Human Vision and Electronic Imaging XVIII

Bernice E. Rogowitz
Thrasyvoulos N. Pappas
Huib de Ridder
Editors

4–7 February 2013
Burlingame, California, United States

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

Cosponsored by
Qualcomm Inc. (United States)
Datacolor (United States)
Dolby Laboratories, Inc. (United States)

Published by
SPIE

Volume 8651
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:


ISSN: 0277-786X
ISBN: 9780819494245

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 © 2013, 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/13/$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

<table>
<thead>
<tr>
<th>Page</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>ix</td>
<td>Conference Committee</td>
</tr>
<tr>
<td>xiii</td>
<td>Introduction</td>
</tr>
</tbody>
</table>

## KEYNOTE SESSION

<table>
<thead>
<tr>
<th>Paper Number</th>
<th>Title</th>
<th>Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>8651 03</td>
<td>World, environment, Umwelt, and innerworld: a biological perspective on visual awareness (Keynote Paper) [8651-3]</td>
<td>J. J. Koenderink, Technische Univ. Delft (Netherlands) and Univ. of Leuven (Belgium)</td>
</tr>
<tr>
<td>8651 04</td>
<td>Does evolution favor true perceptions? (Keynote Paper) [8651-4]</td>
<td>D. D. Hoffman, Univ. of California, Irvine (United States); M. Singh, Rutgers Univ. (United States); J. Mark, Univ. of California, Irvine (United States)</td>
</tr>
</tbody>
</table>

## LIGHTNESS AND COLOR

<table>
<thead>
<tr>
<th>Paper Number</th>
<th>Title</th>
<th>Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>8651 05</td>
<td>Mapping luminance onto lightness in vision and art (Invited Paper) [8651-5]</td>
<td>A. Gilchrist, Rutgers Univ. (United States)</td>
</tr>
<tr>
<td>8651 06</td>
<td>Human lightness perception is guided by simple assumptions about reflectance and lighting [8651-6]</td>
<td>R. F. Murray, York Univ. (Canada)</td>
</tr>
<tr>
<td>8651 07</td>
<td>Spatial imaging in color and HDR: prometheus unchained (Invited Paper) [8651-7]</td>
<td>J. J. McCann, McCann Imaging (United States)</td>
</tr>
</tbody>
</table>

## VISION AND THE EVOLUTION OF TECHNOLOGY

<table>
<thead>
<tr>
<th>Paper Number</th>
<th>Title</th>
<th>Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>8651 08</td>
<td>Visual stimuli: past and present (Invited Paper) [8651-8]</td>
<td>G. Westheimer, Univ. of California, Berkeley (United States)</td>
</tr>
<tr>
<td>8651 09</td>
<td>Emergent technologies: 25 years (Invited Paper) [8651-9]</td>
<td>H. K. Rising III, Consultant (United States)</td>
</tr>
<tr>
<td>8651 0B</td>
<td>Perceptual approaches to finding features in data (Invited Paper) [8651-11]</td>
<td>B. E. Rogowitz, Visual Perspectives Research and Consulting (United States)</td>
</tr>
</tbody>
</table>

## EARLY VISION IMAGE QUALITY I

<table>
<thead>
<tr>
<th>Paper Number</th>
<th>Title</th>
<th>Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>8651 0C</td>
<td>Is image quality a function of contrast perception? (Invited Paper) [8651-12]</td>
<td>A. M. Haun, E. Peli, Schepens Eye Research Institute, Harvard Medical School (United States)</td>
</tr>
</tbody>
</table>
Visible contrast energy metrics for detection and discrimination (Invited Paper) [8651-13]
A. J. Ahumada, A. B. Watson, NASA Ames Research Ctr. (United States)

EARLY VISION IMAGE QUALITY II

Initial spatio-temporal domain expansion of the Modelfest database [8651-15]
T. Carney, S. Mozaffari, S. Sun, R. Johnson, S. Shirvastava, P. Shen, E. Ly, Univ. of California, Berkeley (United States)

A database of local masking thresholds in natural images [8651-16]
M. Alam, K. P. Vilankar, D. M. Chandler, Oklahoma State Univ. (United States)

Interplay between JPEG-2000 image coding and quality estimation [8651-17]
G. O. Pinto, S. S. Hemami, Cornell Univ. (United States)

HIGHER-LEVEL ISSUES IN IMAGE QUALITY I

From image quality to atmosphere experience: how evolutions in technology impact experience assessment (Invited Paper) [8651-18]
I. Heynderickx, Technische Univ. Delft (Netherlands) and Philips Research Labs. (Netherlands); H. de Ridder, Technische Univ. Delft (Netherlands)

Preference limits of the visual dynamic range for ultra high quality and aesthetic conveyance [8651-19]
S. Daly, T. Kunkel, X. Sun, S. Farrell, P. Crum, Dolby Labs., Inc. (United States)

Quantifying image quality in graphics: perspective on subjective and objective metrics and their performance [8651-20]
R. K. Mantiuk, Bangor Univ. (United Kingdom)

Visualizing lighting with images: converging between the predictive value of renderings and photographs [8651-21]
U. Engelke, M. G. M. Stokkermans, M. J. Murdoch, Philips Research (Netherlands)

HIGHER-LEVEL ISSUES IN IMAGE QUALITY II

A survey on 3D quality of experience and 3D quality assessment [8651-22]
A. K. Moorthy, Texas Instruments Inc. (United States); A. C. Bovik, The Univ. of Texas at Austin (United States)

Visual quality beyond artifact visibility [8651-23]
J. A. Redi, Technische Univ. Delft (Netherlands)

Subjective matters: from image quality to image psychology (Invited Paper) [8651-24]
E. A. Fedorovskaya, RadixNova (United States); H. De Ridder, Technische Univ. Delft (Netherlands)
PERCEPTION AND NATURAL ENVIRONMENTS: IMAGE STATISTICS, TEXTURE, AND FEATURES I

8651 0P The rough side of texture: texture analysis through the lens of HVEI (Invited Paper) [8651-25]  
T. N. Pappas, Northwestern Univ. (United States)

8651 0Q Optimizing visual performance by adapting images to observers (Invited Paper) [8651-26]  
M. A. Webster, Univ. of Nevada, Reno (United States); I. Juricevic, Indiana Univ. (United States)

PERCEPTION AND NATURAL ENVIRONMENTS: IMAGE STATISTICS, TEXTURE, AND FEATURES II

8651 0R Efficient image representations and features (Invited Paper) [8651-27]  
M. Dorr, Schepens Eye Research Institute, Harvard Medical School (United States); E. Vig, Harvard Univ. (United States); E. Barth, Univ. of Lübeck (Germany)

8651 0S Highly overcomplete sparse coding [8651-28]  
B. A. Olshausen, Univ. of California, Berkeley (United States)

8651 0T Blind image quality assessment without training on human opinion scores [8651-29]  
A. Mittal, R. Soundararajan, G. S. Muralidhar, A. C. Bovik, J. Ghosh, The Univ. of Texas at Austin (United States)

ATTENTION AND SALIENCY: FROM PERCEPTION TO APPLICATIONS

8651 0V Saliency identified by absence of background structure [8651-31]  
F. W. M. Stentiford, Univ. College London (United Kingdom)

8651 0W Investigation of eye-catching colors using eye tracking [8651-32]  
M. Baik, H.-J. Suk, J. Lee, K.-A. Choi, KAIST (Korea, Republic of)

8651 0X Can relative skill be determined from a photographic portfolio? [8651-33]  
A. Agrawal, V. Premachandran, Nanyang Technological Univ. (Singapore); R. Somavarapu, The Univ. of Texas at Dallas (United States); R. Kakarala, Nanyang Technological Univ. (Singapore)

EYE MOVEMENTS AND VISUAL TASKS IN COMPLEX ENVIRONMENTS

8651 0Y Binocular eye movements in health and disease (Invited Paper) [8651-34]  
C. W. Tyler, Smith-Kettlewell Institute (United States)

8651 0Z Reflexive and voluntary control of smooth eye movements [8651-35]  
J. B. Mulligan, NASA Ames Research Ctr. (United States); S. B. Stevenson, Univ. of Houston College of Optometry (United States); L. K. Cormack, The Univ. of Texas at Austin (United States)
8651 10  **Simple gaze-contingent cues guide eye movements in a realistic driving simulator**  
[8651-36]  
L. Pomarjanschi, Univ. of Lübeck (Germany); M. Dorr, P. J. Bex, Schepens Eye Research Institute, Harvard Medical School (United States); E. Barth, Univ. of Lübeck (Germany)

8651 11  **Designing an obstacle display for helicopter operations in degraded visual environment**  
[8651-37]  
P. M. Knabl, N. Peinecke, Deutsches Zentrum für Luft- und Raumfahrt e.V. (Germany)

### 3D ATTENTION AND VISUAL TRACKING

8651 12  **Visual storytelling in 2D and stereoscopic 3D video: effect of blur on visual attention**  
[8651-38]  
Q. Huynh-Thu, C. Vienne, L. Blondé, Technicolor (France)

8651 13  **Using natural versus artificial stimuli to perform calibration for 3D gaze tracking**  
[8651-39]  
C. Maggia, N. Guyader, A. Guérin-Dugué, Lab. of Images Speech Signal Automatism (France)

8651 14  **Study of center-bias in the viewing of stereoscopic image and a framework for extending 2D visual attention models to 3D**  
[8651-40]  
J. Wang, M. Perreira Da Silva, P. Le Callet, V. Ricordel, LUNAM Univ., Univ. de Nantes, CNRS (France)

8651 15  **How visual attention is modified by disparities and textures changes?**  
[8651-41]  
D. Khaustova, J. Fournier, E. Wyckens, France Télécom R&D France (France); O. Le Meur, Univ. of Rennes 1 (France)

### ART AND PERCEPTION

8651 16  **Copy-paste in depth**  
[8651-43]  
M. W. A. Wijntjes, Technische Univ. Delft (Netherlands)

8651 17  **Drawing accuracy measured using polygons**  
[8651-44]  
L. Carson, Univ. of Waterloo (Canada); M. Millard, Stanford Univ. (United States); N. Quehl, J. Danckert, Univ. of Waterloo (Canada)

8651 18  **Fractals in art and nature: why do we like them?**  
[8651-45]  
B. Spehar, The Univ. of New South Wales (Australia); R. P. Taylor, The Univ. of Oregon (United States)

### INTERACTIVE PAPER SESSION

8651 19  **Picture perception and visual field**  
[8651-46]  
A. J. van Doorn, H. de Ridder, Technische Univ. Delft (Netherlands); J. Koenderink, Technische Univ. Delft (Netherlands) and Univ. of Leuven (Belgium)
8651 1A Measurements of achromatic and chromatic contrast sensitivity functions for an extended range of adaptation luminance [8651-47]
K. J. Kim, Seoul National Univ. (Korea, Republic of); R. Mantuik, Bangor Univ. (United Kingdom); K. H. Lee, Seoul National Univ. (Korea, Republic of)

8651 1B Viewer preferences for adaptive playout [8651-48]
S. Deshpande, Sharp Labs. of America Inc. (United States)

8651 1C The effect of familiarity on perceived interestingness of images [8651-49]
S. L. Chu, Virginia Polytechnic and State Univ. (United States); E. Fedorovskaya, RadixNova Ltd. (United States); F. Quek, Virginia Polytechnic and State Univ. (United States); J. Snyder, Kodak Research Labs. (United States)

8651 1D Quantifying patterns of dynamics in eye movement to measure goodness in organization of design elements in interior architecture [8651-51]
H. Mirkia, A. Sangari, M. Nelson, A. H. Assadi, Univ. of Wisconsin-Madison (United States)

8651 1E Development of a human vision simulation camera and its application: implementation of specific color perception [8651-52]
H. Okumura, S. Takubo, S. Ozaki, T. Kawasaki, I. N. Abdullah, K. Arai, Saga Univ. (Japan); O. Fukuda, Measurement Solution Research Ctr., AIST (Japan)

8651 1F IMF-based chaotic characterization of AP and ML visually-driven postural responses [8651-53]
H. Azhar, G. Giraudet, J. Faubert, Univ. de Montréal (Canada)

8651 1G Application of imaging technology for archaeology researches: framework design for connectivity analysis in pieces of Jomon pottery [8651-54]
K. Miyata, National Museum of Japanese History (Japan); R. Yajima, K. Kobayashi, Chuo Univ. (Japan)

8651 1H Top-down visual search in Wimmelbild [8651-55]
J. Bergbauer, Tecnical Univ. Munich (Germany); S. Tari, Middle East Technical Univ. (Turkey)

8651 1I Visual discrimination and adaptation using non-linear unsupervised learning [8651-56]
S. Jiménez, V. Laparra, J. Malo, Univ. de València (Spain)

8651 1J Chromatic induction and contrast masking: similar models, different goals? [8651-57]
S. Jiménez, Univ. de València (Spain); X. Otazu, Univ. Autònoma de Barcelona (Spain); V. Laparra, J. Malo, Univ. de València (Spain)

8651 1K Aesthetics and entropy II: a critical examination [8651-58]
M. R. V. Sahyun, Consultant (United States)

Author Index
Conference Committee

Symposium Chair

Gaurav Sharma, University of Rochester (United States)

Symposium Cochair

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

Conference Chairs

Bernice E. Rogowitz, Visual Perspectives Consulting (United States)
Thrasyvoulos N. Pappas, Northwestern University (United States)
Huib de Ridder, Technische Universität Delft (Netherlands)

Conference Program Committee

Albert J. Ahumada Jr., NASA Ames Research Center (United States)
Jan P. Allebach, Purdue University (United States)
Erhardt Barth, Universität zu Lübeck (Germany)
Walter R. Bender, MIT Media Laboratory (United States)
Michael H. Brill, Datacolor (United States)
John C. Dalton, Synthetik Software (United States)
Scott J. Daly, Dolby Labs., Inc. (United States)
Elena A. Fedorovskaya, Kodak Research Laboratories (United States)
James A. Ferwerda, Rochester Institute of Technology (United States)
Jennifer L. Gille, Qualcomm Inc. (United States)
Sergio R. Goma, Qualcomm Inc. (United States)
Sheila S. Hemami, Cornell University (United States)
Laurent Itti, The University of Southern California (United States)
Stanley A. Klein, University of California, Berkeley (United States)
Patrick Le Callet, Université de Nantes (France)
Lora T. Likova, The Smith-Kettlewell Eye Research Institute (United States)
John J. McCann, McCann Imaging (United States)
Jeffrey B. Mulligan, NASA Ames Research Center (United States)
Karol Myszkowski, Max-Planck-Institut für Informatik (Germany)
Adar Pelah, The University of York (United Kingdom)
Eliezer Peli, Schepens Eye Research Institute (United States)
Robert Pepperell, Cardiff School of Art & Design (United Kingdom)
Sylvia C. Pont, Technische Universität Delft (Netherlands)
Hawley K. Rising III, Consultant (United States)
Sabine Süssstrunk, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
Christopher W. Tyler, The Smith-Kettlewell Eye Research Institute (United States)
Andrew B. Watson, NASA Ames Research Center (United States)
Michael A. Webster, University of Nevada, Reno (United States)

Session Chairs

Keynote Session
Bernice E. Rogowitz, Visual Perspectives Consulting (United States)
Thrasyvoulos N. Pappas, Northwestern University (United States)
Huib de Ridder, Technische Universiteit Delft (Netherlands)

1 Lightness and Color
Bernice E. Rogowitz, Visual Perspectives Consulting (United States)

2 Vision and the Evolution of Technology
Andrew B. Watson, NASA Ames Research Center (United States)

3 Early Vision Image Quality I
Thrasyvoulos N. Pappas, Northwestern University (United States)

4 Early Vision Image Quality II
Eliezer Peli, Schepens Eye Research Institute (United States)

5 Higher-Level Issues in Image Quality I
Huib de Ridder, Technische Universiteit Delft (Netherlands)

6 Higher-Level Issues in Image Quality II
Bernice E. Rogowitz, Visual Perspectives Consulting (United States)

7 Perception and Natural Environments: Image Statistics, Texture, and Features I
Erhardt Barth, Universität zu Lübeck (Germany)

8 Perception and Natural Environments: Image Statistics, Texture, and Features II
Jeffrey B. Mulligan, NASA Ames Research Center (United States)

9 The Dark Side of Color: Joint Session with Conferences 8651 and 8652
Carinna E. Parraman, University of the West of England (United Kingdom)

10 Attention and Saliency: From Perception to Applications
Thrasyvoulos N. Pappas, Northwestern University (United States)

11 Eye Movements and Visual Tasks in Complex Environments
Bernice E. Rogowitz, Visual Perspectives Consulting (United States)
12  3D Attention and Visual Tracking
Elena A. Fedorovskaya, Kodak Research Laboratories (United States)

13  Art and Perception
Bernice E. Rogowitz, Visual Perspectives Consulting (United States)
Introduction

This volume celebrates the 25th Anniversary of the Conference on Human Vision and Electronic Imaging (HVEI). Over the years, HVEI has become an intellectual beacon for multidisciplinary research on how humans perceive and interact with electronic media. The papers in this conference are written by scientists trained in sensory psychophysics, perception, and cognition, by artists and designers, by domain experts who use imaging to solve real-world problems, and by scientists and engineers trained in image/signal processing, mathematics, computer vision and machine learning. The conference covers the whole range of electronic imaging technologies, including displays, digital compression, digital libraries, 3-D and stereoscopic displays, graphics, data mining and visualization.

This year marks a turning point for HVEI. As electronic media take center stage in the world of commerce, entertainment, medicine, education, finance, and communication, the focus is shifting from the technology, per se., to the interaction between the technology and the human. Increasingly, the focus is on the human who creates, absorbs and interacts with the data produced by these technologies, and with the algorithms that transform it. The human not only judges image quality, but also uses electronic media to find patterns, make decisions, and express creativity. The Conference on Human Vision and Electronic Imaging is dedicated to providing the research and technology to drive this future.

The first two papers in this volume are the keynote presentations, which frame a broad multidisciplinary scope. Jan Koenderink (T.U. Delft) presented a philosophical essay on how our perception of reality is shaped by our umwelt, or world view. Don Hoffman (UC Irvine) hypothesized that we are unable to experience the real world veridically, and presented a simulation designed to test this hypothesis. At the conference, the audience also heard presentations by Aude Oliva (MIT), who explored the question of image memorability with experiments using thousands of images on the internet, and by Walter Bender (Sugar Labs), on how research presented at HVEI influenced the design of “One Laptop Per Child,” which is not only an inexpensive device, but also, an interactive learning system.

This volume also features ten papers that explore the evolution of key multidisciplinary trends over the past 25 years through the lens of HVEI. These surveys provide a conceptual and historical backdrop for each major “theme,” and explore opportunities and challenges for the future. Several papers examine fundamental and applied issues at the intersection between technology and research in color vision (Mc Cann), feature perception (Rogowitz), texture analysis...
(Pappas), natural image statistics (Dorr, Vig, and Barth), and eye movements (Tyler). Several papers provide a tour of early-vision issues in image quality and coding (Haun and Peli; Ahumada and Watson), complemented by two papers examining higher-level issues in image quality (Heynderickx, and de Ridder; Federovskaya and de Ridder). The final theme paper focuses on research driven by emerging technologies (Rising) and aesthetics. This volume also includes three invited papers-- on lightness perception in imaging and art (Gilchrist), on novel high-level adaptation effects (Webster) and on the co-evolution of the technologies for producing visual stimuli and the problems they were invented to explore (Westheimer).

The peer-reviewed contributed papers in the proceedings support the major themes above and also help shape directions for HVEI in the years ahead. One emerging theme is the technology, psychology, and aesthetics of art and design, which ran through the conference and culminated in a session on Art and Perception. Another is visual attention, which plays a major role in research on image quality and coding. This year, there are several papers which expand the scope to include the allocation of attention in 3-D environments and complex real-world settings.

Looking back over the history of the Conference on Human Vision and Electronic Imaging, we are proud of the truly multi-disciplinary community that it has fostered. As many of the theme papers reveal, career-changing insights were experienced at HVEI, resulting in new fundamental scientific results and new technologies. We are proud that the conference has introduced scientists, engineers, and artists who might never have met each other had it not been for HVEI, and we are proud of all the collaborations that have sprung from this venue. By focusing on discussion and interaction, and by being ferociously inclusive, the Conference on Human Vision and Electronic Imaging continues to be a place where creative professionals from a wide range of disciplines, geographies, and perspectives come to learn, share, and be inspired.

Please come visit our website: http://hvei.eecs.northwestern.edu

And join the Human Vision and Electronic Imaging Group on LinkedIn: http://tinyurl.com/d9l9khe

Bernice E. Rogowitz
Thrasyvoulos N. Pappas
Huib de Ridder