electronic IMAGING 2021

IS&T International Symposium on Electronic Imaging Science and Technology

11–28 January 2021 • Online

PROCEEDINGS

Color Imaging XXVI: Displaying, Processing, Hardcopy, and Applications

Editors: **Reiner Eschbach,** Norwegian University of Science and Technology (Norway) and Monroe Community College (United States),
Gabriel G. Marcu, Apple Inc. (United States), and
Alessandro Rizzi, Università degli Studi di Milano (Italy)

These papers represent the program of Electronic Imaging 2021, held online 11–28 January 2021.

IS&T International Symposium on Electronic Imaging 2021
Color Imaging XXVI: Displaying, Processing, Hardcopy, and Applications

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Color Imaging XXVI: Displaying, Processing, Hardcopy, and Applications

Conference overview

Color imaging has historically been treated as a phenomenon sufficiently described by three independent parameters. Recent advances in computational resources and in the understanding of the human aspects are leading to new approaches that extend the purely metrological view towards a perceptual view of color in documents and displays. Part of this perceptual view is the incorporation of spatial aspects, adaptive color processing based on image content, and the automation of color tasks, to name a few. This dynamic nature applies to all output modalities, including hardcopy devices, but to an even larger extent to soft-copy displays.

Spatially adaptive gamut and tone mapping, dynamic contrast, and color management continue to support the unprecedented development of the display hardware spreading from mobile displays to large size screens and emerging technologies. This conference provides an opportunity to present, to interact, and to learn about the most recent developments in color imaging researches, technologies, and applications. Focus of the conference is on color basic research and testing, color image input, dynamic color image output and rendering, color image automation, emphasizing color in context and color in images, and reproduction of images across local and remote devices.

In addition, the conference covers software, media, and systems related to color. Special attention is given to applications and requirements created by and for multidisciplinary fields involving color and/or vision.

Conference Chairs: Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States); Gabriel G. Marcu, Apple Inc. (United States); and Alessandro Rizzi, Università degli Studi di Milano (Italy)

Program Committee: Jan P. Allebach, Purdue University (United States); Vien Cheung, University of Leeds (United Kingdom); Scott J. Daly, Dolby Laboratories, Inc. (United States); Philip J. Green, Norwegian University of Science and Technology (Norway); Yasuyo G. Ichihara, Kogakuin University (Japan); Michael A. Kriss, MAK Consultants (United States); Fritz Lebowsky, Consultant (France); John J. McCann, McCann Imaging (United States); Carinna E. Parraman, University of the West of England (United Kingdom); Caterina Ripamonti, Cambridge Research Systems Ltd. (United Kingdom); Shoji Tominaga, Chiba University (Japan); Sophie Triantaphillidou, University of Westminster (United Kingdom); and Stephen Westland, University of Leeds (United Kingdom)

Paper authors listed as of 1 January 2021; refer to manuscript for final authors. Titles that are not listed with the proceedings files were presentation-only.

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TUESDAY 19 JANUARY 2021

PLENARY: DEEP INTERNAL LEARNING—DEEP LEARNING WITH ZERO EXAMPLES
Session Chair: Charles Bouman, Purdue University (United States)
10:00 – 11:10

Deep internal learning—Deep learning with zero examples
Michal Irani, *professor, Department of Computer Science and Applied Mathematics, Weizmann Institute of Science (Israel)*

Michal Irani is a professor at the Weizmann Institute of Science. Her research interests include computer vision, AI, and deep learning. Irani's prizes and honors include the Maria Petrou Prize (2016), the Helmholtz "Test of Time Award" (2017), the Landau Prize in AI (2019), and the Rothschild Prize in Mathematics and Computer Science (2020). She also received the ECCV Best Paper Awards (2000 and 2002), and the Marr Prize Honorable Mention (2001 and 2005).

KEYNOTE: CULTURAL HERITAGE   **JOINT SESSION**
Moderator: Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States) / Session Chair: Mathieu Hebert, Université Jean Monnet de Saint Etienne (France)
13:30 – 14:30

This session is jointly sponsored by: Color Imaging XXVI: Displaying, Processing, Hardcopy, and Applications, and Material Appearance 2021.

MAAP-086
KEYNOTE: Imaging sciences for cultural heritage, *Clotilde Boust, Centre for Research and Restoration of the Museums of France (C2RMF) (France)*

Keynote speaker Clotilde Boust is assistant professor in color and digital imaging, Center for Research and Restoration for French Museums (C2RMF). Boust received her engineering degree in photography from the Ecole Nationale Supérieure Louis Lumière, France (1998). After working for two years as a color consultant in the press industry and one year as a researcher in the vision laboratory of the Museum National d'Histoire Naturelle, she began a PhD in image quality with Océ Print Logic Technologies and Paris VI University. She is now a researcher in visual appearance since 2006 at C2RMF and works on color, gloss, and roughness measurements for different cultural heritage objects.

WEDNESDAY 20 JANUARY 2021

MATERIALS AND LIGHTING   JOINT SESSION

Moderator: Alessandro Rizzi, Università degli Studi di Milano (Italy) / **Session Chair:** Lionel Simonot, Université de Poitiers (France)
11:45 – 12:45

This session is jointly sponsored by: Color Imaging XXVI: Displaying, Processing, Hardcopy, and Applications, and Material Appearance 2021.

11:45   MAAP-131
Why a clear coating modifies halftone color prints, *Mathieu Hebert[1] and Lionel Simonot[2]; [1]Université Jean Monnet de Saint Etienne and [2]Université de Poitiers (France)*

12:05   MAAP-132
Next best light position (NBLP) estimation for automating the RTI acquisition process, *Ramamoorthy Luxman, Marvin Nurit, Gaetan Le Goic, Franck Marzani, and Alamin Mansouri, Universite de Bourgogne (France)*

12:25   MAAP-133
Objective evaluation of relighting models on translucent materials from multispectral RTI images, *Vlado Kitanovski and Jon Yngve Hardeberg, Norwegian University of Science and Technology (Norway)*

THURSDAY 21 JANUARY 2021

PLENARY: THE DEVELOPMENT OF INTEGRAL COLOR IMAGE SENSORS AND CAMERAS

Session Chair: Jonathan B. Phillips, Google Inc. (United States)
10:00 – 11:10

The development of integral color image sensors and cameras
Kenneth A. Parulski, *expert consultant: mobile imaging (United States)*

Kenneth Parulski is an expert consultant to mobile imaging companies and leads the development of ISO standards for digital photography. He joined Kodak in 1980 after graduating from MIT and retired in 2012 as research fellow and chief scientist in Kodak's digital photography division. His work has been recognized with a Technical Emmy and other major awards. Parulski is a SMPTE fellow and an inventor on more than 225 US patents.

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IS&T International Symposium on Electronic Imaging 2021
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MONDAY 25 JANUARY 2021

PLENARY: MAKING INVISIBLE VISIBLE
Session Chair: Jonathan B. Phillips, Google Inc. (United States)
10:00 – 11:10

Making invisible visible
Ramesh Raskar, *associate professor, MIT Media Lab (United States)*

Ramesh Raskar is an associate professor at MIT Media Lab and directs the Camera Culture research group. His focus is on AI and imaging for health and sustainability. They span research in physical (e.g., sensors, health-tech), digital (e.g., automated and privacy-aware machine learning), and global (e.g., geomaps, autonomous mobility) domains. He received the Lemelson Award (2016), ACM SIGGRAPH Achievement Award (2017), DARPA Young Faculty Award (2009), Alfred P. Sloan Research Fellowship (2009), TR100 Award from MIT Technology Review (2004), and Global Indus Technovator Award (2003). He has worked on special research projects at Google [X] and Facebook and cc-founded/advised several companies.

TUESDAY 26 JANUARY 2021

IMAGE & PRINT QUALITY I
Moderator: Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States / **Session Chair:** Carinna Parraman, University of the West of England (United Kingdom)
10:12 – 11:15

10:15   COLOR-252
Improved content-color-dependent screening (CCDS): Adaptive bilateral filtering and color-aware Sobel edge detector, *Yang Yan and Jan Allebach, Purdue University (United States)*

10:35   COLOR-253
Color text fading detection, *Runzhe Zhang[1], Yousun Bang[2], Minki Chc[2], Mark Shaw[3], and Jan Allebach[1]; [1]Purdue University (United States), [2]HP Printing Korea (Republic of Korea), and [3]HP Inc. (United States)*

10:55   COLOR-254
Streak detection in color printed customer content, *Runzhe Zhang[1], Yousun Bang[2], Minki Chc[2], Mark Shaw[3], and Jan Allebach[1]; [1]Purdue University (United States), [2]HP Printing Korea (Republic of Korea), and [3]HP Inc. (United States)*

IMAGE & PRINT QUALITY II
Moderator: John McCann, McCann Imaging (United States) / **Session Chair:** Gabriel Marcu, Apple Inc. (United States)
11:45 – 12:45

11:45   COLOR-243
Deep learning approaches to determining optimal resolution for scanned text documents, *Litao Hu[1], Peter Bauer[2], Todd Harris[2], and Jan Allebach[1]; [1]Purdue University and [2]HP Inc. (United States)*

12:05   COLOR-244
Determining optimal resolution for scanned document raster content, *Zhenhua Hu[1], Peter Bauer[2], Todd Harris[2], and Jan Allebach[1]; [1]Purdue University and [2]HP Inc. (United States)*

12:25   **COLOR-245**

Banding defect detection and image quality classification, *Yi Yang[1], Runzhe Zhang[1], Yousun Bang[2], Minki Cho[2], Mark Shaw[3], and Jan Allebach[1]; [1]Purdue University (United States), [2]HP Printing Korea (Republic of Korea), and [3]HP Inc. (United States)*

COLOR TRANSFORM & CHARACTERIZATION

Moderator: Alessandro Rizzi, Università degli Studi di Milano (Italy) / **Session Chair:** John McCann, McCann Imaging (United States)
13:15 – 14:15

13:15   **COLOR-221**

3D-LUT optimization for high dynamic range and wide color gamut color processing, *Stefano Andriani[1], Aurora Zaboi[2], Giancarlo Calvagnc[2], and JD Vandenberg[3]; [1]Arnold & Richter Cine Technik GmbH (Germany), [2]University of Padova (Italy), and [3]Walt Disney and Marvel Studios (United States)*

13:35   **COLOR-222**

A novel camera colour characterisation model for the colour measurement of human skin, *Ruili He[1], Kaida Xiac[1], Michael Pointer[1], Yoav Bressler[2], Zhen Liu[1], and Yan Lu[1]; [1]University of Leeds (United Kingdom) and [2]Stratasys Ltd (Israel)*

13:55   **COLOR-328**

Improving an inkjet printer: Saturation enhancement based on segmentation and hue, *Sige Hu[1], Baekdu Choi[1], Davi He[2], Zillion Lin[2], George Chiu[1], and Jan Allebach[1]; [1]Purdue University (United States) and [2]Sunvalley Tek (China)*

WEDNESDAY 27 JANUARY 2021

PLENARY: REVEALING THE INVISIBLE TO MACHINES WITH NEUROMORPHIC VISION SYSTEMS: TECHNOLOGY AND APPLICATIONS OVERVIEW

Session Chair: Radka Tezaur, Intel Corporation (United States)
10:00 – 11:10

Revealing the invisible to machines with neuromorphic vision systems: Technology and applications overview
Luca Verre, *CEO and cc-founder, Prophesee (France)*

Luca Verre is cc-founder and CEO of Prophesee, the inventor of the world's most advanced neuromorphic vision systems. Verre is a World Economic Forum technology pioneer. His experience includes project and product management, marketing, and business development roles at Schneider Electric. Prior to Schneider Electric, Verre worked as a research assistant in photonics at the Imperial College of London. Verre holds a MSc in physics, electronic and industrial engineering from Politecnico di Milano and Ecole Centrale and an MBA from Institut Européen d'Administration des Affaires, INSEAD.

THURSDAY 28 JANUARY 2021

NOVEL DEVICES I
Moderator: Jan Allebach, Purdue University (United States) / **Session Chair:** Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States)
10:15 – 11:15

10:15   COLOR-339
Design and fabrication of microfluidics paper-based devices for contaminant detection using a wax printer, *Qiyue Liang, Min Zhao, George Chiu, and Jan Allebach, Purdue University (United States)*

10:35   COLOR-340
Adaptive learning-based method for nitrate sensor quality assessment in on-line scenarios, *Qingyu Yang, Kerry Maize, Ye Mi, George Chiu, Ali Shakouri, and Jan Allebach, Purdue University (United States)*

10:55   COLOR-341
Thin-film nitrate sensor performance prediction based on preprocessed sensor images, *Xihui Wang, Kerry Maize, Ye Mi, Ali Shakouri, George Chiu, and Jan Allebach, Purdue University (United States)*

NOVEL DEVICES II
Moderator: Alessandro Rizzi, Università degli Studi di Milano (Italy) / **Session Chair:** Gabriel Marcu, Apple Inc. (United States)
11:45 – 12:45

11:45   COLOR-342
Spectral imaging to differentiate contaminant levels, *Min Zhao, Qiyue Liang, Susana Diaz-Amaya, George Chiu, Lia Stanciu, Amanda J. Deering, and Jan Allebach, Purdue University (United States)*

12:05   COLOR-343
Fluorescence guided precision surgery – Real-time illumination of tumors and nerves (Invited), *Quyen Nguyen, University of California, San Diego (United States)*

Invited speaker Quyen Nguyen, MD/PhD, is the founder and CEO of Alume Biosciences, Inc. (Alume). Nguyen is a professor in the Department of Surgery at the University of California San Diego (UCSD). She received her combined MD/PhD from Washington University, School of Medicine in St. Louis, MO. She completed her general surgery internship at Barnes-Jewish Hospital in St. Louis and residency in head and neck surgery and subspecialty fellowship training in neurotology/skull base surgery at UCSD. She is board certified in both head and neck surgery and neurotology/skull base surgery. Her clinical practice is at UCSD Health Systems where she cares for patients with diseases of the facial nerve, ear, and skull base. She also specializes in hearing restoration surgeries including cochlear implantation. She is director of the Facial Nerve Clinic. Nguyen's interest in molecular imaging for surgical navigation began during her fellowship at UCSD where she collaborated with Dr. Roger Tsien (1952-2016), Nobel Laureate, Chemistry 2008. She has been awarded the Presidential Early Career Award for Scientists and Engineers (PECASE, April 2014). The Presidential Award is the highest honor bestowed by the US government on outstanding scientists and engineers beginning their independent careers.

DEVICE COLOR ADVANCES AND QUESTIONS
Moderator: Scott Daly, Dolby Laboratories (United States) / **Session Chair:** Sophie Triantaphillidou, University of Westminster (United Kingdom)
13:15 – 14:35

13:15   COLOR-323
What if colorimetry does not work, *Alessandro Rizzi, Università degli Studi di Milano (Italy)*

13:35   COLOR-324

Optimization of monochromatic primaries in RGB system: On the specific question of purples, *Lionel Simonot[1], Philippe Colanton[2], and Mathieu Hébert[2]; [1]Université de Poitiers and [2]Universite de Lyon (France)*

13:55   COLOR-325

Colour deceives continually, *Carinna Parraman and Susanne Klein, University of the West of England (United Kingdom)*

14:15   COLOR-348

Image data's hidden assumptions: Consequences in colorimetry and natural scenes, *John McCann, McCann Imaging (United States)*

DISPLAY

Moderator: Gabriel Marcu, Apple Inc. (United States) / **Session Chair:** Scott Daly, Dolby Laboratories (United States)
18:15 – 19:15

18:15   COLOR-326

Image quality comparison between LCD and OLED display, *Garam Seong, Youngju Lee, and Youngshin Kwak, Ulsan National Institute of Science and Technology (Republic of Korea)*

18:35   COLOR-327

The effect of ambient lighting on the preferred color temperature of television, *YeSeul Baek[1], Hyesun Han[1], Youngshin Kwak[1], Jae Sung Park[2], Junhee Woc[2], Jiman Kim[2], and Seongwoon Jung[2]; [1]Ulsan National Institute of Science and Technology and [2]Samsung Electronics (Republic of Korea)*

18:55   COLOR-223

Estimating spectral sensitivities of a smartphone camera, *Shoji Tominaga[1,2], Shogo Nishi[3], and Ryo Ohtera[4]; [1]Norwegian University of Science and Technology (Norway), [2]Nagano University (Japan), [3]Osaka Electrc-Communication University (Japan), and [4]Kobe Institute of Computing (Japan)*

COLOR AND VISION

Moderator: Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States) / **Session Chair:** Shoji Tominaga, Norwegian University of Science and Technology (Norway) and Nagano University (Japan)
19:45 – 20:45

19:45   COLOR-307

Color discrimination experiments using metameric ipRGC stimuli, *Masaya Ohtsu, Akihiro Kurata, and Keita Hirai, Chiba University (Japan)*

20:05   COLOR-308

Examining spatial attributes for color deficient observers, *Reiner Eschbach[1,2] and Peter Nussbaum[1]; [1]Norwegian University of Science and Technology (Norway) and [2]Monroe Community College (United States)*

20:25   COLOR-309

Application of a new color universal design method based on the color appearance of dichromats to a campus map, *Satoshi Hano[1], Shoji Sunaga[1], and Maya Nakamuta[2]; [1]Kyushu University and [2]MED / Environmental Graphic Design (Japan)*