segmentation. Comparison with some state of the art methods in which both subjective and objective evaluation are applied proves the good performance of the proposed method. The subjective evaluation is obtained by visually analyzing of the segmentation results and for objective evaluation manually segmented ground truth data are used. Moreover, the segmentation results with post-processing (median filtering, morphological operations) are applied to provide fair comparison. Additionally, the computational complexity is also considered in which the elapsed time for the techniques are measured.

6077-69, Poster Session

Region-based transform-domain video scrambling

F. Dufaux, T. Ebrahimi, Emittal S.A. (Switzerland) and École Polytechnique Fédérale de Lausanne (Switzerland)

In this paper, we address the problem of scrambling regions of interest in a video sequence. We target applications such as video surveillance preserving privacy, anonymous video communications, or TV news safeguarding the anonymity of a source. We propose an efficient solution based on transform-domain scrambling. More specifically, the sign of selected transform coefficients is flipped during encoding. We address the two cases of Motion JPEG 2000 and MPEG-4. Simulation

results show that it can be successfully applied to conceal information in regions of interest in the scene while providing with a good level of security. Furthermore, the scrambling is flexible and allows adjusting the amount of distortion introduced. Finally, this is achieved with a small impact on coding performance and negligible computational complexity increase.

6077-70, Poster Session

Robust face detection based on components and their topology

L. Goldmann, U. Mönich, T. Sikora, Technische Univ. Berlin (Germany)

This paper presents a novel approach for automatic and robust object detection. It utilizes a component-based approach that combines techniques from both statistical and structural pattern recognition domain. While the component detection relies on Haar-like features and an AdaBoost trained classifier cascade, the topology verification is based on graph matching techniques. The system is used for face detection and the experiments show its outstanding performance in comparison to other face detection approaches. Especially in the presence of partial occlusions, uneven illumination and out-of-plane rotations it yields higher robustness.

The paper starts by providing a taxonomy for object detection systems, which is used for the comparison of various state-of-the-art approaches. An overview of the system and a description of its components is provided along with visual examples to illustrate them. The evaluation is based on a comprehensive set of face databases in order to obtain reliable and general results. Objective evaluation is done using well-known ROC curves, which are widely used for detection tasks. Furthermore visual examples are provided for subjective evaluation. For the comparison one of the best state of the art face detectors is considered. By analyzing the experimental results reasons for the outstanding performance are provided and directions for future research are given.

6077-72, Poster Session

Resolution scalable SPIHT

D. Choundappan, P. Salama, M. Rizkalla, M. El-Sharkawy, Indiana Univ./Purdue Univ. at Indianapolis

No abstract available.

6077-73, Poster Session

Robust global motion estimation in video stabilization for reducing visually induced motion sickness

I. Tsubaki, Kanagawa Univ. (Japan); T. Morita, NHK Engineering Services (Japan); K. Aizawa, The Univ. of Tokyo (Japan); T. Saito, Kanagawa Univ. (Japan)

Video sequences acquired by handheld cameras are often affected by camera shaking, and can cause motion sickness for viewers. Video stabilization is the process of generating a corrected video sequence where image motion by camera's undesirable shake is removed, and it is effective to reduce motion sickness.

We present a robust global motion estimation method to improve the accuracy of video stabilization. The outliers of motion vectors are the major cause of degradation of accuracy. The robust model fitting methods, M-estimator, RANSAC and MDPE, are applied to global motion estimation, and the accuracy is evaluated. In the experimental results, the influence of outliers occupying more than half of the image area is removed by MDPE, and the accuracy of video stabilization is improved. In the video stabilization, the intentional camera motion is left by low pass filtering of global motion parameters in time domain.

6077-74, Poster Session

Spatially variant morphological image processing: theory and applications

N. Bouaynaya, D. Schonfeld, Univ. of Illinois at Chicago

Originally, mathematical morphology was a theory of signal transformations which are invariant under Euclidean translations. An interest in the extension of mathematical morphology to spatially-variant (SV) operators has emerged due to the requirements imposed by numerous applications in adaptive signal (image) processing. This paper presents a general theory of spatially-variant mathematical morphology in the Euclidean space. We define the binary and gray-level spatially-variant basic morphological operators (i.e., erosion, dilation, opening and closing) and study their properties. We derive the spatially-variant umbra homomorphism theorem, which establishes a homomorphism between SV binary morphology and SV gray-level morphology. We subsequently derive kernel representations for a large class of binary and gray-level SV operators in terms of the basic SV morphological operators. The theory of SV mathematical morphology is used to extend and analyze two important image processing applications: morphological image restoration and skeleton representation of binary images. For morphological image restoration, we obtain new realizations of adaptive median filters in terms of the basic SV morphological operators. For skeleton representation, we develop an algorithm to construct the optimal structuring elements, in the sense of minimizing the cardinality of the SV morphological skeleton representation. Experimental results show the power of the proposed theory in practical image processing applications.

6077-75, Poster Session

Video frame rate up conversion under inconsistent camera

J. Wang, Wayne State Univ.; N. Patel, W. Grosky, Univ. of Michigan/Dearborn

In this paper, we address the problem of video frame rate up conversion (FRC) in compressed domain. FRC is often recognized as video temporal interpolation. The problem is very challenging when targeted for a video sequence with an inconsistent camera and object motion. A novel compressed domain motion compensation scheme is presented and applied in this paper. The proposed algorithm uses MPEG-2 compressed motion vectors to undergo a cumulative spatiotemporal interpolation over a temporal sliding window of frames. An iterative rejection scheme based on the affine motion model is exploited to detect the global camera motion. Subsequently, the foreground object separation is performed by examining the temporal consistency of the output of iterative rejections. This consistency check process helps to conglomerate the resulting foreground macroblocks and weeds out the unqualified blocks, thus further refines the crude segmentation results. Finally, different strategies for compensating the camera motion and the object motion are applied to interpolate the new frames. Illustrative examples are provided to demonstrate the efficacy of the proposed approach. Experimental results are compared with the popular block based frame interpolation approach.

6077-76, Poster Session

Pre-compression rate allocation for JPEG2000 in power-constrained devices

F. Chebil, Nokia Americas

The JPEG2000 image coding standard is slowly getting into use in imaging applications. The standard offers several new features and improved compression efficiency compared to the baseline JPEG. The additional features of the JPEG2000 standard, on the other hand, lead to a higher computational load for encoding and decoding of images, making its usage in constrained devices, such as mobile phones or PDAs, challenging. The entropy coding stage of the JPEG2000 coding

system represents the main bottleneck stage, in computational cost. In practice, JPEG2000 encoder implementations apply a rate distortion optimization for the targeted bit rate after encoding all the bit planes of the transformed coefficients. For medium and low bit rate applications, this approach leads to extra compressed bitstream to be discarded while generating the final bitstream to fit the desired rate budget. In this paper we present a pre-compression rate allocation algorithm that estimates the number of bit planes to encode, based on the target rate and image characteristics to reduce the encoding complexity and help adoption of JPEG2000 in constrained application environments.

6077-77, Poster Session

Distortion fluctuation control for 3D wavelet-based video coding

V. Seran, L. P. Kondi, SUNY/Univ. at Buffalo

As an alternative approach to traditional predictive coding for video, wavelet based coding has emerged as a viable option. All current wavelet-based video codecs that employ temporal filtering exhibit a significant fluctuation in the PSNR of the reconstructed frames within a GOF. This distortion variation within a GOF is not directly related to the motion in the sequence as in the case of hybrid video coding schemes. The distortion fluctuation is more pronounced with longer filters and is undesirable at low bitrates. The temporal wavelet filter properties play a vital role in distortion fluctuation. The temporal distortion fluctuation is due to different filter synthesis gains for even and odd frames. In this work, we propose a method to control distortion fluctuation in 3D wavelet based video coding. A novel technique of assigning priorities to temporal subbands at different levels are used to smoothen the temporal PSNR. The relationship between the distortion in temporal wavelet subbands and the reconstructed frames are examined. Based on this relationship, an optimal condition for controlling distortion fluctuation is derived.

6077-78, Poster Session

Reduction of MPEG ringing artifacts using adaptive sigma filter

H. Pan, Sharp Labs. of America, Inc.

In this paper, we propose a novel computationally efficient post-processing algorithm to reduce ringing artifacts in the decoded DCT-coded video without using coding information. While the proposed algorithm is based on edge information as most filtering-based de-ringing algorithms do, this algorithm solely uses one single computationally efficient nonlinear filter, namely sigma filter, for both edge detection and smoothing. Specifically, the sigma filter, which was originally designed for nonlinear filtering, is extended to generate edge proximity information. Different from other adaptive filtering-based methods, whose filters typically use a fixed small window but flexible weights, this sigma filter adaptively switches between small and large windows. The adaptation is designed for removing ringing artifacts only, so the algorithm cannot be used for de-blocking. Overall, the proposed algorithm achieves a good balance among removing ringing artifacts, preserving edges and details, and computational complexity.

6077-79, Poster Session

Bit-stream extraction to maximize perceptual quality using quality information table in SVC

Y. S. Kim, Y. J. Jung, T. C. Thang, Y. M. Ro, Information and Communications Univ. (South Korea)

In scalable video coding (SVC), video quality can be controlled by bit-stream extraction. The bit-stream extraction is to extract network abstraction layer (NAL) units for the required quality. Since scalable bit-stream is packed in NAL units, quality control of SVC video is highly related to NAL unit extraction policy at a given bit-rate. Therefore, effective extraction policy is required to provide SVC video with optimal

quality. In this paper, a SVC bit-stream extraction method based on perceptual quality is proposed. The main goal of this work is to find the optimal extraction policy for SVC bit-stream that contain the spatial, temporal, and SNR scalability at a given bit-rate. Also, to consider perceptual quality relied on video characteristics, the video segments are classified into different classes, namely action, crowd, dialog, scenery, and text&graphic. As a result of a subjective test on the classified video scenes, consistent characteristic of perceptual quality preference is achieved. Based on this, quality information table (QIT) has been determined for each class which guides the bit-stream extraction process. The determined QIT is applied to SVC bit-stream extraction depending on to which class a video segment belongs. In the experiment, the proposed extraction scheme is applied for SVC bit-stream extraction belongs to action class. Extraction policy to maximize perceptual quality of action class is applied based on QIT for action class. The extracted video and multi-dimensional scalability resulted from the proposed scheme are also described.

6077-80, Poster Session

Active surfaces for video tracking and 3D segmentation based on a new method for multidimensional optimization

N. Bouaynaya, D. Schonfeld, Univ. of Illinois at Chicago

We propose an optimal framework for active surface extraction from video sequences. An active surface is a collection of active contours in successive frames such that the active contours are constrained by spatial and temporal energy terms. The spatial energy terms impose constraints on the active contour in a given frame. The temporal energy terms relate the active contours in different frames to preserve desired properties of the active surface. For computational efficiency, we reduce the 3-D active surface optimization problem to a 2-D model by considering only point indices along normal lines of each contour and define the energy terms in a causal way. We develop an n-D dynamic tree programming algorithm to find the optimum of n-D semi-causal functions. We prove that the n-D dynamic tree programming algorithm converges to the global optimum. In particular, the classical 1-D dynamic programming algorithm is a special case of the n-D dynamic tree programming algorithm. The optimal active surface is subsequently obtained by using the 2-D dynamic tree programming algorithm. Simulation results show the efficiency and robustness of the proposed approach in active surface extraction for video tracking and segmentation of the human head in real-world video sequences.

6077-81, Poster Session

Robust transmission of packet-based H.264/AVC video with data partitioning over DS-CDMA wireless channels

A. V. S. Mantravadi, M. Bansal, L. P. Kondi, SUNY/Univ. at Buffalo

In this paper, we address the problem of robust transmission of packet based H.264/AVC video over direct sequence-code division multiple access (DS-CDMA) channels. H.264 based data partitioning is used to produce video packets of unequal importance with regards to their need in terms of the decoded video quality. For transmission, the data partitioned video packets are packetized as per IP/UDP/RTP protocol stack and are sorted into different levels for giving unequal error protection (UEP) using Rate Compatible Punctured Convolutional (RCPC) codes. Constant size framing is done at the link layer and Cyclic Redundancy Check header (CRC) is attached for error detection. A multipath Rayleigh fading channel with Additive White Gaussian Noise (AWGN) and interference from other users is considered at the physical layer. The link layer frames are channel encoded, spread and transmitted over the channel. The received data is despread/demodulated using the Auxiliary Vector (AV) filter or RAKE matched filter (RAKE-MF) receiver and subsequently channel and source decoded. Our experimental results show the effectiveness of using data partitioning for wireless transmissions when compared to the system

not using data partitioning. Also the superior interference mitigation capabilities of AV receiver is shown in comparison to the RAKE-MF receiver.

6077-82, Poster Session

A novel VLC-based on second-run-level coding and dynamic truncation

C. H. Cui, W. Y. Liu, X. Jin, Huazhong Univ. of Science and Technology (China)

In this paper, a more efficient VLC method for coding DCT coefficients is proposed, which sufficiently exploits and utilizes the context information by employing three novel approaches-2nd-run-level coding, dynamic truncation and adaptive EG/GR selection. It is well observed that after traditional run-level coding, the levels with absolute value equal to 1 and the runs equal to 0 are considerable, thus 2nd-run-level coding is introduced to compress these levels and runs more efficiently through pair coding. Equally important is that it will result in a large amount of table memories to realize adaptation to statistical behavior of 2D symbols, only by switching VLC tables. To solve this problem, dynamic truncation is proposed and applied together with table switch to achieve a higher degree of context adaptability and coding efficiency. In addition, the coding performance can be further improved by enabling adaptive codeword selection between exp-Golomb (EG) codes and Golomb-Rice (GR) codes without any complexity increment. Experimental results show that when compared with context-based 2D-VLC, the proposed VLC method gains 0.25 dB ~0.79 dB in PSNR and achieves 5.30% ~ 11.58% improvement in bit rate reduction.

6077-83, Poster Session

Efficient coding scheme for super high definition video based on extending H.264 high profile

S. Naito, A. Matsumura, KDDI R&D Labs. (Japan)

H.264 High Profile, one of the standard video coding schemes, can be utilized for super high definition video since target image resolution is up to 4096_2304. However, in the case of encoding super high definition video such as the 4Kx2K system whose resolution corresponds to 4096x2160, the coding syntax might be redundant since available macroblock size become quite small compared to the image resolution. The problem is caused by the limitation of the macroblock size by which motion compensated prediction is conducted. To overcome the problem within the framework of the H.264 High Profile encoder, extending the limitation of macroblock size is required. From this perspective, this paper describes an efficient coding scheme applicable to super high definition video based on extending the H.264 High Profile. As the key technology of the proposed coding scheme, an approach for extending the limitation of available macroblock size is introduced. From experimental results, it was confirmed that the outstanding coding gain was achieved by the proposed scheme especially for the low bit-rate condition.

6077-85, Poster Session

Fish tracking by combining motion-based segmentation and particle filtering

E. Bichot, L. Mascarilla, P. Courtellemont, Univ. de La Rochelle (France)

This paper describes a new particle filter relying on motion segmentation. It consists in generating hypotheses from particle filtering corresponding to blobs of similar motion to target using importance sampling. Hence, target search is restricted to high likelihood regions of state space. We also exploit segmentation to update target model. Once the moving target has been identified, a representative model is learnt from its spatial support. We refer to this

model in the correction step of the tracking process which is based on color information. Consequently, our approach combines both motion and color information. The proposed filter, including the new importance sampling scheme and the strategy to update target model, has been applied on real fish tank sequences and compared to a simple Bootstrap filter. Experiments show that our filter improves tracking performances in case of color ambiguity, occlusions and variations of target appearance.

6077-86, Poster Session

Multiresolution color patch extraction

P. Obrador, Hewlett-Packard Labs.

Certain applications require the extraction of patches of color from an image, their size and location. These applications may be: color harmonization algorithms, non-photorealistic rendering, etc. These applications use not too big a palette of colors, and in both cases large areas of homogeneous color are favored along with high detail preserved in the smaller areas with a lot of color activity. The main problem this paper will tackle is to identify the underlying color in an image region, which will be referred to as its underlying color patch, and also try to protect as much as possible the high color activity detail areas. No perfect scene object segmentation is intended in this process, since different objects may be quantized to the same color, the result may be a merged color patch.

The main contributions of this paper are: a parallel symmetrical alternating sequential filters scheme which allows for color patch extraction at a certain scale while maintaining edges; a multi-resolution implementation of such filters so that the detail regions with high color activity are preserved; and a maximum likelihood scheme to fix edge jitter in color morphological filters applied to sparsely quantized images.

6077-87, Poster Session

Disparity estimation using edge model for stereo video compression

H. J. Kim, Y. Lee, J. B. Ra, Korea Advanced Institute of Science and Technology (South Korea)

Stereo video becomes an important issue with the developments of 3D display technologies. While a stereo system provides the perception of 3D depth, the amount of data for stereo video may be doubled compared to mono video. So an efficient stereo video coding technique is essential. Since the stereo video is taken from the same object in the two different views, most of objects in a stereo pair are translated only to the horizontal direction, while objects in subsequent frames of a mono video can be translated to an arbitrary direction, rotated, and zoomed. Hence, unlike in the mono video, the disparity in a stereo pair can be well estimated by a translational motion or disparity if the object boundary is exactly described. In this paper, we propose an efficient disparity estimation scheme based on an edge model describing object boundary in a block, and apply the estimated disparity to stereo video compression. In addition, a disparity regularization scheme, which is proper for the edge model, is proposed to reduce the bits required for coding the block motion vectors and disparity values. It has been found that the proposed algorithms significantly improve the coding efficiency of stereo video sequences.

6077-88, Poster Session

Adaptive λ estimation in Lagrangian rate-distortion optimization for video coding

L. Chen, Mobilyer Corp.

In this paper, adaptive Lagrangian multiplier λ estimation in Lagrangian R-D optimization for video coding is presented that is based on the λ -domain linear rate model and distortion model. It yields that λ is a function of rate, distortion and coding input statistics and can be written as $\lambda(R, D, \sigma^2) = \lambda(\ln(\sigma^2/D) + \sigma^2/R + k_0)$, with λ , σ^2 and k_0 as

coding constants, σ^2 is variance of prediction error input. $\lambda(R, D, \sigma^2)$ describes its ubiquitous relationship with coding statistics and coding input in hybrid video coding such as H.263, MPEG-2/4 and H.264/AVC. And it provides a different viewpoint of the Lagrangian multiplier in the Lagrangian RDO from the traditional one. The proposed λ estimation is de-coupled with quantization parameter yet the λ can be any continuous value instead of a step value with QP. Therefore it enables a fine encoder design and control.

6077-17, Session 3

Rate-distortion analysis of SP and SI frames

E. Setton, P. Ramanathan, B. Girod, Stanford Univ.

SP and SI are new picture types in the H.264 video coding standard. These types can be used to compress a picture with inter-frame prediction or without inter-frame prediction and can be substituted for one another in the bitstream without creating any decoding drift. SP and SI frames can be used for error resilience, bitstream switching or random access. Despite a widespread interest in SP and SI frames, no work so far has addressed the question of how efficient SI and SP frames are, and how their relative sizes can be traded off. The purpose of this work is to address these questions by proposing a model for the rate-distortion functions of SP and SI frames. This model extends earlier rate-distortion models for I frames and P-frames and is derived for Gaussian signals. The model is used to analyze the properties of these pictures and to derive encoder settings to minimize the transmitted bit-rate when SP frames are used for video streaming with packet losses. We compare the model to experimental results, obtained with our implementation of an SP encoder, made publicly available and recently adopted by JVT. The results confirm the validity of the model.

6077-18, Session 3

Wyner-Ziv video coding with universal prediction

Z. Li, L. Liu, E. J. Delp III, Purdue Univ.

The coding efficiency of a Wyner-Ziv video codec relies significantly on the quality of side information extracted at the decoder. The construction of efficient side information is difficult thanks in part to the fact that the original video sequence is not available at the decoder. Conventional motion search methods are widely used in the Wyner-Ziv video decoder to extract side information. This substantially increases the Wyner-Ziv video decoding complexity. In this paper, we propose a new method to construct side estimation based on the idea of universal prediction. This method, referred to as Wyner-Ziv video coding with Universal Prediction (WZUP), does not perform motion search or assume underlying model of original input video sequences at the decoder. Instead, WZUP estimates the side information based on its observations on past reconstructed video data. We show that WZUP can significantly reduce decoding complexity at the decoder and achieve fair side estimation performance, thus make it possible to design both the video encoder and the decoder with low computational complexity.

6077-19, Session 3

Hybrid scalable video coding with multiple description and layered coding

G. Zhang, R. L. Stevenson, Univ. of Notre Dame

We propose a hybrid scalable video coding algorithm in which two types of scalabilities, i.e., layered scalability and parallel scalability, are combined to achieve higher order of flexibility for heterogeneous networks and mixed client requirements. The scalable video has two layers, containing three descriptions. In space domain, SNR scalable video coding is used to give layered scalability on frame quality; while in temporal domain, a multiple description approach, the Multiple State Video Coding (MSVC), provides parallel scalability to the base layer video. Two coarsely quantized, independently decodable sub-streams

are yielded using MSVC and form the base layer. Residual signals of all frames in the video sequence are coded into a third sub-stream and form the enhancement layer. Simulations based on H.264 codec show that the hybrid scalable video protects the base layer using multiple description coding and has better performance than conventional layered scalable video when a base layer picture is damaged. It also gives similar performance as SNR scalable video when the enhancement layer encounters errors. In general packet drop networks, the proposed hybrid scalable video achieves better error resilience capability than the original MSVC video and single description video in high packet drop rate environments.

6077-20, Session 3

Wyner-Ziv video coding: a motion estimation perspective

Z. Li, L. Liu, E. J. Delp III, Purdue Univ.

Wyner-Ziv video coding has gained considerable interests in the research community. In this paper, we examine the Wyner-Ziv video coding performance and compare it with conventional motion-compensated prediction (MCP) based video coding. Theoretical and simulation results show that although Wyner-Ziv video coding can achieve as much as 6dB gain over conventional video coding without motion search, it still falls 6dB or more

behind current best MCP-based INTER-frame video coding. We further investigate the use of sub-pixel and multi-reference motion search methods to improve Wyner-Ziv video coding efficiency.

6077-21, Session 3

A new approach to motion compensation in spatially scalable video coding

M. L. Comer, Purdue University

No abstract yet.

6077-31, Session 6

Parallel multiple target tracking using multiple cooperative trackers

W. Qu, D. Schonfeld, Univ. of Illinois at Chicago; M. A. Mohamed, Motorola, Inc.

In this paper, we present a parallel multiple target tracking framework using multiple cooperative trackers. The multiple target occlusion problem is handled by modeling the interaction among different targets' observations and solving the data association through a recursive estimation. The computational complexity of the proposed approach increases linearly with the number of targets which yields a much faster implementation than existing multiple target tracking algorithms. Experimental results have been demonstrated on real-world videos.

6077-32, Session 6

Rao-Blackwellised particle filter with adaptive system noise and its evaluation for tracking in surveillance

X. Xu, B. Li, Arizona State Univ.

In the visual tracking domain, Particle Filtering (PF) can become quite inefficient when being applied into high dimensional state space. Rao-Blackwellisation [1] has been shown to be an effective method to reduce the size of the state space by marginalizing out some of the variables analytically [2]. In this paper based on our previous work [3] we proposed RBPF tracking algorithm with adaptive system noise model. Experiments using both simulation data and real data show that the proposed RBPF algorithm with adaptive noise variance improves its

performance significantly over conventional Particle Filter tracking algorithm. The improvements manifest in three aspects: increased estimation accuracy, reduced variance for estimates and reduced particle numbers are needed to achieve the same level of accuracy.

6077-33, Session 6

Spatial detection of logos as outliers from the content

A. Ekin, Philips Research Labs. (Netherlands)

This paper proposes a purely image-based TV channel logo detection algorithm that can detect logos independently from their motion and transparency features. The proposed algorithm can robustly detect any type of logos, such as transparent and animated, without requiring any temporal constraints whereas known methods have to wait for the occurrence of large motion in the scene and assume stationary logos. The algorithm models logo pixels as outliers from the actual scene content that is represented by multiple 3-D histograms in the YCBCR space. We use four scene histograms corresponding to each of the four corners because the content characteristics change from one image corner to another. A further novelty of the proposed algorithm is that we define image corners and the areas where we compute the scene histograms by a cinematic technique called Golden Section Rule that is used by professionals. The robustness of the proposed algorithm is demonstrated over a dataset of representative TV content.

6077-34, Session 6

Finding corners in images by foveated search

T. L. Arnow, A. C. Bovik, The Univ. of Texas at Austin

In this paper we present a new foveated, multifixating strategy for locating corners in natural images and compare its performance with that of human observers. This approach combines foveated edge detection and curvature calculation with long and short saccades of foveal location. Each saccade moves the fovea to a location of high curvature combined with high edge gradient. Edges are located using a foveated Canny edge detector with spatial constant that increases with eccentricity. Next, we calculate a measure of local corner strength, based on a product of curvature and gradient. An inhibition factor based on previous visits to a region of the image prevents the system from repeatedly returning to the same locale. A long saccade is intended to move the fovea to previously unexplored areas of the image. Subsequent short saccades improve the accuracy of the location of the corner approximated by the long saccade. The system is tested on two natural scenes and the results compared against subjects observing the same test images through an eyetracker. Results show that the algorithm is a good locator of corners but a poor predictor of visual fixations.

6077-35, Session 6

Two-dimensional regularized disparity estimation based on the Gabor transform

X. Huang, E. Dubois, Univ. of Ottawa (Canada)

Disparity estimation is a long standing problem. Due to its ill-posed nature, there is much ambiguity in the estimation process. Further improvement should be possible under the multiview framework in which the constraint relations among different images can be exploited to resolve the ambiguities and to improve the performance. For multiview image correspondences, the disparity estimations should usually be performed in two dimensions and sometimes without calibration information. Thus, the traditional one-dimensional disparity estimation needs to be extended to the two-dimensional case. This paper presents a hybrid disparity estimation algorithm that combines three different kinds of techniques: Gabor transform, variational refinement and region-based affine parameter estimation for disparity calculation. The Gabor transform is implemented using a set of quadrature-pair filters for estimating the two-dimensional

correspondences between the two images without the calibration information, and the estimated coarse disparity maps are applied to a variational refinement process which involves solving a set of partial differential equations (PDEs). Then the refined disparity values are used with the image segmentation information so that the parameters of affine transforms for the correspondence of each region can be calculated by singular value decomposition (SVD), and these affine parameters can be applied in turn to bring more refined disparity maps.

6077-36, Session 6

Plane-based calibration of cameras with zoom variation

C. Yu, G. Sharma, Univ. of Rochester

Plane-Based calibration algorithms have been widely adopted for the purpose of camera calibration task. These algorithms have the advantage of robustness compared to self-calibration and flexibility compared to traditional algorithms which require a 3D calibration pattern. While the common assumption is that the intrinsic parameters during the calibration process are fixed, limited consideration has been given to the general case when some intrinsic parameters maybe varying, others maybe fixed or known. We first discuss these general cases for camera calibration. Using a counting argument we enumerate all cases where plane-based calibration may be utilized and list the number of images required for each of these cases.

Then we extend the plane-based framework to the problem of cameras with zoom variation, which is the most common case. The approach presented and may be extended to incorporate additional varying parameters described in the general framework. The algorithm is tested using both synthetically generated images and actual images captured using a digital camera. The results indicate that the method performs very well and inherits the advantage of robustness and flexibility from plane-based calibration algorithms.

6077-22, Session 4

Distributed sender-driven video streaming

J. Chakareski, P. Frossard, École Polytechnique Fédérale de Lausanne (Switzerland)

A system for sender-driven video streaming from multiple servers to a single receiver is considered in this paper. The receiver monitors incoming packets on each network path and returns, to the senders, estimates of the available bandwidth on all the network paths. The senders in turn employ this information to compute transmission schedules for packets belonging to the video stream sent to the receiver. An optimization framework is proposed that enables the senders to compute their transmission schedules in a distributed way, and yet to dynamically coordinate them over time such that the resulting video quality at the receiver is maximized. Experimental results demonstrate that the proposed streaming framework provides superior performance over distortion-agnostic transmission schemes that perform proportional packet scheduling based only on the available network bandwidths.

6077-23, Session 4

Advances in video encoder optimization

A. Dumitras, Apple Computer, Inc.

Numerous efforts have been directed toward identifying the best methods to optimize video encoders. These efforts focused on removing spatial, temporal and perceptual redundancies from a video source with the objective of representing the data efficiently. However, so far there is no unique "best method" to optimize a video encoder. Instead, there exist various methods that address (usually distinctly) different aspects of the optimization problem and different applications. This talk will present a taxonomy and an overview of advanced, interdisciplinary methods that enable video encoder optimization. Such methods combine knowledge from video encoding, video analysis,

computer graphics and software engineering domains, and achieve encoder optimization tradeoffs at the algorithmic and implementation levels.

6077-24, Session 4

Suprathreshold visual psychophysics and structure-based visual masking

S. S. Hemami, D. M. Chandler, B. Chern, J. A. Moses, Cornell Univ.

Current state-of-the-art algorithms that process visual information for end use by humans treat images and video as traditional signals and employ sophisticated signal processing strategies to achieve their excellent performance. These algorithms also incorporate characteristics of the human visual system (HVS), but typically in a relatively simplistic manner, and achievable performance is reaching an asymptote. However, large gains are still realizable with current techniques by aggressively incorporating HVS characteristics to a much greater extent than is presently done. Achieving these gains requires HVS characterizations which better model natural image perception ranging from sub-threshold perception (where distortions are not visible) to supra-threshold perception (where distortions are clearly visible). This paper reviews classical psychophysical HVS characterizations focused on the visual cortex (V1), pertaining to the contrast sensitivity function, summation, and masking, which have been obtained using unrealistic stimuli such as sinusoids and white noise. Complementary results are then presented which have been obtained using realistic stimuli derived from or consisting of natural images, along with several applications of these results. Finally, a new structure-based masking model is proposed to model masking in homogeneous natural image patches as a function of the image type: textures, edges, or structures.

6077-89, Session 4

Video compression with flexible playback order based on distributed source coding

N. Cheung, H. Wang, A. Ortega, Univ. of Southern California

Some emerging applications may require flexible playback features for time-based media, such as video, that cannot be directly supported by current compression standards, because for these decoding of frames can only be done in a predetermined order. An example would be a video application where both backward and forward frame-by-frame playback are to be supported. A standard codec would need additional delay and memory to support backward playback, or at the cost of reduced coding efficiency. Other example applications where flexible playback may be desirable include switching between different views in multiview video coding, and accessing individual spectral bands in hyperspectral imagery. In this work we address flexible playback by showing that it becomes feasible when a particular data unit can be decoded using information from either one of a number of other data units. We cast this problem as one of source coding with uncertainty about decoder side-information and propose a solution based on distributed source coding. In addition, we propose macroblock-based mode switching algorithms in the context of distributed video coding to improve coding efficiency. Our results show that our proposed solution can achieve good coding efficiency without incurring additional delay and memory overhead.

6077-37, Session 7

Classification-based hybrid filters for image processing

H. Hu, Technical Univ. of Eindhoven (Netherlands); G. de Haan, Philips Research Labs. (Netherlands)

The paper proposes a new type of nonlinear filters, classification-based hybrid filters, which jointly utilize spatial, rank order and structural information in image processing. The hybrid filter is a direct

combination of a linear filter and an order statistic filter and it exploits both spatial and rank information in the image content. Nevertheless, the hybrid filter alone could not accommodate the optimal task for all different image structures, that is, it fails to utilize the important structure information from which more robust estimation can be constructed. The proposed hybrid filters use a vector containing the observation samples in both spatial and rank order. The filter coefficients depend on the local structure of the image content, which can be classified based on the luminance pattern in the filter window. The optimal coefficients for each class are obtained by the Least Mean Square optimization. We show that the proposed classification-based hybrid filters exhibit improved performance over linear filters and order statistic filters in several applications, image de-blocking, impulsive noise reduction and image interpolation. Both quantitative and qualitative comparisons have also been presented in the paper.

6077-39, Session 7

Solving occlusion in film judder elimination

E. B. Bellers, Philips Semiconductors; J. van Gorp, Philips Semiconductors (Netherlands); J. Janssen, Philips Semiconductors; R. A. C. Braspenning, R. Wittebrood, Philips Research Labs. (Netherlands)

Tracking motion of moving objects in a video scene by the human eye results in a stationary picture on the retina. However, if the motion is irregular, tracking can be difficult, resulting in the perception of motion blur or motion judder. This is a typical result due to the broadcast of film material. Film is captured at 24 Hz, and by picture repetition displayed at either 50 or 60 Hz.

Motion judder can be eliminated at the receiver end by temporally correcting for the motion. Although this significantly improves the viewing experience, it can cause picture degradation at the boundaries of moving objects due to improper interpolation in and around occlusion areas. In these occlusion areas, extrapolation techniques need to be applied rather than interpolation. However, a reliable occlusion detection and classification is needed to prevent artifacts in the up-converted video which might result due to improper interpolation / extrapolation in the misclassified regions.

In the paper, we present a solution to the occlusion problem, which is addressed in the motion estimator and temporal up-converter.

6077-40, Session 7

Similarity-independent and non-iterative algorithm for subpixel motion estimation

M. Shimizu, S. Chang, M. Okutomi, Tokyo Institute of Technology (Japan)

This study presents an alternative method to estimate motion parameters to the gradient-based method. The proposed method is a faster version of a hyperplane-intersection method.

The hyperplane-intersection method estimates the motion parameters between images as an intersection position of estimated hyperplanes in a parameter space. The hyperplanes approximate the zero positions of partial derivatives of a continuous similarity measure with respect to each parameter. The method employs a straightforward computation to estimate the parameters, instead of using an iterative framework. The non-iterative method is suitable for hardware implementation. The method is the region-based and intensity-based technique that is capable of using any dissimilarity or similarity measure such as sum of squared differences (SSD) or zero-mean normalized cross correlation (ZNCC), which can be selected adequately in consideration of a property of input image sequence and a required computation time.

The faster version of the method is realized with pre-computed warped images of the template, which reduce the computational cost for each input frame. Experiments using synthesized-motion sequences and real image sequences are performed to confirm the comparisons. The faster version of the hyperplane-intersection method using ZNCC

demonstrates robustness to a non-uniform illumination change in the image sequences.

6077-26, Session 5

H.264 redundant slices for systematic lossy error protection of video

S. D. Rane, B. Girod, Stanford Univ.

We propose the use of H.264/AVC redundant slices for Systematic Lossy Error Protection (SLEP) of a video signal transmitted over an error-prone channel. In SLEP, the video signal is transmitted to the decoder without channel coding. Additionally, a Wyner-Ziv encoded version of the video signal is transmitted in order to provide error-resilience. In the event of channel errors, the Wyner-Ziv description is decoded as a substitute for the error-prone portions of the primary video signal. Since the Wyner-Ziv description is typically coarser than the primary video signal, SLEP is a lossy error protection technique which trades-off residual quantization distortion for improved error-resilience properties, such as graceful degradation of decoder picture quality. We describe how H.264/AVC redundant slices can be used to generate the Wyner-Ziv description, and present simulation results to demonstrate the advantages of this method over traditional methods such as FEC.

6077-27, Session 5

Correlation estimation and performance optimization for distributed image compression

Z. He, Univ. of Missouri/Columbia

Correlation estimation plays a critical role in resource allocation and rate control for distributed data compression. A Wyner-Ziv encoder for distributed image compression is often considered as a lossy source encoder followed by a lossless Slepian-Wolf encoder. The source encoder consists of spatial transform, quantization, and bit plane extraction. In this work, we find that Gray code, which has been extensively used in digital modulation, is able to significantly improve the correlation between the source data and its side information. Theoretically, we analyze the behavior of Gray code within the context of distributed image compression. Using this theoretical model, we are able to efficiently allocate the bit budget and determine the code rate of the Slepian-Wolf encoder. Our experimental results demonstrate that the Gray code, coupled with accurate correlation estimation and rate control, significantly improves the picture quality, by up to 4 dB, over the existing methods for distributed image compression.

6077-28, Session 5

Correlation structure analysis for distributed video compression over wireless video sensor networks

Z. He, Univ. of Missouri/Columbia

From the information-theoretic perspective, as stated by the Wyner-Ziv theorem, the distributed source encoder doesn't need any knowledge about its side information in achieving the R-D performance limit. However, from the system design and performance analysis perspective, correlation modeling plays an important role in analysis, control, and optimization of the R-D behavior of the Wyner-Ziv video coding. In this work, we observe that videos captured from a wireless video sensor network (WVSN) are uniquely correlated under the multi-view geometry. We propose to utilize this computer vision principal, as well as other existing information, which is already available or can be easily obtained from the encoder, to estimate the source correlation structure. The source correlation determines the R-D behavior of the Wyner-Ziv encoder, and provide useful information for rate control and performance optimization of the Wyner-Ziv encoder.

6077-29, Session 5

Distributed multiview video coding

X. Guo, Harbin Institute of Technology (China) and Microsoft Research Asia (China); Y. Lu, F. Wu, Microsoft Research Asia (China); W. Gao, Institute of Computing Technology (China); S. Li, Microsoft Research Asia (China) and Beijing Institute of Technology (China)

There are mainly two key points which can affect the efficiency of multi-view video capture and transmission system largely: communication between cameras and computing complexity of encoder. In this paper, we propose a practical framework of distributed multi-view video coding, in which inter-camera communication is avoided and the large computing complexity is moved from encoder to decoder. In this scheme, multi-camera video sources are encoded separately and decoded dependently, and the traditional inter frame is replaced by Wyner-Ziv frame. To reach this goal, Wyner-Ziv theory on source coding with side information is employed as the basic coding principle. A Wyner-Ziv coding method based on wavelet transform and turbo codes is used as the core of the scheme. To further improve the coding performance, we also consider exploiting the large redundancy between adjacent views. A more flexible prediction method that can jointly use temporal and view correlations is proposed to generate the side information at the decoder. The experimental results show that the coding performance of proposed DMVC scheme is very promising compared to the traditional intra coding.

6077-30, Session 5

Free viewpoint switching in multiview video streaming using Wyner-Ziv video coding

X. Guo, Harbin Institute of Technology (China); Y. Lu, F. Wu, Microsoft Research Asia (China); W. Gao, Institute of Computing Technology (China); S. Li, Microsoft Research Asia (China)

The free viewpoint switching is one of the most important features of multi-view video streaming. The key problem lies in how to achieve the best performance when the camera processing capability and the network bandwidth are limited. In this paper, we propose a novel free viewpoint switching scheme for multi-view video scenario, in which the distributed video coding technique is employed. In this scheme, the multi-camera video sources are encoded separately with the traditional hybrid video coding scheme, and meanwhile an alternative bitstream is produced for every frame based on the Wyner-Ziv coding method for the purpose of error correction when the viewpoint switching occurs. When switching happens, the Wyner-Ziv bits corresponding to the actual reference frame at the switching point is transmitted and used to recover the true reference. Instead of completely removing the mismatch, the proposed switching scheme tries to reduce the mismatch to an acceptable level so as to save the bits for the switching frame. A wavelet transform domain Wyner-Ziv coding method is proposed to produce the Wyner-Ziv bits for the switching frame. Conclusively, with the proposed scheme, the inter-camera communication can be avoided and the drifting error can be controlled efficiently when the viewpoint switching occurs.

6077-41, Session 8

A wavelet-based two-stage near-lossless coder with L-infinity error scalability

S. Yea, W. A. Pearlman, Rensselaer Polytechnic Institute

We present a wavelet-based near-lossless coder with L-infinity error scalability. The method presented consists of a wavelet-based lossy layer encoder followed by multiple stages of residual refinements for L-infinity error scalability. We introduce a successive refinement scheme in L-infinity error sense for residual layers reminiscent of popular set-partitioning algorithms for embedded coding. The initial near-lossless error bound is attained by our previously proposed two-stage scheme which determines the bit-rate for the lossy layer 'on-the-fly' without any

iteration. The resulting residual which is defined by the difference between the original and the initial near-lossless reconstruction is then further refined in L-infinity error sense up to lossless reconstruction. This scheme provides a combination of L2-error embedded lossy reconstruction up to an automatically determined high-fidelity plus optional layers of scalable L-infinity error. This may turn out to be particularly useful for scalable archival applications where the fidelity of reconstructions on the high-bit end needs to be strictly controlled.

6077-42, Session 8

Region of interest access with three-dimensional SBHP algorithm

Y. Liu, W. A. Pearlman, Rensselaer Polytechnic Institute

One interesting feature of image compression is support of region of interest (ROI) access, in which an image sequence can be encoded only once and then the decoder can directly extract a subset of the bitstream to reconstruct a chosen ROI of required quality. In this paper, we apply Three-dimensional Subband Block Hierarchical Partitioning (3-D SBHP), a highly scalable wavelet transform based algorithm, for volumetric medical image compression to support ROI access. The code-block selection method by which random access decoding can be achieved is outlined and the performance empirically investigated. The experimental results show that there are a number of parameters that affect the effectiveness of ROI access, the most important being the size of the ROI size, code-block size, wavelet composition level, number of filter taps and target bit rate. Finally, one possible way to optimize ROI access performance is addressed.

6077-43, Session 8

Optimal JPEG2000 rate control mechanism applicable for super low delay distribution of HDTV programs

S. Naito, A. Koike, Kokusai Dinshin Denwa KK (Japan)

JPEG2000 technology has been adopted even for encoding motion pictures because of its high coding performance and the scalability of the stream format. Since it includes the additional advantage of employing intra frame coding technology such as JPEG2000, it allows drastic reduction in the latency accompanied by encoding and decoding process can be extremely reduced. On the other hand, a low delay transmission has been required especially for a FPU (Field Pick-up Unit) terminal or a piece of wireless camera equipment which may be utilized for a real-time remote hookup. In many such terminals, compression coding was conducted by typical MPEG-2 video, and the codec latency of more than 300 msec was forced basically from its coding algorithm. In this paper, HDTV is assumed to be a typical video application, and an optimal rate control mechanism for the JPEG2000 encoder is introduced as a key technology to achieve a low delay in transmission while maintaining high coding performance. Our study introduces advanced key technologies as yet unrecognized officially. Coding experiments using those technologies confirmed that significant coding delay elimination was achieved when compared to conventional encoding schemes.

6077-45, Session 9

Error resilience in network driven Wyner-Ziv video coding

L. Liu, P. Sabria, Purdue Univ.; J. Prades-Nebot, Univ. Politècnica de València (Spain); E. J. Delp III, Purdue Univ.

Previously we presented a network-driven Wyner-Ziv video coding method, in which the motion vectors are derived at the decoder and sent back to the encoder through a reliable backward channel. Compared to the schemes based on channel coding schemes, the method reduces the dependency of the INTRA modes and significantly improves the coding efficiency. In this paper, we consider the scenario

when the backward channel is error resilient. We study the performance of error resilient methods for our codec. A symmetrical Reversible Variable Length Code (RVLC) is used to reduce the bandwidth requirement of the backward channel. After the detection of the delay, a hybrid scheme with selective coding is proposed to improve the coding efficiency when transmission delay occurs. The delay detector controls the switch between coding in intra frames and pseudo-inter frames. The experimental results show that the data rate of the backward channel is reduced to less than 2% of the forward channel. In addition, these error resilient methods can consistently improve the video quality at the decoder.

6077-46, Session 9

Receiver buffer requirement for video streaming over TCP

T. Kim, Freescale Semiconductor, Inc.; M. H. Ammar, Georgia Institute of Technology

TCP is one of the most widely used transport protocols for video streaming. However, the rate variability of TCP makes it difficult to provide good video quality. To accommodate the variability, video streaming applications require receiver-side buffering. In current practice, however, there are no systematic guidelines for the provisioning of the receiver buffer, and smooth playout is insured through over-provisioning. In this work, we are interested in memory-constrained applications where it is important to determine the right size of receiver buffer in order to insure a prescribed video quality. To that end, we characterize video streaming over TCP in a systematic and quantitative manner. We first model a video streaming system analytically and derive an expression of receiver buffer requirement based on the model. Our analysis shows that the receiver buffer requirement is determined by the network characteristics and desired video quality. Experimental results validate our model and demonstrate that the receiver buffer requirement achieves desired video quality.

6077-47, Session 9

Effective overlay multicast tree constructing algorithm over multiple differentiated-service networks

D. B. Lee, H. Song, Pohang Univ. of Science and Technology (South Korea)

This paper presents an overlay multicast tree constructing algorithm to satisfy delay constraint for real-time media service with the minimum networking price over QoS network. It has provided an effective multicast tree to keep the maximum delay less than the tolerable value with the minimum price. Furthermore, a dynamic tree maintaining algorithm has been proposed to satisfy the maximum delay constraint and provide the seamless service by minimally updating the tree when End-systems join and leave. Our control variables are the tree structure among Proxy-senders and end-systems and the class vector of each Proxy-sender. During the experiment, NS-2 is employed and two Competitiveness, Delay Competitiveness (DC) and Price Competitiveness (PC), are employed to evaluate the performance of dynamic tree maintenance algorithm. We compare the proposed algorithm with ALMI MST since it is also a center based tree algorithm same as the proposed algorithm and handles a similar problem. By the experimental results, we have shown that overlay multicast over QoS network can be an effective solution to support multicast service and QoS concurrently over the next generation Internet.

6077-48, Session 9

A novel source rate control algorithm for video streaming over the Internet

Z. Peng, Tsinghua Univ. (China); W. Zeng, Univ. of Missouri/Columbia; C. W. Li, Tsinghua Univ. (China)

In this paper, we propose a novel source rate control algorithm for video streaming over the Internet. With the incorporation of a virtual network buffer management mechanism (VB), the QoS requirements of the application can be translated into the source rate constraints, based on which the source rate control is implemented. The maximum admissible bandwidth (or send rate) constraint, which is imposed by the encoder and decoder buffer sizes of the application, is also derived. To make sure the send rate not exceeding the maximum bandwidth constraint, a rate regulator using the token bucket approach is adopted at the application layer to limit the output rate of the encoder buffer when necessary. Simulation results show that our proposed algorithm can help the application reduce the overflow and underflow of the decoder buffer, and achieve better video quality and quality smoothness than traditional source rate control algorithms.

6077-49, Session 9

Motion-embedded residual error for packet loss recovery of video transmission and encryption

S. Sun, Institute of Information Science (Taiwan); J. Chen, National Central Univ. (Taiwan); C. Lu, Institute of Information Science (Taiwan); P. Chang, K. Fan, National Central Univ. (Taiwan)

Media encryption technologies actively play the first line of defense in securing the access of multimedia data.

Traditional cryptographic encryption can achieve provable security but is unfortunately sensitive to a single bit error, which will cause an unreliable packet to be dropped to create packet loss.

In order to achieve robust media encryption, error resilience in media encryption can be treated to be equivalent to error resilience in media transmission.

This study proposes an embedded block hash searching scheme at the decoder side to achieve motion estimation and recover the lost packets, while maintaining format compliance and cryptographic provable security.

It is important to note that the proposed framework is a kind of joint error-resilient video transmission/encryption and copyright protection.

6077-50, Session 10

A new structure of 3D dual-tree discrete wavelet transforms and applications to video denoising and coding

F. Shi, B. Wang, I. W. Selesnick, Y. Wang, Polytechnic Univ.

This paper introduces an anisotropic decomposition structure of a recently introduced 3-D dual-tree discrete wavelet transform (DDWT), and explores the applications for video denoising and coding. The 3-D DDWT is an attractive video representation because it isolates motion along different directions in separate subbands, and thus leads to sparse video decompositions. Our previous investigation shows that the 3-D DDWT, compared to the standard discrete wavelet transform (DWT), complies better with the statistical models based on sparse presumptions, and gives better visual and numerical results when used for statistical denoising algorithms. Our research on video compression also shows that even with 4:1 redundancy, the 3-D DDWT needs fewer coefficients to achieve the same coding quality (in PSNR) by applying the iterative projection-based noise shaping scheme proposed by Kingsbury. The proposed anisotropic DDWT extends the superiority of

isotropic DDWT with more directional subbands without adding to the redundancy. Unlike the original 3-D DDWT which applies dyadic decomposition along all three directions and produces isotropic frequency spacing, it has a non-uniform tiling of the frequency space. By applying this structure, we can improve the denoising results, and the number of significant coefficients can be reduced further, which is beneficial for video coding.

6077-51, Session 10

On scalable lossless video coding based on subpixel accurate MCTF

S. Yea, W. A. Pearlman, Rensselaer Polytechnic Institute

We propose two approaches to scalable lossless coding of motion video. They achieve SNR-scalable bitstream up to lossless reconstruction based upon the subpixel-accurate MCTF-based wavelet video coding. The first approach is based upon a two-stage encoding strategy where a lossy reconstruction layer is augmented by a following residual layer in order to obtain (nearly) lossless reconstruction. The key advantages of our approach include an 'on-the-fly' determination of bit budget distribution between the lossy and the residual layers, freedom to use almost any progressive lossy video coding scheme as the first layer and an added feature of near-lossless compression. The second approach capitalizes on the fact that we can maintain the invertibility of MCTF with an arbitrary sub-pixel accuracy even in the presence of an extra truncation step for lossless reconstruction thanks to the lifting implementation. Experimental results show that the proposed schemes achieve compression ratios not obtainable by intra-frame coders such as Motion JPEG-2000 because of their inter-frame coding nature. Also they are shown to outperform the state-of-the-art non-scalable inter-frame coder H.264 (JM) lossless mode, with the added benefit of bitstream embeddedness.

6077-52, Session 10

Aliasing reduction via frequency roll-off for scalable image/video coding

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The extracted low resolution video from a motion compensated 3-D subband/wavelet scalable video coder is unnecessarily sharp and sometimes contains significant aliasing, compared to that of the MPEG4 lowpass filter. In this paper, we propose a content adaptive method for aliasing reduction in subband/wavelet scalable video coding. We try to make the low resolution frame (LL subband) visually similar to that of the MPEG4 decimation filter through frequency roll-off. Scaling of the subbands is introduced to make the variances of the subbands comparable in these two cases. Thanks to the embedded properties of the EZBC coder, we can achieve the needed scaling of energies in each subband by sub-bitplane shift in the extractor and coefficient scaling in the decoder. An analysis is presented for the relationship between sub-bitplane shift and scaling, which shows that our selected sub-bitplane shift works well for high to medium bitrates. Two different energy-matching structures, i.e. a dyadic decomposition and non-dyadic decomposition, are proposed. The first dyadic method has low complexity but low accuracy for energy matching, while the second non-dyadic method is more accurate for energy matching but has higher analysis/synthesis complexity. The first scheme introduces no PSNR loss for full resolution video, while the second one introduces a slight PSNR loss for full resolution, due to our omission of interband context modeling in this case. Both methods offer substantial PSNR gain for lower spatial resolution, as well as substantial reduction in visible aliasing.

6077-53, Session 10

Adaptive in-band motion compensated temporal filtering based on motion mismatch detection in the high-pass subbands

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This paper presents an adaptive in-band motion compensated temporal filtering (MCTF) scheme for 3-D wavelet based scalable video coding. The proposed scheme overcomes the problem of visual artifacts due to motion mismatch when motion information of the spatial lowpass subband is inaccurately applied to the highpass subbands in decoding high spatial resolution video. More specifically, the proposed scheme determines if the mismatch energy is beyond an acceptable threshold in the wavelet domain and then adaptively switches between using the motion information from the spatial lowpass and highpass subbands in the MCTF prediction step. As a result, the amount of motion overhead needs to be transmitted is minimized and a good trade-off between motion information and texture is realized. Experimental results show that the proposed scheme greatly improves the quality of the decoded video at high spatial resolutions while achieving a high coding efficiency. Furthermore, the proposed adaptive scheme requires only modifications when performing MCTF in the highpass subbands, hence the original strength of in-band MCTF for decoding low spatial resolution video is well preserved.

6077-54, Session 10

Quality-fluctuation-constrained rate allocation for MCTF-based video coding

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This paper presents a new rate allocation algorithm for MCTF-based video coding with the aim to control quality fluctuation. Distortion analysis is conducted for MCTF using a simplified signal model. Based on the analysis, the aim to control quality fluctuation is posed as a quadratic programming problem and its solution forms the basis for our proposed algorithm. After discussions on some extensions of the proposed rate allocation method, we verify it on MPEG SVC reference software and the experimental results demonstrate that the proposed rate allocation scheme can achieve trade-off between coding efficiency and quality fluctuation.

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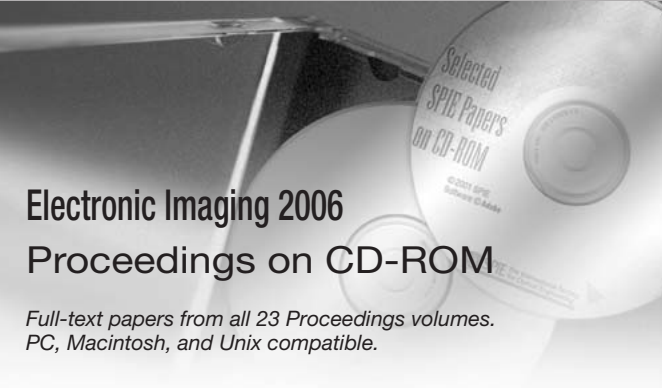
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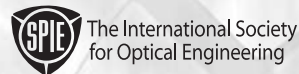
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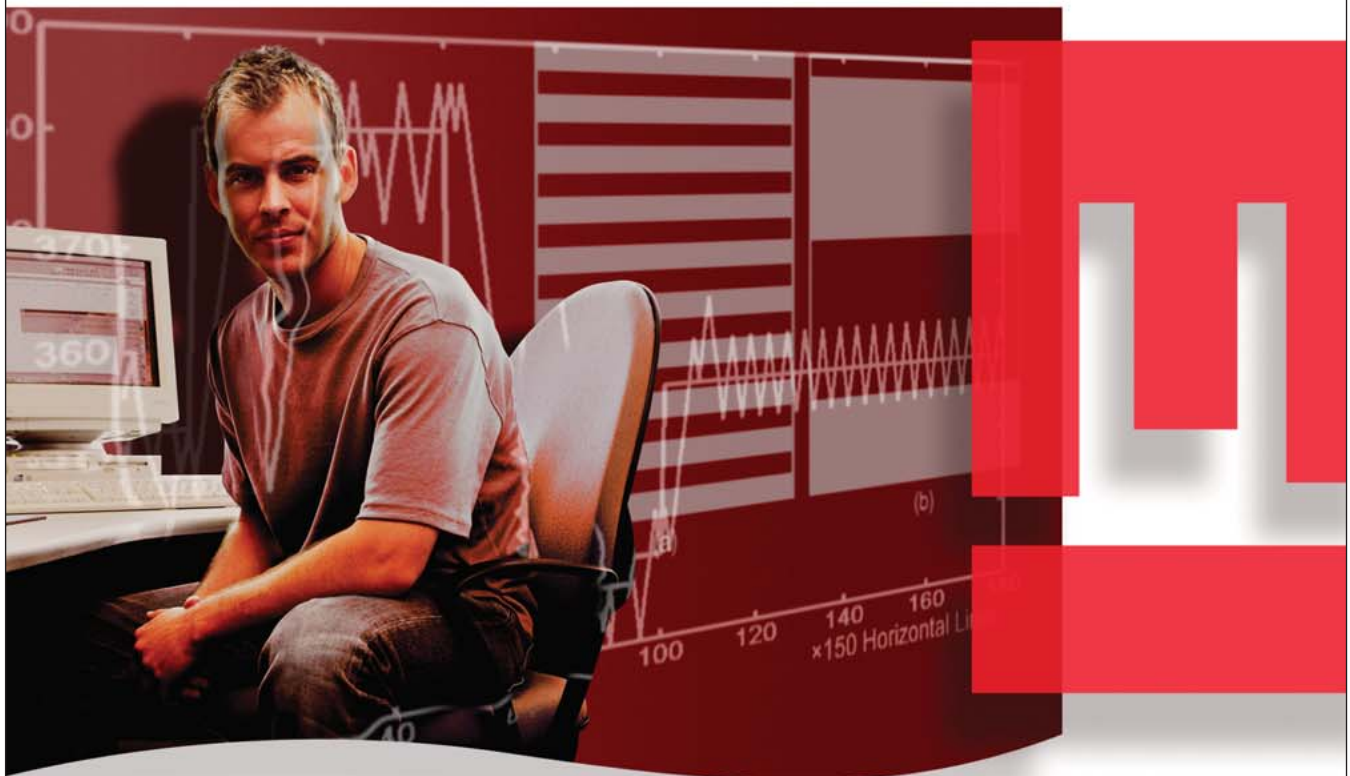
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