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# ***Stereoscopic Displays and Applications XXV***

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

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# 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 Remblier (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 Baylauca (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) †
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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 Pfan (Brazil) †
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24. "Morpheus Trailer" – John Hart (USA) †
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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](http://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), Hirotsugu 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 Favolora 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](http://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 IP, 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 **Volfony** (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](http://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](http://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

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## 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>