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# ***Stereoscopic Displays and Applications XXIV***

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

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# Stereoscopic Displays and Applications XXIV

The World's Premier Conference for 3D Innovation

## Introduction

For a 24th year, the IS&T/SPIE Stereoscopic Displays and Applications (SD&A) conference was 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 two keynote presentations, participated in a very candid discussion panel, and delivered technical presentations. The conference had an excellent technical program covering the entire stereoscopic imaging pipeline from capture, processing, and display, to perception.

This conference proceedings volume contains the technical papers in support of both the oral presentations and posters given at the conference and is published as the Proceedings of IS&T/SPIE Electronic Imaging Volume 8648. 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.

This year's SD&A conference was held 4–6 February 2013 as part of the 2013 Electronic Imaging: Science and Technology Symposium, at the Hyatt Regency San Francisco Airport Hotel, next to San Francisco International Airport, in Burlingame, California, USA. Attendance included representatives from key groups across the world with approximately one third from North America, one third from Asia and one third from Europe.

The **first day** had seven technical sessions, running in two parallel rooms. Topics covered visual comfort, image quality, content, coding, autostereoscopic displays, multi-layer displays and human factors. There was our first keynote, the two-hour 3D theatre, and our conference banquet.

The **first keynote presentation** was given by Vivian Walworth of StereoJet Inc. She gave an excellent history of the development of stereoscopic printing and polarising materials and the broader applications of devices using polarisation. Her demonstrations on the following day of Vectograph and StereoJet prints showed how effective these technologies can be.

The two-hour **3D Theatre Session** (chaired by Andrew Woods and Chris Ward) is a regular highlight event that showcases 3D content from around the world. It was again the most well attended session of the conference. This year, we screened the following pieces (or segments thereof) on the 5.6 meter (18 foot) diagonal stereoscopic projection screen:

### Competition Category

- Ninety Three Million Miles – Site-Eye Time-Lapse Films (directors: Brian McClave and Gavin Peacock) (UK)
- Nuts & Robbers – ToonBox Entertainment Ltd. (Canada) and Redrover Co., Ltd. (South Korea)
- 3D Clouds Throughout the Day – Masuji Suto (Japan)
- The Art Of Flight 3D – Red Bull Media House in association with Brain Farm Digital Cinema (USA)
- Cosmic Encounters – Jürgen Hansen & Simone Stripp (France)

- Bolts & Blip: Battle of the Lunar League - Movie Trailer – ToonBox Entertainment Ltd. and Redrover Co., Ltd. (Canada)
- The Best of 3DGuy – Al Caudullo (USA)
- Fugaku Hyakkei - 3D Converted Ukiyo-e Japanese Woodblock Prints – Waseda University, Toppan Printing Co., Ltd (Japan)
- Get Lost in 3D – Andrew Woods (Australia)
- Anvil – Per Nyman (Sweden)
- Prometheus Cave – Zaza Lomidze (Georgia)
- Moonglow - The Lives – Chang Hae-Rang (South Korea)
- Stereoscopic Memories from Catalonia – Lluís Dubreuil (Spain)
- Transmutation – Volker Kuchelmeister (Australia)
- Balloon in the City – Cheers Elephant (band), Ryan Suits (director) (USA)
- The Charlatan – Ray Zone (USA)
- Canals of Amsterdam – Masuji Suto (Japan)
- China Cup International Regatta 2012 – Film Magic Limited (Hong Kong)
- Sawdust Teaser – Wayne Schoenfeld and Anthony Coogan (USA)
- Dream Defenders – Tiny Island Productions Pte Ltd (Singapore)
- The Collection – Andrew Murchie (UK)
- The Chopin Shorts Collection: 3D; Papa's Boy – BreakThru Films (producer: Hugh Welchman) (Poland)
- The Chopin Shorts Collection: 3D; Spirits of the Piano – BreakThru Films (producer: Hugh Welchman) (Poland)
- Make Every Second Count: Jim Dellevalle's Chapter – Nat Bartholomew (USA)
- The End of the Dark Ages of the Universe – Ralf Kaehler (SLAC), Marcelo Alvarez (CITA) & Tom Abel (SLAC) (USA)
- Eastern State Penitentiary – Terry Wilson (USA)
- Soulmates 3D – The S3D Centre (Canada)
- Storm Surfers 3D – sixty Foot Films (Australia)
- Digital Darkroom: The Art of 3D – Steven Kochones (USA)
- Skyscrapers – OK Go (USA)

#### Demonstration Category

- Finding Nemo 3D – Pixar Animation Studios (USA)
- Flying Swords of Dragon Gate – Bona Entertainment Company Limited (China)
- A Day in the Life of an Audi Driver – Audi Le Mans – Chris Curtis for Passion Pictures (UK)
- Karatchi Scramble – Chris Casady (USA)
- Hooked – Parus Studio in collaboration with Tritone Studio (Latvia)
- James Stewart 3D – GoPro Media Team (USA)
- London 2012 Olympic Games – Olympic Broadcasting Service (UK)
- Titans of the Ice Age – Giant Screen Films (USA)
- Mapping Change in Sierra Nevada Forests – Steven McQuinn (USA)
- Intel 3D-TRI-GATE Trailer – KUK Filmproduction Munich (Germany)
- The Last Reef – Giant Screen Films (USA)
- La Luna – Pixar Animation Studios (USA)

This year's esteemed judges of the SD&A 3D Theater session were: Eric Kurland from 3-DIY, stereographer on the Oscar nominated, "Maggie Simpson in The Longest Daycare," and president of the Los Angeles 3-D Club; Jason Goodman, from 21st Century 3D and stereographer on "The Amazing Spider-Man"; and Lenny Lipton, founder of StereoGraphics Corp. and former CTO of RealD. The judges were impressed with the high quality and inventiveness of the content, and had a challenging task to choose the winning entries from among a strong field. Entries in the Demonstration category were not judged.

The judges chose the following two Best of Show winners:

The Best of Show award for 3D live action went to:  
“**Ninety Three Million Miles**” from Site-Eye Time-Lapse Films  
(directors: Brian McClave and Gavin Peacock) (UK).

The Best of Show award for 3D CGI went to:  
“**Nuts & Robbers**” from ToonBox Entertainment Ltd. (Canada)  
and Redrover Co., Ltd. (South Korea).

An illustrated listing of the content shown during this year's 3D Theatre session is available from the conference website:

[www.stereoscopic.org/3dcinema](http://www.stereoscopic.org/3dcinema)

The producers of the 2013 SD&A 3D Theater were Andrew Woods (Curtin University, Australia), Chris Ward (Lightspeed Design, USA), and John Stern (retired). A considerable amount of back-end support was also provided by Dan Lawrence (Lightspeed Design).

The evening concluded with our traditional conference dinner. This year it was held at the Elephant Bar restaurant on the bay-front near the conference hotel, where conference attendees ate, mingled, talked and had a great time.

The **second day** of the conference began with the second SD&A keynote. This was a fascinating description of the 3D coverage of the London 2012 Olympic Games by Jim DeFillipis, a broadcast engineering consultant who has worked on five Olympic Games. Jim described how the 275 hours of 3D stereoscopic programming was made and distributed via the 3D Olympic channel to the rights holding broadcasters. This coverage was provided via three mobile production units and six single camera field production units linked to three outside broadcast trucks. Jim presented the unique challenges in providing 3D coverage, from organizing the 3D channel to the technical challenge of covering sports in 3D while accommodating the full-up 2D production. His talk was accompanied with wonderful 3D sequences from the games to illustrate the technical success of the project.

This was followed by three technical sessions covering 2D/3D Conversion, Depth Grading, Image Quality, 3D Games, and 3D Audio.

The final event of the day was the ever-popular **Demonstration Session**, which has run every year since 1990.

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

- **LET'S Corporation Ltd.** (Yusuke Sakaguchi) demonstrated DepthChecker: An ergonomic evaluation system for stereoscopic content which measures parallax distribution.
- **Wolfvision, Inc.** (Andrea Mayer and Andreas Wohlgenannt) demonstrated their "live" stereoscopic video presentation solution.
- **Lightspeed Design Group** (Chris Ward and Dan Lawrence) showed their DepthQ polarization modulator.
- **Volfofi Group** (Bernard Mendiburu) exhibited their head-tracked and eye-tracked active 3D eyewear and their CRYSTAL polarization modulator.
- **IMAX Corporation** provided a large collection of IMAX 3D movie posters for distribution to attendees.
- **PolarScreens Inc.** (Jean-Etienne Gaudreau) showed a head tracked full resolution glasses-free 3D display monitor.



- **Tokyo University of Agriculture and Technology** (Kenji Hirabayashi) introduced a prototype multi-view display module employing a MEMS projector array as discussed in their paper.<sup>[1]</sup>
- **University of Tokushima** (Hirotugu Yamamoto) demonstrated two different types of 3D techniques. An aerial display technique which forms the real image of an LED sign, which is floating in the air – as presented in their paper 8648-21. They also showed an image processing method to increase depth range in DFD (Depth-Fused 3D) display – as discussed in their paper.<sup>[2]</sup>
- **University of St. Andrews** (Dhanraj Vishwanath) demonstrated the phenomenon he coined as monocular stereopsis – as described in the corresponding manuscript.<sup>[3]</sup>
- **Philips Research** (Patrick Vandewalle) presented a new glasses-free multi-view 3D display which showed a selection of content converted from stereo to multiview - as discussed in their paper.<sup>[4]</sup>
- **ELDIM** (Pierre Boher and Vincent Leroux) demonstrated measurement instruments for polarization analysis of stereoscopic displays.
- **HoloGraphics** (John Toeppen) and **Odyssey Expeditions** (Jason Buchheim) showed their software for online viewing of giga-pixel immersive stereoscopic panoramas and also 3D panorama capture hardware from their paper.<sup>[5]</sup>
- **Tokyo Polytechnic University** (Hisaki Nate) presented their 3D conversion method on a large-screen 3DTV which was the subject of a user study described in their paper.<sup>[6]</sup>
- **Osaka City University** (Yuki Maeda) showed a volumetric display consisting of a projector and a motor-driven image rotator – as presented in their paper.<sup>[7]</sup>
- **StereoJet, Inc.** (Vivian Walworth) displayed a range of historical and contemporary 3D polarized images (Vectograph images and StereoJet prints) as described in her keynote presentation.<sup>[8]</sup>

Also on show in the exhibit area:

- **NVIDIA Corporation** (David Cook) and **Tekamaki LLC** (Robert Loney) demonstrated a triple-wide immersive stereoscopic 3D video game theater running a selection of different visually-rich stereoscopic games. The system consisted of a large curved screen (4.6 m wide x 1 m high) providing a 150 degree horizontal field of view), three projectionDesign F35 AS3D projectors mounted on custom rigging, driven by a PC powered by an NVIDIA Quadro Kepler 5000 graphics card and NVIDIA 3D Vision Pro active glasses. The total display resolution was an impressive 4800 x 1080 pixels per eye.
- The annual **Phantogram exhibit** was again masterfully setup by Terry Wilson. As a particular treat the display included winning phantograms from the First Inter-Galactic Phantogram Competition, sponsored by Barry Rothstein, held in mid- 2012. The work of a range of different phantogram artists was shown including: Claus Krarup, Manuel San Martin, Eric Kurland, Dennis Weins, Wesley Lamont, Gilbert Detillieux, Rick Unger, David Richardson, David Tank, Faramarz Ghahremanifar, Sam Paechter, Grant Campos, James Staub, Andrew Hazelden, Andrew Woods, Zoran Zelic, Oliver Dean, Eugene Mitofsky, Larry Fischer, Lise Paquet. There was also a large selection of phantograms from Terry Wilson's own collection. Attendees were also fortunate to see two examples of full-color phantograms: A full-color StereoJet phantogram of a hydrangea flower prepared by Vivian Walworth (StereoJet Inc) from an image captured by Terry Wilson, and a full-color rear-projected video phantogram of a walking robot viewed using active 3D glasses created by Eric Kurland (3-DIY).

Some additional 3D items were also seen walking the show floor in the hands of attendees. Donald Dansereau (from University of Sydney) was seen taking photos with a Lytro camera, James Ferwerda (from Rochester Institute of Technology) had a tablet computer running an anaglyph phantogram app (as described in another EI conference manuscript<sup>[9]</sup>), some

attendees were flaunting tablet computers with autostereoscopic screens, and of course there were lots of 3D cameras snapping photos around the room.

The prize for the **Best Demonstration** at the conference demonstration session was awarded to John Toeppen and Jason Buchheim for their "Giga-pixel Immersive Stereoscopic Panoramas" – as chosen by the SD&A committee.

Interestingly there were three separate demonstrations in the demonstration session which illustrated the effect of the perception of depth from monocular images. The human brain extracts depth information from a scene using a wide range of as depth cues. It is widely acknowledged that stereopsis provides the strongest perception of depth of all depth cues. Each of the three demonstrations illustrated in their own way that in the absence of stereopsis the human brain can be more inclined to interpret a stronger sense of depth in flat images from monocular cues, without stereopsis sitting in the background providing instructions that the image is flat.

An extensive photo montage and listing 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 five technical sessions on accommodation, applications, volumetric displays, 3D cinema, and 3D developments. In the afternoon attendees also experienced the discussion forum, the interactive paper / poster session, and the symposium reception.

The **discussion forum** considered whether there is enough depth in 3D movies. The panel comprised Gregg Favalora (Optics for Hire) as moderator along with panelists whose expertise spanned 3-D perception, 2-D to 3-D conversion, and cinematic stereography. The expert panelists were: Eric Kurland (Stereographer, 3-DIY, USA), Jenny Read (Vision Scientist, University of Newcastle, UK), Paul Judkins (Director of Technical Film Projects, IMAX Corp., Canada), and Phil McNally (Stereoscopic Supervisor, Dreamworks Animation, USA).

Capping off the end of the SD&A conference, the Electronic Imaging Symposium Reception on the Wednesday evening was a great way to chat and relax with colleagues.

Many of the presentations in the main SD&A conference hall, including the keynotes and panel, were video recorded. Editing is underway and the content made available online via:

[www.stereoscopic.org/2013/program.html](http://www.stereoscopic.org/2013/program.html)

The prize for the **Best use of 3D** during the technical presentations was awarded to Jim Defillipis for his keynote presentation, "Coverage of the London 2012 Olympic Games in 3D," which included a behind-the-scenes documentary which showed the 3D cameras used at the 2012 Olympics in 3D action. The winner was chosen by the SD&A conference chairs.

This year's prize pack for our four winners comprised:

- "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 – kindly donated by SPIE Press,
- "Sony Vegas Pro" (full license) – kindly donated by Sony Creative Software, and
- A T-Shirt for the "Los Angeles 3-D Movie Festival" – kindly donated by the LA 3-D Movie Festival which is a partner of the SD&A 3D Theatre.

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

Two special presentations were given at the conference:

- Andrew Woods presented "Characterizing and reducing crosstalk in printed anaglyph stereoscopic 3D images," which will soon be published as an open access journal paper in SPIE's *Optical Engineering*.<sup>[10]</sup>
- Gregg Favolora presented, "Two notes: a 198-view autostereoscopic projection display with a vibrating lenticular array, and chirped gratings for an HOE-based lightfield display," which will not have an accompanying manuscript because it was a standby presentation.

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

- There were six major sponsors of this year's conference. Our gold sponsors were **IMAX** Corporation (Canada), **DepthQ by Lightspeed Design** (USA), and **Volfoni** (France). Our silver sponsors were **ELDIM** (France) and **Google Chrome** (USA). Conference sponsorship is a valuable way for companies to support the running of the conference and to gain marketing exposure. Our sponsors include 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 **Fakespace Labs** (USA). The ability to present high-quality large-screen stereoscopic images and video at the conference is vital to the success of the conference. This year we had a Christie Digital Mirage HD10K-M projector (1920x1080 resolution, 16:9 aspect ratio, 3 chip DLP, 10,000 ANSI lumens, provided by Christie Digital) projecting onto a 4.9x2.7 meter silvered screen (provided by STRONG / MDI Screen Systems), outputting frame-sequential circularly-polarized 3D (at 120Hz) by way of a DepthQ active polarization modulator (provided by Lightspeed Design). The system was driven by a DepthQ stereoscopic media server for playback of all of the stereoscopic video content shown during the 3D Theatre. Many thanks also to the individuals who facilitated the installation: Chris Ward and Dan Lawrence from DepthQ Stereoscopic; Wayne Bickley from Christie Digital; John Miller from Dep3D; and Adrian Romero and staff from Spectrum Audio Visual. The AV setup was project managed by Andrew Woods (Curtin University) and Diana Gonzalez (IS&T).
- We thank our media sponsors who helped promote the conference: **Veritas et Visus**, **3D Roundabout**, and **Display Central**.
- We very much appreciate the dedicated support of Stephan R. Keith (SRK Graphics Research) who helped support the AV needs of all of our presenters in the main room, and Dan Merritt (The Merritt Group) who also helped with a range of author AV support at the meeting.
- We are grateful to all of the providers of 3D content for the 3D Theatre session for allowing their content to be shown to the conference audience.
- Thanks to the demonstration session presenters for bringing equipment to show. A lot of equipment traveled from overseas, making the contribution to the meeting particularly worthy of additional praise.
- 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.

This year we had 90 abstract submissions. At the conference there were 57 technical papers presented orally (62%), with an additional 18 papers presented as posters (20%), and a rejection rate of approximately 12%.

The full conference proceedings from SD&A 2013 is available for purchase as a printed proceedings, as part of the "Electronic Imaging 2013" symposium DVD-ROM, or electronically via the SPIE Digital Library:

<http://www.stereoscopic.org/proc/index.html#2013>

The long-term benefit to authors of presenting and publishing at the SD&A conference is that it has a well established reputation and a very good citation record. Importantly, a significant number of the most highly cited stereoscopic research papers have been published in the SD&A proceedings over its 24-year history. A recent analysis of citation statistics performed by Nick Holliman found that SD&A had 14 of the top 100 cited stereoscopic imaging research papers† - this is the highest number of any single publication outlet and represents an impressive record for the SD&A conference.

A further manual search using Google Scholar has also found a good number of SD&A papers with very impressive citation counts:

Papers	Citations
C. Fehn (2004) "Depth-image-based rendering (DIBR), compression, and transmission for a new approach on 3D-TV" Stereoscopic Displays and Applications XV, Proc. SPIE Vol. 5291	540
A.J. Woods, T. Docherty, R. Koch (1993) "Image distortions in stereoscopic video systems" Stereoscopic Displays and Applications IV, Proc. SPIE Vol. 1915	344
D. Drascic, P. Milgram (1996) "Perceptual issues in augmented reality" Stereoscopic Displays and Applications VII, Proc. SPIE Vol. 2653	203
G.R. Jones, D. Lee, N.S. Holliman, D Ezra (1997) "Controlling perceived depth in stereoscopic images" Stereoscopic Displays and Applications VIII, Proc. SPIE Vol. 4297	123
N.A. Dodgson (2004) "Variation and extrema of human interpupillary distance" Stereoscopic Displays and Applications XV, Proc. SPIE Vol. 5291	109
C. Van Berkel (1999) "Image preparation for 3D LCD" Stereoscopic Displays and Applications X, Proc. SPIE Vol. 3639	105

Data collected using Google Scholar 19 March 2013.

This list is incomplete and there may well be other papers with high (or higher) citation counts.

Over the years the SD&A Chairs and committee have been actively working to continuously improve the quality of the material published in the SD&A proceedings – it is felt that the additional quality will help improve citations and also help improve the impact of the SD&A proceedings.

This coming year we will be trialing a new additional publication mode for the Stereoscopic Displays and Applications conference. Traditionally presentations at the SD&A conference have been supported by a manuscript published in the SD&A conference proceedings. Authors who publish their work this way have benefited from and contributed to SD&A being the most cited publications in the stereoscopic imaging field. In order to offer additional options for authors, for the 2014 conference we will be offering authors the opportunity to publish their work directly in the *Journal of Electronic Imaging (JEI)* and present the paper at the SD&A conference. This will mainly be of benefit to academic authors whose Universities may associate more value to refereed journal publications. The call for papers for the 2014

† "Publish or Perish"<sup>(11)</sup> software was used to generate the top 1000 Google scholar articles by citation count, with the keyword "stereoscopic" in the title, and time period 2008-2013. This list was then edited to remove articles that were not about electronic displays (mostly these were medical and pure astronomy articles). The survey was conducted on 17th March 2013.

SD&A conference will offer the direct JEl publication method, however since journal publication has a much longer lead time it will be necessary for authors to submit their full journal manuscript much earlier in the year in order to allow enough time for the full journal review process to take place. If you are interested in journal publication of your work, and presenting your work at the SD&A conference, please think seriously about this option and start thinking about having your full paper ready for the earlier time frame. There will be no substantive change to the existing conference paper publication method and it will remain available for those authors who wish to continue publishing this way.

Conference activities do not stop at the end of the January meeting. The SD&A conference website and LinkedIn group provide focuses for conference activities during the time between conferences. We will soon be actively seeking abstracts for the 2014 conference, with a deadline in June 2013 - 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 LinkedIn group is available at:

[www.linkedin.com/groups?gid=1945944](http://www.linkedin.com/groups?gid=1945944)

You may 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 25th annual SD&A conference will be held for three days in the period 3–6 February 2014 at a new location – the Hilton San Francisco Union Square Hotel in downtown San Francisco, as part of the 2014 IS&T/SPIE Electronic Imaging: Science and Technology Symposium. The hotel can be accessed from the San Francisco International Airport (SFO) via BART (rail), shuttle bus or taxi. The new hotel is just six blocks from The Moscone Center (the venue of SPIE Photonics West) meaning the Photonics West exhibits will be easily accessible.

The 2014 SD&A conference will continue a tradition of presenting and demonstrating the latest technologies relevant to stereoscopic displays and applications. Please join us at the 2014 event to celebrate 25 years of SD&A. We hope to see you there!

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

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