

# **IS&T International Symposium on Electronic Imaging (EI 2022)**

Color Imaging XXVII: Displaying,  
Processing, Hardcopy, Applications

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# Color Imaging XXVII: Displaying, Processing, Hardcopy, and Applications

## MONDAY 17 JANUARY 2022

### PLENARY: Quanta Image Sensors: Counting Photons Is the New Game in Town

10:00 – 11:10

Eric R. Fossum, Dartmouth College (United States)

The Quanta Image Sensor (QIS) was conceived as a different image sensor—one that counts photoelectrons one at a time using millions or billions of specialized pixels read out at high frame rate with computation imaging used to create gray scale images. QIS devices have been implemented in a CMOS image sensor (CIS) baseline room-temperature technology without using avalanche multiplication, and also with SPAD arrays. This plenary details the QIS concept, how it has been implemented in CIS and in SPADs, and what the major differences are. Applications that can be disrupted or enabled by this technology are also discussed, including smartphone, where CIS-QIS technology could even be employed in just a few years.

*Eric R. Fossum is best known for the invention of the CMOS image sensor “camera-on-a-chip” used in billions of cameras. He is a solid-state image sensor device physicist and engineer, and his career has included academic and government research, and entrepreneurial leadership. At Dartmouth he is a professor of engineering and vice provost for entrepreneurship and technology transfer. Fossum received the 2017 Queen Elizabeth Prize from HRH Prince Charles, considered by many as the Nobel Prize of Engineering “for the creation of digital imaging sensors,” along with three others. He was inducted into the National Inventors Hall of Fame, and elected to the National Academy of Engineering among other honors including a recent Emmy Award. He has published more than 300 technical papers and holds more than 175 US patents. He co-founded several startups and co-founded the International Image Sensor Society (IIS), serving as its first president. He is a Fellow of IEEE and OSA.*

## TUESDAY 18 JANUARY 2022

### Color Management I

**Session Chairs:** Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States) and Gabriel Marcu, Apple Inc (United States)

10:00 – 11:20

10:00

N/A

**Estimating spectral reflectances using mobile phone cameras,** Shoji Tominaga<sup>1,2</sup>, Shogo Nishi<sup>3</sup>, and Ryo Ohtera<sup>4</sup>; <sup>1</sup>Norwegian University of Science and Technology (Norway), <sup>2</sup>Nagano University (Japan), <sup>3</sup>Osaka Electro-Communication University (Japan), and <sup>4</sup>Kobe Institute of Computing (Japan)

10:20

COLOR-140

**Non-standard colorimetry in ICC colour management,** Peter Nussbaum, Milan Kresović, and Phil Green, Norwegian University of Science and Technology (Norway)

10:40

COLOR-141

**Camera response function assessment in multispectral HDR imaging,** Majid Ansari-Asl, Jean-Baptiste Thomas, and Jon Yngve Hardeberg, Norwegian University of Science and Technology (Norway)

11:00

COLOR-142

**Problems in image target-based color correction,** Gabriele Simone<sup>1</sup>, Marco Gaiani<sup>2</sup>, Andrea Bellabeni<sup>2</sup>, and Alessandro Rizzi<sup>1</sup>; <sup>1</sup>Università degli Studi di Milano and <sup>2</sup>University of Bologna (Italy)

### AI Applications for Color

**Session Chair:** Jan Allebach, Purdue University (United States)

11:50 – 13:10

11:50

COLOR-156

**Effect of hue shift towards robustness of convolutional neural networks,** Kanjar De<sup>1,2</sup> and Marius Pedersen<sup>2</sup>; <sup>1</sup>Lulea University of Technology (Sweden) and <sup>2</sup>Norwegian University of Science and Technology (Norway)

12:10

COLOR-157

**Deep learning approach for classifying contamination levels with limited samples**, Min Zhao<sup>1</sup>, Susana Diaz-Amaya<sup>1,2</sup>, Amanda J. Deering<sup>1</sup>, Lia Stanciu<sup>1</sup>, George T.-C. Chiu<sup>1</sup>, and Jan Allebach<sup>1</sup>; <sup>1</sup>Purdue University and <sup>2</sup>Bayer at Convergence - Bayer Crop Science (United States)

12:30

COLOR-158

**Mimicking DBS halftoning via a deep learning approach**, Baekdu Choi and Jan P. Allebach, Purdue University (United States)

12:50

COLOR-159

**Improvements to color image and machine learning based thin-film nitrate sensor performance prediction: New texture features, repeated cross-validation, and auto-tuning of hyperparameters**, Xihui Wang, Jan Allebach, George T.-C. Chiu, Ali Shakouri, and Ye Mi, Purdue University (United States)

## Color Management II

**Session Chairs:** Phil Green, Norwegian University of Science and Technology (NTNU) (Norway) and Shoji Tominaga, Norwegian University of Science and Technology (Norway) and Nagano University (Japan) (Japan)

19:15 – 19:55

19:15

COLOR-180

**An exploration of color reproduction for inkjet FDM color 3D printing**, Piyarat Silapasuphakornwong<sup>1</sup>, Chulapong Panichkriangkrai<sup>2</sup>, Parinya Punpongsonon<sup>3</sup>, Masahiro Suzuki<sup>4</sup>, and Kazutake Uehira<sup>1</sup>; <sup>1</sup>Kanagawa Institute of Technology (Japan), <sup>2</sup>Chulalongkorn University (Thailand), <sup>3</sup>Osaka University (Japan), and <sup>4</sup>Seisen University (Japan)

19:35

COLOR-181

**Considering chromatic adaptation in camera white balance**, Minchen Wei<sup>1</sup>, Yiqian Li<sup>1</sup>, and Xiandou Zhang<sup>2</sup>; <sup>1</sup>The Hong Kong Polytechnic University (Hong Kong) and <sup>2</sup>Huawei Tech (China)

## WEDNESDAY 19 JANUARY 2022

### PLENARY: In situ Mobility for Planetary Exploration: Progress and Challenges

10:00 – 11:15

**Larry Matthies, Jet Propulsion Laboratory (United States)**

This year saw exciting milestones in planetary exploration with the successful landing of the Perseverance Mars rover, followed by its operation and the successful technology demonstration of the Ingenuity helicopter, the first heavier-than-air aircraft ever to fly on another planetary body. This plenary highlights new technologies used in this mission, including precision landing for Perseverance, a vision coprocessor, new algorithms for faster rover traverse, and the ingredients of the helicopter. It concludes with a survey of challenges for future planetary mobility systems, particularly for Mars, Earth's moon, and Saturn's moon, Titan.

Larry Matthies received his PhD in computer science from Carnegie Mellon University (1989), before joining JPL, where he has supervised the Computer Vision Group for 21 years, the past two coordinating internal technology investments in the Mars office. His research interests include 3-D perception, state estimation, terrain classification, and dynamic scene analysis for autonomous navigation of unmanned vehicles on Earth and in space. He has been a principal investigator in many programs involving robot vision and has initiated new technology developments that impacted every US Mars surface mission since 1997, including visual navigation algorithms for rovers, map matching algorithms for precision landers, and autonomous navigation hardware and software architectures for rotorcraft. He is a Fellow of the IEEE and was a joint winner in 2008 of the IEEE's Robotics and Automation Award for his contributions to robotic space exploration.

## Material Appearance I

**Session Chairs:** Mathieu Hebert, Université Jean Monnet de Saint Etienne (France) and Lionel Simonot, Université de Poitiers (France)

12:40 – 13:20

12:40

COLOR-221

**Light scattering in translucent layers: Angular distribution and internal reflections at flat interfaces**, Arthur Gautheron<sup>1,2</sup>, Raphael Clerc<sup>3,4</sup>, Vincent Duveiller<sup>3,4</sup>, Lionel Simonot<sup>5</sup>, Bruno Montcel<sup>1,2</sup>, and Mathieu Hebert<sup>3,4</sup>; <sup>1</sup>CREATIS, <sup>2</sup>Université Claude Bernard Lyon 1, <sup>3</sup>Université Jean Monnet de Saint Etienne, <sup>4</sup>Institut d'Optique Graduate School, and <sup>5</sup>University de Poitiers (France)

13:00

COLOR-222

**Exploring the role of caustics in translucency perception — An eye tracking approach**, Davit Gigilashvili, Aditya Sole, Shaikat Deb Nath, and Marius Pedersen, Norwegian University of Science and Technology (Norway)

## Imaging I

**Session Chairs:** Vien Cheung, University of Leeds (United Kingdom) and Alessandro Rizzi, Università degli Studi di Milano (Italy)

**13:55 – 14:35**

13:55

N/A

**Smartphones' skin colour reproduction analysis for neonatal jaundice detection (JIST-first)**, Mekides A. Abebe<sup>1</sup>, Jon Yngve Hardeberg<sup>1</sup>, and Gunnar Vartdal<sup>2</sup>; <sup>1</sup>Norwegian University of Science and Technology and <sup>2</sup>Picterus AS (Norway)

14:15

COLOR-234

**Motion detection in a color video sequence with an application to monitoring a baby**, Yang Yan, Purdue University (United States)

## Appearance and Perception I

**Session Chairs:** John McCann, McCann Imaging (United States) and Hyeon-Jeong Suk, Korea Advanced Institute of Science and Technology (KAIST) (Republic of Korea)

**18:20 – 19:00**

18:20

COLOR-245

**A measurement of the overall vividness of a color image based on RGB color model**, Tieling Chen, University of South Carolina (United States)

18:40

COLOR-246

**Experimental methods to investigate time-course of chromatic adaptation**, Seonyoung Yoon<sup>1</sup>, Youngshin Kwak<sup>1</sup>, and Hyosun Kim<sup>2</sup>; <sup>1</sup>Ulsan National Institute of Science and Technology and <sup>2</sup>Samsung Display Co., Ltd. (Republic of Korea)

## Material Appearance II

**Session Chairs:** Mathieu Hebert, Université Jean Monnet de Saint Etienne (France) and Ingeborg Tastl, HP-Labs (United States)

**19:15 – 20:15**

19:15

COLOR-252

**Modeling the 3D shape of a fingernail and pre-distorting an image to be printed on the fingernail to yield the correct appearance**, Marshia A. Seto<sup>1</sup>, Rain Guo<sup>2</sup>, White He<sup>2</sup>, Davi He<sup>2</sup>, George T.-C. Chiu<sup>1</sup>, and Jan P. Allebach<sup>1</sup>; <sup>1</sup>Purdue University (United States) and <sup>2</sup>SunValley (China)

19:35

N/A

**Glossy appearance editing for heterogeneous material objects (JIST-first)**, Yusuke Manabe, Midori Tanaka, and Takahiko Horiuchi, Chiba University (Japan)

## THURSDAY 20 JANUARY 2022

### Imaging II

**Session Chairs:** Alessandro Rizzi, Università degli Studi di Milano (Italy) and Sophie Triantaphillidou, University of Westminster (United Kingdom)

**10:00 – 11:00**

10:00

COLOR-259

**Measuring colorant fading within raster regions of printed scanned customer content using a novel unsupervised clustering method**, Runzhe Zhang<sup>1</sup>, Yousun Bang<sup>2</sup>, Minki Cho<sup>2</sup>, Mark Shaw<sup>3</sup>, and Jan P. Allebach<sup>1</sup>; <sup>1</sup>Purdue University (United States), <sup>2</sup>HP Printing Korea Co., Ltd. (Republic of Korea), and <sup>3</sup>HP Inc. (United States)

10:20

N/A

**Colorization of monochrome night vision videos for a baby monitor based on a reference daylight image of the same scene**, Yang Yan, Purdue University (United States)

10:40

COLOR-261

**Image segmentation based on content-color-dependent screening (CCDS) using U-net**, Altyngul Jumabayeva and Adnan Yazici, Nazarbayev University (Kazakhstan)

## Print I

**Session Chairs:** Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States) and Gabriel Marcu, Apple Inc (United States)

**11:35 – 12:35**

11:35

COLOR-277

**Printer spectral color characterization adjustment for change in substrates,** Anastasiia Gudzenchuk<sup>1</sup>, Phil Green<sup>2</sup>, and Hans Don<sup>3</sup>; <sup>1</sup>Norwegian University of Science and Technology (Norway), <sup>2</sup>London College of Communication (United Kingdom), and <sup>3</sup>Wageningen University & Research (the Netherlands)

11:55

N/A

**Structure-aware halftoning using the iterative method controlling the dot placement (JIST-first),** Fereshteh Abedini<sup>1</sup>, Sasan Gooran<sup>1</sup>, Vlado Kitanovski<sup>2</sup>, and Daniel Nyström<sup>1</sup>; <sup>1</sup>Linköping University (Sweden) and <sup>2</sup>Norwegian University of Science and Technology (Norway)

12:15

COLOR-279

**Improving an inkjet printer: Removing stray-dots by constraining error diffusion in highlight regions,** Sige Hu<sup>1</sup>, George T.-C. Chiu<sup>1</sup>, Davi He<sup>2</sup>, Rain Guo<sup>2</sup>, White He<sup>2</sup>, and Jan P. Allebach<sup>1</sup>; <sup>1</sup>Purdue University (United States) and <sup>2</sup>SunValley Tek (China)

## Print II

**Session Chairs:** Mathieu Hebert, Université Jean Monnet de Saint Etienne (France) and Gabriel Marcu, Apple Inc (United States)

**13:00 – 14:00**

13:00

COLOR-284

**Developing a gamut mapping method for a novel inkjet printer,** Baekdu Choi<sup>1</sup>, Sige Hu<sup>1</sup>, Rain Guo<sup>2</sup>, White He<sup>2</sup>, Davi He<sup>2</sup>, George T.-C. Chiu<sup>1</sup>, and Jan P. Allebach<sup>1</sup>; <sup>1</sup>Purdue University (United States) and <sup>2</sup>Sunvalley Tek (China)

13:20

COLOR-285

**Measuring margin and skew errors in scanned printed customer content,** Runzhe Zhang<sup>1</sup>, Ki-Youn Lee<sup>2</sup>, Yousun Bang<sup>2</sup>, Mark Shaw<sup>3</sup>, and Jan P. Allebach<sup>1</sup>; <sup>1</sup>Purdue University (United States), <sup>2</sup>HP Printing Korea Co., Ltd. (Republic of Korea), and <sup>3</sup>HP Inc. (United States)

13:40

COLOR-286

**Measuring CMYK color plane misregistration from scanned printed customer content image,** Yi Yang<sup>1</sup>, Ki-Youn Lee<sup>2</sup>, Yousun Bang<sup>2</sup>, Mark Shaw<sup>3</sup>, and Jan P. Allebach<sup>1</sup>; <sup>1</sup>Purdue University (United States), <sup>2</sup>HP Printing Korea Co., Ltd. (Republic of Korea), and <sup>3</sup>HP Inc. (United States)

## TUESDAY 25 JANUARY 2022

### PLENARY: Physics-based Image Systems Simulation

10:00 – 11:00

**Joyce Farrell, Stanford Center for Image Systems Engineering, Stanford University, CEO and Co-founder, ImagEval Consulting (United States)**

Three quarters of a century ago, visionaries in academia and industry saw the need for a new field called photographic engineering and formed what would become the Society for Imaging Science and Technology (IS&T). Thirty-five years ago, IS&T recognized the massive transition from analog to digital imaging and created the Symposium on Electronic Imaging (EI). IS&T and EI continue to evolve by cross-pollinating electronic imaging in the fields of computer graphics, computer vision, machine learning, and visual perception, among others. This talk describes open-source software and applications that build on this vision. The software combines quantitative computer graphics with models of optics and image sensors to generate physically accurate synthetic image data for devices that are being prototyped. These simulations can be a powerful tool in the design and evaluation of novel imaging systems, as well as for the production of synthetic data for machine learning applications.

*Joyce Farrell is a senior research associate and lecturer in the Stanford School of Engineering and the executive director of the Stanford Center for Image Systems Engineering (SCIEN). Joyce received her BS from the University of California at San Diego and her PhD from Stanford University. She was a postdoctoral fellow at NASA Ames Research Center, New York University, and Xerox PARC, before joining the research staff at Hewlett Packard in 1985. In 2000 Joyce joined Shutterfly, a startup company specializing in online digital photofinishing, and in 2001 she formed ImagEval Consulting, LLC, a company specializing in the development of software and design tools for image systems simulation. In 2003, Joyce returned to Stanford University to develop the SCIEN Industry Affiliates Program.*

## PANEL: The Brave New World of Virtual Reality

11:00 – 12:00

Advances in electronic imaging, computer graphics, and machine learning have made it possible to create photorealistic images and videos. In the future, one can imagine that it will be possible to create a virtual reality that is indistinguishable from real-world experiences. This panel discusses the benefits of this brave new world of virtual reality and how we can mitigate the risks that it poses. The goal of the panel discussion is to showcase state-of-the-art synthetic imagery, learn how this progress benefits society, and discuss how we can mitigate the risks that the technology also poses. After brief demos of the state-of-the-art, the panelists will discuss: creating photorealistic avatars, Project Shoah, and digital forensics.

*Panel Moderator: Joyce Farrell, Stanford Center for Image Systems Engineering, Stanford University, CEO and Co-founder, ImagEval Consulting (United States)*

*Panelist: Matthias Neissner, Technical University of Munich (Germany)*

*Panelist: Paul Debevec, Netflix, Inc. (United States)*

*Panelist: Hany Farid, University of California, Berkeley (United States)*

## Invited: Postmondrianism

**Session Chairs:** Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States) and Gabriel Marcu, Apple Inc (United States)

12:50 – 13:30

N/A

**Postmondrianism (Invited),** *Scott Daly, Dolby Laboratories, Inc. (United States)*

## Appearance and Perception II

**Session Chairs:** Phil Green, Norwegian University of Science and Technology (NTNU) (Norway) and John McCann, McCann Imaging (United States)

13:55 – 14:35

13:55

COLOR-363

**Initial findings on changing the background in pseudo-isochromatic charts,** *Reiner Eschbach<sup>1,2</sup> and Peter Nussbaum<sup>1</sup>;*

*<sup>1</sup>Norwegian University of Science and Technology (Norway) and <sup>2</sup>Monroe Community College (United States)*

14:15

COLOR-364

**Similarity between two color areas,** *Tieling Chen, University of South Carolina (United States)*

## Beauty

**Session Chairs:** Jan Allebach, Purdue University (United States) and Scott Daly, Dolby Laboratories, Inc. (United States)

18:20 – 19:00

18:20

COLOR-373

**A color image analysis tool to help users choose a makeup foundation color,** *Yafei Mao<sup>1</sup>, Christopher Merkle<sup>2</sup>, and Jan P.*

*Allebach<sup>1</sup>; <sup>1</sup>Purdue University and <sup>2</sup>MIME Inc. (United States)*

18:40

COLOR-374

**New image processing algorithm towards more realistic expression on hair coloring,** *Boram Kim and Hyeon-Jeong Suk, Korea Advanced Institute of Science and Technology (KAIST) (Republic of Korea)*

## Applications

**Session Chairs:** Scott Daly, Dolby Laboratories, Inc. (United States) and Reiner Eschbach, Norwegian University of Science and Technology (Norway) and Monroe Community College (United States)

19:15 – 20:15

19:15

COLOR-375

**Printed paper-based devices for detection of food-borne contaminants: New device design and new colorimetric image analysis methods,** *Qiyue Liang, Min Zhao, Ana M. Ulloa Gomez, George T.-C. Chiu, Lia Stanciu, Amanda J. Deering, and Jan P.*

*Allebach, Purdue University (United States)*

19:35

COLOR-376

**Prototyping of low-cost color enhancement lighting using multicolor LEDs**, *Camille Kabore<sup>1</sup>, Masaru Tsuchida<sup>2</sup>, Ikunori Suzuki<sup>1</sup>, Satoshi Sugaya<sup>1</sup>, Akisato Kimura<sup>2</sup>, and Noboru Harada<sup>2</sup>*; <sup>1</sup>Institute of Technologists and <sup>2</sup>NTT Communication Science Laboratories (Japan)

19:55

COLOR-377

**Pokemon color adjustments for augmented reality contents**, *Taesu Kim, Donggun Lee, and Hyeon-jeong Suk*, Korea Advanced Institute of Science and Technology (KAIST) (Republic of Korea)