

PROCEEDINGS



Stereoscopic Displays and Applications XXV

**Andrew J. Woods
Nicolas S. Holliman
Gregg E. Favalora**
Editors

**3–5 February 2014
San Francisco, California, United States**

Sponsored by
IS&T—The Society for Imaging Science and Technology
SPIE

Cosponsored by
IMAX (Canada)
Volfoni (France)
DepthQ 3D

Published by
SPIE

Volume 9011

Proceedings of SPIE, 0277-786X, v. 9011

Stereoscopic Displays and Applications XXV, edited by Andrew J. Woods, Nicolas S. Holliman, Gregg E. Favalora,
Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 9011, 901101 · © 2014 SPIE-IS&T
CCC code: 0277-786X/14/\$18 · doi: 10.1117/12.2063274

SPIE-IS&T/ Vol. 9011 901101-1

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publishers are not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in *Stereoscopic Displays and Applications XXV*, edited by Andrew J. Woods, Nicolas S. Holliman, Gregg E. Favalora, Proceedings of SPIE-IS&T Electronic Imaging, SPIE Vol. 9011, Article CID Number (2014)

ISSN: 0277-786X

ISBN: 9780819499288

Copublished by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445

SPIE.org

and

IS&T—The Society for Imaging Science and Technology

7003 Kilworth Lane, Springfield, Virginia, 22151 USA

Telephone +1 703 642 9090 (Eastern Time) · Fax +1 703 642 9094

imaging.org

Copyright © 2014, Society of Photo-Optical Instrumentation Engineers and The Society for Imaging Science and Technology.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by the publishers subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/14/\$18.00.

Printed in the United States of America.

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID Number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID Number.

Contents

xi	<i>Conference Committee</i>
xiii	<i>Introduction</i>
xxiii	<i>Special Presentations from the Journal of Electronic Imaging</i>

SESSION 1 STEREOSCOPIC APPLICATIONS I

9011 03	The impact of stereo 3D sports TV broadcasts on user's depth perception and spatial presence experience [9011-2] K. Weigelt, J. Wiemeyer, Technische Univ. Darmstadt (Germany)
---------	--

SESSION 2 AUTOSTEREOSCOPIC DISPLAYS I

9011 05	A novel stereoscopic display technique with improved spatial and temporal properties [9011-3] P. V. Johnson, J. Kim, M. S. Banks, Univ. of California, Berkeley (United States)
9011 06	Frameless multiview display modules employing flat-panel displays for a large-screen autostereoscopic display [9011-4] K. Hirabayashi, M. Tokoro, Y. Takaki, Tokyo Univ. of Agriculture and Technology (Japan)
9011 08	Vertical parallax added tabletop-type 360-degree three-dimensional display [9011-6] Y. Takaki, J. Nakamura, Tokyo Univ. of Agriculture and Technology (Japan)
9011 09	A variable-collimation display system [9011-80] R. Batchko, S. Robinson, Holochip Corp. (United States); J. Schmidt, Consultant (United States); B. Graniela, Naval Air Warfare Ctr. Training Systems Div. (United States)

SESSION 3 SUBJECTIVE QUALITY OF 3D SYSTEMS

9011 0A	Subjective evaluation of a 3D videoconferencing system [9011-7] H. Rizek, Acreo Swedish ICT AB (Sweden); K. Brunnström, K. Wang, Acreo Swedish ICT AB (Sweden) and Mid Sweden Univ. (Sweden); B. Andrén, Acreo Swedish ICT AB (Sweden); M. Johanson, Alkit Communications AB (Sweden)
9011 0B	Subjective quality assessment for stereoscopic video: case study on robust watermarking [9011-8] R. Bensaid, M. Mitrea, A. Chammem, Télécom SudParis (France); T. Ebrahimi, Ecole Polytechnique Fédérale de Lausanne (Switzerland)

- 9011 0C **Measuring perceived depth in natural images and study of its relation with monocular and binocular depth cues** [9011-9]
P. Lebreton, A. Raake, Technische Univ. Berlin (Germany); M. Barkowsky, P. Le Callet, L'Univ. Nantes Angers le Mans (France) and Institut de Recherche en Communications, CNRS, Univ. de Nantes (France)
- 9011 0D **Subjective evaluation of two stereoscopic imaging systems exploiting visual attention to improve 3D quality of experience** [9011-10]
P. Hanhart, T. Ebrahimi, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- 9011 0E **Subjective quality and depth assessment in stereoscopic viewing of volume-rendered medical images** [9011-11]
J. Rousson, Barco N.V. (Belgium) and Univ. Gent (Belgium); J. Coutouro, Télécom Saint-Etienne (France); A. Vetsuyens, Barco N.V. (Belgium); L. Platasa, A. Kumcu, Univ. Gent (Belgium); T. Kimpe, Barco N.V. (Belgium); W. Philips, Univ. Gent (Belgium)

SESSION 4 STEREOSCOPIC APPLICATIONS II

- 9011 0F **Interlopers 3D: experiences designing a stereoscopic game** [9011-12]
J. Weaver, Durham Univ. (United Kingdom); N. S. Holliman, The Univ. of York (United Kingdom)
- 9011 0G **Architecture for high performance stereoscopic game rendering on Android** [9011-13]
J. Flack, H. Sanderson, S. Shetty, Dynamic Digital Depth Australia Pty. (Australia)
- 9011 0H **Comprehensive evaluation of latest 2D/3D monitors and comparison to a custom-built 3D mirror-based display in laparoscopic surgery** [9011-14]
D. Wilhelm, Klinikum Rechts der Isar (Germany) and Technische Univ. München (Germany); S. Reiser, Technische Univ. München (Germany); N. Kohn, Klinikum Rechts der Isar (Germany) and Technische Univ. München (Germany); M. Witte, U. Leiner, L. Mühlbach, D. Ruschin, W. Reiner, Fraunhofer-Institut für Nachrichtentechnik, Heinrich-Hertz-Institut (Germany); H. Feussner, Klinikum Rechts der Isar (Germany) and Technische Univ. München (Germany)
- 9011 0I **A stereoscopic system for viewing the temporal evolution of brain activity clusters in response to linguistic stimuli** [9011-15]
A. Forbes, J. Villegas, K. R. Almryde, E. Plante, The Univ. of Arizona (United States)

SESSION 5 DEPTH MAP CAPTURE AND PROCESSING

- 9011 0J **Fusion of Kinect depth data with trifocal disparity estimation for near real-time high quality depth maps generation** [9011-16]
G. Boisson, P. Kerbiriou, V. Drazic, O. Bureller, N. Sabater, A. Schubert, Technicolor (France)
- 9011 0K **Depth map post-processing for depth-image-based rendering: a user study** [9011-17]
M. Nezveda, N. Brosch, Technische Univ. Wien (Austria); F. Seitner, emotion3D GmbH (Austria); M. Gelautz, Technische Univ. Wien (Austria)

- 9011 OL **Local disparity remapping to enhance depth quality of stereoscopic 3D images using stereoacuity function** [9011-18]
H. Sohn, Y. J. Jung, Y. M. Ro, KAIST (Korea, Republic of)
- 9011 OM **Efficient quality enhancement of disparity maps based on alpha matting** [9011-19]
N. Brosch, M. Nezveda, M. Gelautz, Technische Univ. Wien (Austria); F. Seitner, emotion3D GmbH (Austria)

SESSION 6 3D DISPLAY SYSTEMS

- 9011 ON **Description of a 3D display with motion parallax and direct interaction** [9011-20]
J. Tu, M. F. Flynn, zSpace (United States)
- 9011 OO **LCD masks for spatial augmented reality** [9011-21]
Q. Y. J. Smithwick, D. Reetz, L. Smoot, Disney Research (United States)
- 9011 OP **Transparent stereoscopic display and application** [9011-22]
N. Ranieri, H. Seifert, M. Gross, ETH Zürich (Switzerland)
- 9011 OQ **A hand-held immaterial volumetric display** [9011-28]
A. Sand, I. Rakkolainen, Univ. of Tampere (Finland)

SESSION 7 HUMAN FACTORS I

- 9011 OR **Perceived crosstalk assessment on patterned retarder 3D display** [9011-24]
B. Zou, Y. Liu, Y. Huang, Y. Wang, Beijing Institute of Technology (China)
- 9011 OS **Subjective evaluation of an active crosstalk reduction system for mobile autostereoscopic displays** [9011-25]
A. Chappuis, M. Rerabek, P. Hanhart, T. Ebrahimi, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
- 9011 OT **Study of blur discrimination for 3D stereo viewing** [9011-26]
M. Subedar, Arizona State Univ. (United States) and Intel Corp. (United States); L. J. Karam, Arizona State Univ. (United States)
- 9011 OU **The effect of stereoscopic acquisition parameters on both distortion and comfort** [9011-27]
R. H. Black, S. M. Wuerger, G. Meyer, Univ. of Liverpool (United Kingdom)

SESSION 8 3D DEVELOPMENTS

- 9011 OW **Fully automatic 2D to 3D conversion with aid of high-level image features** [9011-29]
V. Appia, U. Batur, Texas Instruments Inc. (United States)
- 9011 OX **Stereoscopy for visual simulation of materials of complex appearance** [9011-30]
F. da Graça, A. Paljic, Mines ParisTech (France); D. Lafon-Pham, Ecole des Mines d'Alès (France); P. Callet, Mines ParisTech (France) and Ecole Centrale de Paris (France)

- 9011 0Z **A multilayer display augmented by alternating layers of lenticular sheets** [9011-32]
H. Gotoda, National Institute of Informatics (Japan)

SESSION 9 STEREOSCOPIC PANORAMAS AND 3D IMAGING

- 9011 12 **Automatic detection of artifacts in converted S3D video** [9011-82]
A. Bokov, D. Vatolin, A. Zachesov, A. Belous, M. Erofeev, Lomonosov Moscow State Univ. (Russian Federation)
- 9011 14 **Integration of multiple view plus depth data for free viewpoint 3D display** [9011-36]
K. Suzuki, Nagoya Univ. (Japan); Y. Yoshida, T. Kawamoto, Chukyo TV Broadcasting Co., Ltd. (Japan); T. Fujii, K. Mase, Nagoya Univ. (Japan)

SESSION 10 HUMAN FACTORS II

- 9011 15 **Disparity modifications and the emotional effects of stereoscopic images** [9011-37]
T. Kawai, D. Atsuta, Y. Tomiyama, S. Kim, Waseda Univ. (Japan); H. Morikawa, Waseda Univ. (Japan) and Aoyama Gakuin Univ. (Japan); R. Mitsuya, Waseda Univ. (Japan); J. Häkkinen, Univ. of Helsinki (Finland)
- 9011 16 **Improving perception of binocular stereo motion on 3D display devices** [9011-38]
P. Kellnhofer, Max-Planck-Institut für Informatik (Germany); T. Ritschel, Max-Planck-Institut für Informatik (Germany) and Saarland Univ. (Germany); K. Myszkowski, H.-P. Seidel, Max-Planck-Institut für Informatik (Germany)
- 9011 17 **Measurement of perceived stereoscopic sensation through disparity metrics and compositions** [9011-39]
S. Toyosawa, Tokuyama Univ. (Japan) and Waseda Univ. (Japan); T. Kawai, Waseda Univ. (Japan)
- 9011 18 **Stereo and motion cues effect on depth perception of volumetric data** [9011-40]
I. Cho, Z. Wartell, W. Dou, X. Wang, W. Ribarsky, The Univ. of North Carolina at Charlotte (United States)

SESSION 11 DIGITAL IMAGING FOR AUTOSTEREOSCOPY

- 9011 1A **Compression for full-parallax light field displays** [9011-41]
D. B. Graziosi, Z. Y. Alpaslan, H. S. El-Ghoroury, Ostendo Technologies, Inc. (United States)
- 9011 1B **Joint estimation of high resolution images and depth maps from light field cameras** [9011-60]
K. Ohashi, K. Takahashi, T. Fujii, Nagoya Univ. (Japan)
- 9011 1C **Enhancing multi-view autostereoscopic displays by viewing distance control (VDC)** [9011-43]
S. Jurk, B. Duckstein, S. Renault, M. Kuhlmeier, R. de la Barré, T. Ebner, Fraunhofer-Institut für Nachrichtentechnik, Heinrich-Hertz-Institut (Germany)

SESSION 12 AUTOSTEREOSCOPIC DISPLAYS II

- 9011 1D **Vision-based calibration of parallax barrier displays** [9011-44]
N. Ranieri, M. Gross, ETH Zürich (Switzerland)
- 9011 1F **Time-division multiplexing parallax barrier based on primary colors** [9011-46]
Q. Zhang, H. Kakeya, Univ. of Tsukuba (Japan)
- 9011 1G **Multi-user autostereoscopic display based on direction-controlled illumination using a slanted cylindrical lens array** [9011-47]
D. Miyazaki, Y. Hashimoto, Osaka City Univ. (Japan); T. Toyota, Panasonic Corp. (Japan); K. Okoda, Osaka City Univ. (Japan); T. Okuyama, T. Ohtsuki, A. Nishimura, H. Yoshida, Panasonic Corp. (Japan)

SESSION 13 OPTICAL ELEMENTS IN 3D SYSTEMS

- 9011 1H **Accommodation response measurements for integral 3D image** [9011-48]
H. Hiura, T. Mishina, J. Arai, Y. Iwadate, NHK Science and Technology Research Labs. (Japan)
- 9011 1I **Optimized design of directional backlight system for time-multiplexed autostereoscopic display based on VHOE** [9011-49]
Y. S. Hwang, B. M. Kim, E. S. Kim, Kwangwoon Univ. (Korea, Republic of)
- 9011 1J **Analysis of multiple recording methods for full resolution multi-view autostereoscopic 3D display system incorporating VHOE** [9011-50]
Y. S. Hwang, K. H. Cho, E. S. Kim, Kwangwoon Univ. (Korea, Republic of)

INTERACTIVE PAPER SESSION: 3D DISPLAY ENGINEERING

- 9011 1K **Practical resolution requirements of measurement instruments for precise characterization of autostereoscopic 3D displays** [9011-51]
P. Boher, T. Leroux, V. Collomb-Patton, T. Bignon, ELDIM (France)
- 9011 1L **Stereoscopic model for depth-fused 3D (DFD) display** [9011-52]
H. Yamamoto, H. Sonobe, A. Tsunakawa, J. Kawakami, S. Suyama, Univ. of Tokushima (Japan)
- 9011 1M **Parallax multi-viewer autostereoscopic three-dimensional display** [9011-53]
L. Sha, D. Schonfeld, Q. Li, Univ. of Illinois at Chicago (United States)
- 9011 1N **Floating volumetric display using an imaging element that consists of a 90° prism sheet and a linear Fresnel lens** [9011-54]
Y. Maeda, D. Miyazaki, T. Mukai, Osaka City Univ. (Japan); S. Maekawa, Univ. of Hyogo (Japan)

INTERACTIVE PAPER SESSION: STEREOSCOPIC RENDERING AND STANDARDS

- 9011 1O **A rendering approach for stereoscopic web pages** [9011-56]
J. Zhang, W. Wang, R. Wang, Q. Chen, Peking Univ. (China)
- 9011 1P **The rendering context for stereoscopic 3D web** [9011-57]
Q. Chen, W. Wang, R. Wang, Peking Univ. (China)
- 9011 1R **The design and implementation of stereoscopic 3D scalable vector graphics based on WebKit** [9011-59]
Z. Liu, W. Wang, R. Wang, Peking Univ. (China)

INTERACTIVE PAPER SESSION: DEPTH MAPS AND VIEW SYNTHESIS

- 9011 1S **Discontinuity preserving depth estimation using distance transform** [9011-61]
W.-S. Jang, Y.-S. Ho, Gwangju Institute of Science and Technology (Korea, Republic of)
- 9011 1U **View synthesis from wide-baseline views using occlusion aware estimation of large disparities** [9011-63]
A. S. Elliethy, H. A. Aly, Military Technical College (Egypt); G. Sharma, Univ. of Rochester (United States)
- 9011 1V **Superpixel-based 3D warping using view plus depth data from multiple viewpoints** [9011-64]
T. Tezuka, K. Takahashi, T. Fujii, Nagoya Univ. (Japan)
- 9011 1W **Stereoscopic augmented reality with pseudo-realistic global illumination effects** [9011-65]
F. de Sorbier, H. Saito, Keio Univ. (Japan)
- 9011 1X **Development of free-viewpoint image synthesis system using time varying projection and spacetime stereo** [9011-66]
T. Mori, K. Takahashi, T. Fujii, Nagoya Univ. (Japan)
- 9011 1Y **General stereoscopic distortion rectification due to arbitrary viewer motion in binocular stereoscopic display** [9011-67]
Q. Li, D. Schonfeld, Univ. of Illinois at Chicago (United States)
- 9011 1Z **Wide-field-of-view image pickup system for multiview volumetric 3D displays using multiple RGB-D cameras** [9011-68]
Y. Luo, H. Kakeya, Univ. of Tsukuba (Japan)
- 9011 20 **Joint upsampling and noise reduction for real-time depth map enhancement** [9011-69]
K. Matsumoto, C. Song, F. de Sorbier, H. Saito, Keio Univ. (Japan)

INTERACTIVE PAPER SESSION: STEREOSCOPIC HUMAN FACTORS

- 9011 22 **Stereoscopic visual fatigue assessment and modeling** [9011-71]
D. Wang, T. Wang, Y. Gong, Institute of Software (China)

- 9011 23 **Visual discomfort under various brightness conditions using eye movements in watching stereoscopic 3D video** [9011-72]
S.-H. Cho, H.-B. Kang, The Catholic Univ. of Korea (Korea, Republic of)
- 9011 24 **On the comparison of visual discomfort generated by S3D and 2D content based on eye-tracking features** [9011-73]
I. Iatsun, M.-C. Larabi, C. Fernandez-Maloigne, XLIM Institut de Recherche, CNRS, Univ. de Poitiers (France)
- 9011 25 **Perception and annoyance of crosstalk in stereoscopic 3D projector systems** [9011-74]
K. Wang, Acreo Swedish ICT AB (Sweden) and Mid Sweden Univ. (Sweden); B. Andrén, M. Hussain, Acreo Swedish ICT AB (Sweden); K. Brunnström, Acreo Swedish ICT AB (Sweden) and Mid Sweden Univ. (Sweden); J. Osterman, LC-Tec Displays AB (Sweden)

INTERACTIVE PAPER SESSION: STEREOSCOPIC PERCEPTION

- 9011 26 **Eliciting steady-state visual evoked potentials by means of stereoscopic displays** [9011-75]
E. Calore, D. Gadia, D. Marini, Univ. degli Studi di Milano (Italy)
- 9011 27 **A new multimodal interactive way of subjective scoring of 3D video quality of experience** [9011-76]
T. Kim, K. Lee, S. Lee, Yonsei Univ. (Korea, Republic of); A. C. Bovik, The Univ. of Texas at Austin (United States)
- 9011 28 **Effect of local crosstalk on depth perception** [9011-77]
H. Watanabe, H. Ujike, AIST (Japan); J. Penczek, P. A. Boynton, National Institute of Standards and Technology (United States)

Author Index

Conference Committee

Symposium Chair

Sergio R. Goma, Qualcomm Inc. (United States)

Symposium Co-chair

Sheila S. Hemami, Northeastern University (United States)

Conference Chairs

Andrew J. Woods, Curtin University (Australia)

Nicolas S. Holliman, The University of York (United Kingdom)

Gregg E. Favalora, VisionScope Technologies LLC (United States)

Program Committee

Neil A. Dodgson, University of Cambridge (United Kingdom)

Hideki Kakeya, University of Tsukuba (Japan)

Takashi Kawai, Waseda University (Japan)

John D. Stern, Intuitive Surgical, Inc. (United States)

Vivian K. Walworth, StereoJet, Inc. (United States)

Chris Ward, Lightspeed Design, Inc. (United States)

Michael A. Weissman, Perspective Systems (United States)

Samuel Zhou, IMAX Corporation (China)

John O. Merritt, The Merritt Group (United States)

Session Chairs

- 1 Stereoscopic Applications I
Nicolas S. Holliman, The University of York (United Kingdom)

SD&A Keynote Session I
Neil A. Dodgson, University of Cambridge (United Kingdom)

- 2 Autostereoscopic Displays I
Nicolas S. Holliman, The University of York (United Kingdom)

- 3 Subjective Quality of 3D Systems
Michael A. Weissman, Perspective Systems (United States)

- 4 Stereoscopic Applications II
John D. Stern, Intuitive Surgical, Inc. (United States)

- 5 Depth Map Capture and Processing
 Neil A. Dodgson, University of Cambridge (United Kingdom)

- 6 3D Display Systems
 Gregg E. Favalora, VisionScope Technologies LLC (United States)

- 7 Human Factors I
 John O. Merritt, The Merritt Group (United States)

- 3D Theatre
 Chris Ward, Lightspeed Design, Inc. (United States)
 John D. Stern, Intuitive Surgical, Inc. (United States)
 Andrew J. Woods, Curtin University (Australia)

- 8 3D Developments
 Takashi Kawai, Waseda University (Japan)

- SD&A Keynote Session II
 Gregg E. Favalora, VisionScope Technologies LLC (United States)

- 9 Stereoscopic Panoramas and 3D Imaging
 Nicolas S. Holliman, The University of York (United Kingdom)

- 10 Human Factors II
 Chris Ward, Lightspeed Design, Inc. (United States)

- 11 Digital Imaging for Autostereoscopy
 Gregg E. Favalora, VisionScope Technologies LLC (United States)

- 12 Autostereoscopic Displays II
 Hideki Kakeya, University of Tsukuba (Japan)

- 13 Optical Elements in 3D Systems
 Nicolas S. Holliman, The University of York (United Kingdom)

Stereoscopic Displays and Applications XXV

The World's Premier Conference for 3D Innovation

Introduction

The 2014 Stereoscopic Displays and Applications (SD&A) conference was the 25th in the series, marking a quarter-century over which the conference has developed into the premier venue for the dissemination of research on stereoscopic displays and their applications.

SD&A attracts key players in the field: stereoscopic experts from industry and academia presented the two keynotes, participated on the discussion panel, and spoke in the technical presentations. The conference had an excellent technical program covering a wide range of stereoscopic topics.

This year the conference received 94 paper submissions. Of these, 49 were accepted for oral presentation (52%), with an additional 28 papers accepted as posters (30%).

This conference proceedings volume contains the technical papers in support of both the presentations and posters given at the conference. This introduction gives an overview of the conference—a reminder for those who attended and an insight into what happened for those who were unable to attend.

SD&A took place 3–5 February 2014 as part of the 2014 IS&T/SPIE Electronic Imaging: Science and Technology Symposium, at the Hilton San Francisco Union Square Hotel, in downtown San Francisco.

The **first day** had seven technical sessions, running in two parallel rooms. Topics covered applications, autostereoscopic displays, quality, depth maps, human factors and 3D systems. The day also included the first of the two keynotes, the two-hour 3D theatre, and the twenty-fifth anniversary conference banquet.

The **first keynote presentation** was given by Jeff Joseph, producer of the three *World 3D Film Expos* in 2003, 2006, and 2013. Across those three Expos, Jeff had been able to screen 43 of the 50 motion pictures made during the Golden Age of

3D motion pictures, in the early 1950s. Jeff gave an overview of the Golden Age movies and explained the various problems that make it impossible to screen the remaining seven, including movies where there is incomplete footage in one eye, and movies where footage does not exist at all. Jeff had interesting (and unusual) stories to tell of how he helped locate and recover several early 3D movies. After his overview, Jeff showed and commented on a 30-minute reel of 3D footage from much earlier in the history of 3D, including the earliest extant 3D footage from the 1920s.

The two-hour **3D Theatre Session** is a regular highlight event that showcases 3D content from around the world. This year, the following forty-two pieces (or segments thereof) were screened:

1. "Metallica Through the Never" – Picturehouse (USA) †
2. "Hamilton" – Ivan Ceriex - Fabien Rembliez (France) †
3. "The Lady Assassin" – Nguyen Quang Dung (Vietnam) †
4. "Puppy" – Illumination Entertainment (USA)
5. "Underwater Predators and Prey" – László Magyar & György Kriska (Hungary) †
6. "Crime Squad: UNDERCOVER3D" – Andrew Murchie (United Kingdom) †
7. "Cosmic Origins 2" – Nick Holliman, University of York;
Carlton Baugh & Carlos Frenk, Durham University (United Kingdom) †
8. "Mars Views 3D (trailer)" – Martin Hans Schmitt (Germany) †
9. "Whoops!" – Chris Casady (USA)
10. "ORA" – Philippe Baylaucq (Canada)
11. "Quadcopter Flying Movies" – Phil Captain 3D McNally (USA) †
12. "Clear Buildings" – Boris Starosta (USA) †
13. "ZeitRaum, an Investigation in Space-time" – Volker Kuchelmeister (Australia) †
14. "Wooden Palace of Russian Tsar" – Andrey Anokhin (Russia) †
15. "Shine 3D" – Jesse Blanchard (USA) †
16. "Baby Blues" – Pegasus Motion Pictures Production Ltd. (China) †
17. "Planes 3D" – DisneyToons Studios (USA)
18. "Atmosphere" – Ikuo Nakamura (USA) †
19. "The Simple Carnival - A Geek Like Me" – Jeff Boller (USA) †
20. "Soir de Fête" – David Robert (France) †
21. "World's Largest Elephant Buffet" – Al Caudullo (USA) †
22. "Hydrochoeruspaedia 3D" – Helio A G Souza & Ludger Pfanzen (Brazil) †
23. "Chasms of Silence" – Marten Berkman (Canada) †
24. "Morpheus Trailer" – John Hart (USA) †
25. "Aloft" – Kate Duhamel, Fountain 3 Films (USA) †
26. "Foxed!" – Geneva Film Co. (Canada) †
27. "3D Natural Wonders of California" – Charles Booth (USA) †
28. "Horn Quest" – Ryan Suits (USA) †
29. "Educational 3D Content: Tumulus" – Shibata Lab, Tokyo University of Social
Welfare (Japan) †
30. "'Being There': Avercamp: Winter landscape - Rijksmuseum - a presentation in
stereoscopic 3D" – René van Gageldonk (The Netherlands)
31. "The Sunday Morning Drive" – Ole Schell (USA) †

32. "Busan 3D" – Kwangwoon University (South Korea) †
33. "Monsters University" – Pixar Animation Studios (USA)
34. "Flight of the Butterflies" – SK Films Inc. (Canada) †
35. "Eurovision Young Dancers" – KUK Filmproduction (Germany)
36. "Formation of the Cosmic Web" – Ralf Kaehler, KIPAC; Carter Emmart, AMNH;
Tom Abel, KIPAC (USA) †
37. "CELLmicrocosmos Cell Modeling SS2012" – Christian Bender, Tobias Hoppe,
Björn Sommer (Germany)
38. "To Space & Back 3D Trailer" – Sky-Skan in association with The Franklin
Institute (USA)
39. "47 Ronin - Feature Trailer" – Universal Pictures, director Carl Rinsch (USA) †
40. "Hsu Ji Derriere L'Ecran - Hsu Ji Behind the Screen" – Thomas Rio (France) †
41. "The Blue Umbrella" – Pixar Animation Studios (USA)
42. "24 Hours of LeMons, Sonoma Raceway" – David Newman (USA)

All entries were screened in high-quality polarized 3D on the conference's large projection screen. The Best of Show awards were judged by Bernard Mendiburu (author of "3D Movie Making" and the follow-up "3D TV and 3D Cinema" books), Julian Flack (Dynamic Digital Depth - DDD) and Lenny Lipton (Leonardo IP). Content contributors self-selected whether they wished their entry to be included in the competition – indicated by (†) in the list above.

The judges chose the following 3D content winners as **Best of Show**:

Live Action – "Soir de Fête", David Robert (France)

Computer Generated – "Morpheus Trailer", John Hart (USA)

The producers of the 2014 SD&A 3D Theater were John Stern (Intuitive Surgical Inc., retired), Chris Ward (Lightspeed Design, USA), and Andrew Woods (Curtin University, Australia). Additional support was provided by Dan Lawrence (Lightspeed Design). The 3D content partner for the session was 3D Content Hub (Germany and Australia) headed by Torsten Hoffman.

The evening concluded with the twenty-fifth anniversary conference dinner at Kuleto's Italian Restaurant on Powell Street, a block from the conference hotel. The longest-serving of the three conference chairs, Andrew Woods, was unexpectedly unable to attend SD&A this year, however, he was able to join the dinner group by video conference. Over the course of dinner, Andrew presented a slide show of photos of committee members over the twenty-five years of the conference (all available at www.stereoscopic.org), and presented a citation analysis and summary of the most cited papers presented at SD&A.

The top ten most-cited papers from the 25-year history of SD&A (using data harvested from Google Scholar) are:

1. "Depth-image-based rendering (DIBR), compression, and transmission for a new approach on 3D-TV". Christoph Fehn. 2004. [704 citations]
2. "Image distortions in stereoscopic video systems". Andrew J. Woods, Tom Docherty, Rolf Koch. 1993. [417 citations]
3. "Perceptual issues in augmented reality". David Drascic, Paul Milgram. 1996. [237 citations]
4. "Controlling perceived depth in stereoscopic images". Graham R. Jones, Delman Lee, Nicolas S. Holliman, David Ezra. 2001. [156 citations]
5. "Variation and extrema of human interpupillary distance". Neil A. Dodgson. 2004. [147 citations]
6. "Image preparation for 3D LCD". Cees van Berkel. 1999. [122 citations]
7. "Effect of disparity and motion on visual comfort of stereoscopic images". Filippo Speranza, Wa J. Tam, Ron Renaud, Namho Hur. 2006. [100 citations]
8. "Geometry of binocular imaging". Victor S. Grinberg, Gregg W. Podnar, Mel Siegel. 1994. [99 citations]
9. "Viewpoint-dependent stereoscopic display using interpolation of multiviewpoint images". Akihiro Katayama, Koichiro Tanaka, Takahiro Oshino, Hideyuki Tamura. 1995. [92 citations]
10. "Rapid 2D-to-3D conversion". Philip V. Harman, Julien Flack, Simon Fox, Mark Dowley. 2002. [90 citations]

The **second day** of the conference had three technical sessions on stereoscopic panoramas, 3D imaging, and human factors. The day also included the second SD&A keynote, the demonstration session and the poster session. The full papers from both the technical sessions and the poster session are all contained in this volume.

The **second keynote presentation** was presented by Gordon Wetzstein, Research Scientist in the Camera Culture Group at the MIT Media Lab. He described a range of glasses-free 3D displays based around the concept of "compressive displays", where optical fabrication, computational processing and perceptual tricks combine to produce the 3D illusion.

The final event of the day was the ever-popular **Demonstration Session**, which has run every year since 1990. Since 2006, this has been a symposium-wide event, open to demonstrators from all of the Electronic Imaging conferences. It was pleasing to see a wide range of demonstrations and to see a large audience actively engaging with the various displays and vendors. The buzz in the demonstration session was excellent.

This year the following 3D hardware and 3D software products were on show at the demonstration session:

Bielefeld University (Germany), Bjorn Sommer. The CELLmicrocosmos CellExplorer and its stereoscopic 3D capabilities. [paper 9011-01]

Dynamic Digital Depth (Australia), Julien Flack. Demonstration of a 3D game driver that seamlessly converts a 2D game to play in stereoscopic 3D on Android platforms. [paper 9011-13]

zSpace (USA), Jerry Tu. Showed a stereoscopic display system with motion parallax and direct manipulation of virtual objects. It demonstrates the immersive user-experience that can be achieved using the techniques described in the paper. The stereoscopic display was particularly notable in that it offered passive polarized 3D viewing via an LCD fitted with a custom polarization modulator. [paper 9011-20]

Chuyko TV Broadcasting Co. (Japan), Yuko Yoshida. Demonstration of a method to generate free viewpoint video by extracting 3D geometry from multiple views plus depth data. The result is converted into polygons with the Marching Cubes method. [paper 9011-36]

ELDIM (France), Pierre Boher. Presentation of optical metrology instruments for 3D displays. [paper 9011-51]

Okushima University, Dep't of Optical Science and Technology (Japan), Hirotugu Yamamoto. Depth-fused 3D (DFD) displays need only two conventional 2D displays in order to provide 3D depth for an observer without glasses. Several types of DFD samples, including deep DFD and protruding DFD, were demonstrated. [paper 9011-52]

Osaka City University (Japan), Yuki Maeda. Demonstrated their system for producing a floating volumetric image using a prism sheet and a linear Fresnel lens. [paper 9011-54]

Peking University Shenzhen Graduate School (China), Qinshui Chen. Demonstrated the visual effects of stereoscopic 3D web pages and a stereoscopic 3D game using 3D web technology. [paper 9011-57]

University of Tsukuba (Japan), Yuan Luo. Demonstrated a multiview volumetric 3D display system that showed a real-time 3D virtual scene captured by multiple Kinects. [paper 9011-68]

The Superhero 3D System (USA), Ole Schell. Demonstrated a way to make 3D possible with the GoPro Hero3 camera. [associated with an entry in the 3D theatre]

The Art Institute of California (USA), Thomas J. Wolfe, Justin K. Vallicis, Stephan R. Keith. Demonstrated a student-designed game that uses the Oculus Rift 3D virtual reality display system run on a Unity game engine, interactively controlled by a Sphero game ball. The game is a flight simulator that runs in a self-contained virtual environment.

VOXON (USA), Alan Jackson. Demonstrated the Voxiebox volumetric 3D game and media system, which provides glasses-less stereoscopic viewing for multiple people from 360 × 180 degrees with full motion parallax.

Delft University of Technology (The Netherlands), Willemijn Elkhuisen. Showed a 3D reproduction of a large oil painting. The original was scanned using structured light. The reproduction was printed using a 2.5D printing process to emulate both the color and surface relief of the original oil painting. [paper 9018-18 from the conference *Measuring, Modeling, and Reproducing Material Appearance*]

A prize was awarded for the best 3D demonstration at the session. The judging panel was Neil Dodgson, Gregg Favalora and Mike Weissman. The prize was awarded to **zSpace** as the best demonstration associated with an SD&A paper.

An extensive photo montage of the demonstration session and exhibits from this year's SD&A conference will be available on the conference website:

www.stereoscopic.org

The **third day** of the SD&A conference had the popular discussion forum and three technical sessions on digital imaging for autostereoscopy, autostereoscopic displays, and optical elements for 3D systems. The evening concluded with the Electronic Imaging symposium reception.

The **discussion forum** considered *3D in Entertainment: A Time of Transition*. The panel comprised **Lenny Lipton** (Leonardo LP, moderator), **Davis S. Cohen** (Variety), **Barry Sandrew** (Legend3D Inc.), and **Chris Ward** (Lightspeed Design Group).

Video recording was made of most sessions in the main SD&A conference hall, including the keynotes and panel. Editing is underway and the content will be available online via the SD&A conference website.

In addition to the prizes for the theatre and demonstrations, a final **prize** was offered at the conference for the best use of the stereoscopic projection tools during the technical presentations. The winner, chosen by the SD&A conference chairs, was:

9011-01 "Stereoscopic cell visualization: from mesoscopic to molecular scale", Björn Sommer, Univ. Bielefeld (Germany)

The prizes this year were copies "Stereoscopic Displays and Applications 1990-2009: A Complete 20-Year Retrospective and The Engineering Reality of Virtual Reality 1994-2009 (Special Collection) (DVD-ROM)" (ISBN: 9780819476593), published by SPIE in 2010. The prizes were kindly donated by SPIE Press.

Congratulations to all our prize-winners in the 3D Theatre, demonstration session, and technical presentation categories.

To celebrate the 25th anniversary, the conference committee organized the **SD&A Magical Mystery 3D Bus Tour** on the day after the conference. About 35 delegates took part, visiting Intuitive Surgical and NVIDIA Corporation in the midst of Silicon Valley. We thank Dave Cook, Ned Finkle, Michael McSorely, Joe Grover, and Dan Merritt from NVIDIA, and Aaron Carrano from Intuitive Surgical for running the tours at the respective locations. The tour was organized by John Stern and Andrew Woods, with assistance from the staff at IS&T.

Many individuals and companies contributed in various ways to the success of this year's SD&A conference:

- There were three major sponsors of this year's conference. Our gold sponsors were **IMAX Corporation** (Canada) and **DepthQ 3D** (USA). Our silver sponsor was **Volfonti** (France). Conference sponsorship is a valuable way for companies to support the running of the conference and to gain marketing exposure. Our sponsors are key players in the stereoscopic industry, and we thank them for their support.
- We also appreciate the support of this year's stereoscopic projection sponsors: **Christie Digital** (USA) and **Tekamaki** (USA). The ability to present high-quality large-screen stereoscopic images and video at the conference is vital to the success of the conference. Many thanks to the individuals who worked tirelessly on-site: **Chris Ward** from Lightspeed Design; **Dan Lawrence** from Lightspeed Design, and **Adrian Romero** and staff from Spectrum Audio Visual. The AV setup was project managed by **Stephan R. Keith**; **Diana Gonzalez** from IS&T; and **Andrew Woods**.
- We very much appreciate the dedicated support of **Stephan R. Keith** (SRK Graphics Research), who had a multi-tasked role at this conference, including help support the AV needs of all of our presenters.
- We are grateful to all of the providers of 3D content and 3D content partner 3D Content Hub for allowing their content to be shown to the conference audience at the 3D Theatre Session.
- Thanks to the demonstration session presenters for bringing equipment to show – especially to the presenters who brought equipment from overseas.
- The conference committee plays an important role throughout the year, ensuring the correct technical direction of the meeting. Sincere thanks go to our founding chair, **John Merritt**, and our committee, **Neil Dodgson**, **Hideki Kakeya**, **Takashi Kawai**, **John Stern**, **Vivian Walworth**, **Chris Ward**, **Michael Weissman**, and **Samuel Zhou**.
- Thanks also to the staff at IS&T and SPIE, the two organizing societies, who were instrumental in organizing all manner of aspects of the meeting.
- Most importantly, we thank the conference authors and attendees, who ultimately made this meeting such a successful event. Thanks especially to those who travel a long way to join us each year.

Conference activities do not stop at the end of the annual meeting. The SD&A conference website and LinkedIn group provide a focus for conference activities

during the time between conferences. We will soon be actively seeking abstracts for the 2015 conference, with a deadline in June 2014 – see the website for details and deadlines. You can join the SD&A LinkedIn group to receive conference announcements. The website has an extensive collection of photographs highlighting the activities of past conferences. In addition the website hosts the stereoscopic virtual library, which contains several historically important books that have been digitized, in full, into PDF format, and are available for free download. The SD&A conference runs an active LinkedIn group which is available at:

www.linkedin.com/groups?gid=1945944

You can visit the conference website to gain an understanding of the past, present, and future of stereoscopic imaging. Please think now about submitting a paper or attending next year's conference. The Stereoscopic Displays and Applications conference website is at:

www.stereoscopic.org

Next year, the 26th annual SD&A conference will be held during the period 8–12 February 2015, at the Hilton San Francisco Union Square Hotel in downtown San Francisco, as part of the 2015 IS&T/SPIE Electronic Imaging: Science & Technology Symposium.

The 2015 SD&A conference will continue a tradition of presenting and demonstrating the latest technologies relevant to stereoscopic displays and applications. Please consider attending, presenting, or demonstrating at the 2015 event. We hope to see you there!

Andrew J. Woods
Nicolas S. Holliman
Gregg E. Favalora

(Additional editorial: Neil A. Dodgson)

Stereoscopic Displays and Applications XXV

The World's Premier Conference for 3D Innovation

Gold Sponsors



Silver Sponsor



Projection Sponsors



SD&A 3D Theatre Content Partner



Special Presentations from the *Journal of Electronic Imaging*

In addition to the usual conference presentations, the Stereoscopic Displays and Applications XXV conference included a "Focal Track" of peer-reviewed papers that have been published in a special section of the *Journal of Electronic Imaging*. As well as being included in this proceedings volume, the JEI articles can also be found on the SPIE Digital Library at the following locations:

1. S. Ishizuka, T. Mukai, H. Kakeya, "Viewing zone of autostereoscopic display with directional backlight using convex lens array", *J. Electron. Imag.* **23**(1), 011002 (2014). <http://dx.doi.org/10.1117/1.JEI.23.1.011002>
2. S. Lee, Y. J. Jung, H. Sohn, Y. M. Ro, "Experimental investigation of discomfort combination: towards visual discomfort prediction for stereoscopic videos", *J. Electron. Imag.* **23**(1), 011003 (2014). <http://dx.doi.org/10.1117/1.JEI.23.1.011003>
3. L. E. Gurrieri, E. Dubois, "Depth consistency and vertical disparities in stereoscopic panoramas", *J. Electron. Imag.* **23**(1), 011004 (2014). <http://dx.doi.org/10.1117/1.JEI.23.1.011004>
4. A. Jones, K. Nagano, J. Liu, J. Busch, X. Yu, M. Bolas, P. Debevec, "Interpolating vertical parallax for an autostereoscopic three-dimensional projector array", *J. Electron. Imag.* **23**(1), 011005 (2014). <http://dx.doi.org/10.1117/1.JEI.23.1.011005>
5. M. Kytö, A. Mäkinen, T. Tossavainen, P. Oittinen, "Stereoscopic depth perception in video see-through augmented reality within action space", *J. Electron. Imag.* **23**(1), 011006 (2014). <http://dx.doi.org/10.1117/1.JEI.23.1.011006>
6. B. Sommer, C. Bender, T. Hoppe, C. Gamroth, L. Jelonek, "Stereoscopic cell visualization: from mesoscopic to molecular scale", *J. Electron. Imag.* **23**(1), 011007 (2014). <http://dx.doi.org/10.1117/1.JEI.23.1.011007>