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PROCEEDINGS

IS&T International Symposium on

# Electronic Imaging

SCIENCE AND TECHNOLOGY

13 January 2019 – 17 January 2019 • Burlingame, CA, USA

## Computational Imaging XVII

Editors: **Charles A. Bouman,** Purdue Univ. (United States),
**Gregery T. Buzzard**, Purdue Univ. (United States),
**Robert Stevenson,** Univ. of Notre Dame (United States)

These papers represent the program of Electronic Imaging 2019,
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# Computational Imaging XVII

## Conference overview

More than ever before, computers and computation are critical to the image formation process. Across diverse applications and fields, remarkably similar imaging problems appear, requiring sophisticated mathematical, statistical, and algorithmic tools. This conference focuses on imaging as a marriage of computation with physical devices. It emphasizes the interplay between mathematical theory, physical models, and computational algorithms that enable effective current and future imaging systems. Contributions to the conference are solicited on topics ranging from fundamental theoretical advances to detailed system-level implementations and case studies.

## Special Session

This year Computational Imaging hosts a special session on AI for Reconstruction and Sensing. Presentations will cover such topics as advances in AI in CT reconstruction, multi-target tracking, and more, presented by researchers from academia, national laboratories and industry.


Conference Chairs: **Charles A. Bouman,** Purdue University (United States), **Gregery T. Buzzard,** Purdue University (United States), and **Robert Stevenson,** University of Notre Dame (United States)

Program Committee: **Ken D. Sauer,** University of Notre Dame (United States)

# COMPUTATIONAL IMAGING XVII

## Monday January 14, 2019

### AI for Reconstruction and Sensing I

**9:10 – 10:10 am**
Harbour AB

COIMG-125
**KEYNOTE: Learning to make images,** *W. Clem Karl, Boston University (United States)*

*W. Clem Karl received his PhD in electrical engineering and computer science (1991) from the Massachusetts Institute of Technology, Cambridge, where he also received his SM, EE, and SB. He held the position of staff research scientist with the Brown-Harvard-MIT Center for Intelligent Control Systems and the MIT Laboratory for Information and Decision Systems from 1992 to 1994. He joined the faculty of Boston University in 1995, where he is currently professor of electrical and computer engineering and biomedical engineering. Karl is currently the Editor-in-Chief of the* IEEE Transactions on Image Processing. *He is a member of the Board of Governors of the IEEE Signal Processing Society, the Signal Processing Society Conference Board, the IEEE Transactions on Medical Imaging Steering Committee, and the Technical Committee Review Board. He co-organized two special sessions of the 2012 IEEE Statistical Signal Processing Workshop, one on Challenges in High-Dimensional Learning and one on Statistical Signal Processing and the Engineering of Materials. In 2011 he was a co-organizer of a workshop on Large Data Sets in Medical Informatics as part of the Institute for Mathematics and Its Applications Thematic Year on the Mathematics of Information. He served as an Associate Editor of the* IEEE Transactions on Image Processing *and was the General Chair of the 2009 IEEE International Symposium on Biomedical Imaging. He is a past member of the IEEE Image, Video, and Multidimensional Signal Processing Technical Committee and is a current member of the IEEE Biomedical Image and Signal Processing Technical Committee. Karl's research interests are in the areas of multidimensional statistical signal and image processing, estimation, inverse problems, geometric estimation, and applications to problems ranging from biomedical signal and image processing to synthetic aperture radar.*

10:10 – 10:50 am Coffee Break

### AI for Reconstruction and Sensing II

**10:50 am – 12:30 pm**
Harbour AB

10:50 COIMG-126
**Light field image reconstruction with generative adversarial networks (Invited),** *Hector Santos-Villalobos, David Bolme, and David Cornett III, Oak Ridge National Laboratory (United States)*

11:10 COIMG-127
**Multi-target tracking with an event-based vision sensor and the GMPHD filter (Invited),** *Benjamin Foster[1], Dong Hye Ye[2], and Charles Bouman[3]; [1]Lockheed Martin, [2]Marquette University, and [3]Purdue University (United States)*

11:30 COIMG-128
**4D reconstruction using consensus equilibrium (Invited),** *Soumendu Majee[1], Thilo Balke[1], Craig Kemp[2], Gregery Buzzard[1], and Charles Bouman[1]; [1]Purdue University and [2]Eli Lilly and Company (United States)*

11:50 COIMG-129
**Joint direct deep learning for one-sided ultrasonic non-destructive evaluation (Invited),** *Hani Almansouri[1], Singanallur Venkatakrishnan[2], Charles Bouman[1], and Hector Santos-Villalobos[2]; [1]Purdue University and [2]Oak Ridge National Laboratory (United States)*

12:10 COIMG-130
**Modeling long range features from serial section imagery of continuous fiber reinforced composites (Invited),** *Sam Sherman[1], Jeffrey Simmons[2], and Craig Przybyla[2]; [1]Air Force Life Cycle Management Center and [2]Air Force Research Laboratory (United States)*

12:30 – 2:00 pm Lunch

### Monday Plenary

**2:00 – 3:00 pm**
Grand Peninsula Ballroom D

**Autonomous Driving Technology and the OrCam MyEye,** *Amnon Shashua, President and CEO, Mobileye, an Intel Company, and senior vice president, Intel Corporation (United States)*

The field of transportation is undergoing a seismic change with the coming introduction of autonomous driving. The technologies required to enable computer driven cars involves the latest cutting edge artificial intelligence algorithms along three major thrusts: Sensing, Planning and Mapping. Shashua will describe the challenges and the kind of computer vision and machine learning algorithms involved, but will do that through the perspective of Mobileye's activity in this domain. He will then describe how OrCam leverages computer vision, situation awareness and language processing to enable blind and visually impaired to interact with the world through a miniature wearable device.

*Prof. Amnon Shashua holds the Sachs chair in computer science at the Hebrew University of Jerusalem. His field of expertise is computer vision and machine learning. Shashua has founded three startups in the computer vision and machine learning fields. In 1995 he founded CogniTens that specializes in the area of industrial metrology and is today a division of the Swedish Corporation Hexagon. In 1999 he cofounded Mobileye with his partner Ziv Aviram. Mobileye develops system-on-chips and computer vision algorithms for driving assistance systems and is developing a platform for autonomous driving to be launched in 2021. Today, approximately 32 million cars rely on Mobileye technology to make their vehicles safer to drive. In August 2014, Mobileye claimed the title for largest Israeli IPO ever, by raising $1B at a market cap of $5.3B. In August 2017, Mobileye became an Intel company in the largest Israeli acquisition deal ever of $15.3B. Today, Shashua is the president and CEO of Mobileye and a senior vice president of Intel Corporation. In 2010 Shashua co-founded OrCam which harnesses computer vision and artificial intelligence to assist people who are visually impaired or blind.*

3:00 – 3:30 pm Coffee Break

**Panel: Sensing and Perceiving for Autonomous Driving** JOINT SESSION

**3:30 – 5:30 pm**
Grand Peninsula Ballroom D

*This session is jointly sponsored by the EI Steering Committee*

**Moderator:** Dr. Wende Zhang, technical fellow, General Motors
**Panelists:**
Dr. Amnon Shashua, professor of computer science, Hebrew University; president and CEO, Mobileye, an Intel Company, and senior vice president, Intel Corporation
Dr. Boyd Fowler, CTO, OmniVision Technologies
Dr. Christoph Schroeder, head of autonomous driving N.A., Mercedes-Benz R&D Development North America, Inc.
Dr. Jun Pei, CEO and co-founder, Cepton Technologies Inc.

*Driver assistance and autonomous driving rely on perceptual systems that combine data from many different sensors, including camera, ultrasound, radar and lidar. The panelists will discuss the strengths and limitations of different types of sensors and how the data from these sensors can be effectively combined to enable autonomous driving.*

5:00 – 6:00 pm All-Conference Welcome Reception

## Tuesday January 15, 2019

7:15 – 8:45 am Women in Electronic Imaging Breakfast

### Medical and Scientific Imaging

**8:50 – 10:10 am**
Harbour AB

8:50 COIMG-131
**Simultaneous denoising and deblurring for full-field tomography,** *Daniel Ching and Doğa Gürsoy, Argonne National Laboratory (United States)*

9:10 COIMG-132
**Autocorrelation-based, passive, non-contact, photoplethysmography: Computationally-efficient, noise-tolerant, extraction of heart rates from video,** *Chadwick Parrish, Kevin Donohue, and Henry Dietz, University of Kentucky (United States)*

9:30 COIMG-133
**Joint density map and continuous angular refinement in Cryo-EM,** *Mona Zehni[1], Laurène Donati[2], Emmanuel Soubies[2], Zhizhen Zhao[1], Minh Do[1], and Michael Unser[2]; [1]University of Illinois at Urbana-Champaign (United States) and [2]École Polytechnique Fédérale de Lausanne (EPFL) (Switzerland)*

9:50 COIMG-134
**Point source localization from projection lines using rotation invariant features,** *Mona Zehni, Shuai Huang, Ivan Dokmanic, and Zhizhen Zhao, University of Illinois at Urbana-Champaign (United States)*

10:00 am – 7:00 pm Industry Exhibition

10:10 – 10:40 am Coffee Break

### Image Enhancement via Neural Network

**10:40 – 11:20 am**
Harbour AB

10:40 COIMG-135
**A comparative study on wavelets and residuals in deep super resolution,** *Ruofan Zhou, Fayez Lahoud, Majed El Helou, and Sabine Süsstrunk, École Polytechnique Fédérale de Lausanne (EPFL) (Switzerland)*

11:00 COIMG-136
**GAN based image deblurring using dark channel prior,** *Shuang Zhang, Ada Zhen, and Robert Stevenson, University of Notre Dame (United States)*

### In Situ 3D/4D Image Capture and Analysis

**11:20 am – 12:40 pm**
Harbour AB

11:20 COIMG-137
**Height estimation of biomass sorghum in the field using LiDAR,** *Matthew Waliman and Avideh Zakhor, University of California, Berkeley (United States)*

11:40 COIMG-138
**In situ width estimation of biofuel plant stems,** *Arda Sahiner, Franklin Heng, Adith Balamurugan, and Avideh Zakhor, University of California, Berkeley (United States)*

12:00 COIMG-139
**Vision guided, hyperspectral imaging for standoff trace chemical detection (Invited),** *Raiyan Ishmam[1], Ashish Neupane[1], Shuchin Aeron[1], Eric Miller[1], Mark Witinski[2], Christian Pfluegl[2], Brandt Pein[2], and Romain Blanchard[2]; [1]Tufts University and [2]Pendar Technologies (United States)*

12:20 COIMG-140
**Through the windshield driver recognition (Invited),** *David Cornett III, Grace Nayola, Diane Montez, Alec Yen, Christi Johnson, Seth Baird, Hector Santos-Villalobos, and David Bolme, Oak Ridge National Laboratory (United States)*

12:40 – 2:00 pm Lunch

### Tuesday Plenary

**2:00 – 3:00 pm**
Grand Peninsula Ballroom D

**The Quest for Vision Comfort: Head-Mounted Light Field Displays for Virtual and Augmented Reality,** *Hong Hua, professor of optical sciences, University of Arizona (United States)*

Hong Hua will discuss the high promises and the tremendous progress made recently toward the development of head-mounted displays (HMD) for both virtual and augmented reality displays, developing HMDs that offer uncompromised optical pathways to both digital and physical worlds without encumbrance and discomfort confronts many grand challenges, both from technological perspectives and human factors. She will particularly focus on the recent progress, challenges and opportunities for developing head-mounted light field displays (LF-HMD), which are capable of rendering true 3D synthetic scenes with proper focus cues to stimulate natural eye accommodation responses and address the well-known vergence-accommodation conflict in conventional stereoscopic displays.

*Dr. Hong Hua is a professor of optical sciences at the University of Arizona. With more than 25 years of experience, Hua is widely recognized through academia and industry as an expert in wearable display technologies and optical imaging and engineering in general. Hua's current research focuses on optical technologies enabling advanced 3D displays, especially head-mounted display technologies for virtual reality and augmented reality applications, and microscopic and endoscopic imaging systems for medicine. Hua has published more than 200 technical papers and filed a total of 23 patent applications in her specialty fields, and delivered numerous keynote addresses and invited talks at major conferences and events worldwide. She is an SPIE Fellow and OSA senior member. She was a recipient of NSF Career Award in 2006 and honored as UA Researchers @ Lead Edge in 2010. Hua and her students shared a total of 8 "Best Paper" awards in various IEEE, SPIE and SID conferences. Hua received her PhD in optical engineering from the Beijing Institute of Technology in China (1999). Prior to joining the UA faculty in 2003, Hua was an assistant professor with the University of Hawaii at Manoa in 2003, was a Beckman Research Fellow at the Beckman Institute of University of Illinois at Urbana-Champaign between 1999 and 2002, and was a post-doc at the University of Central Florida in 1999.*

3:00 – 3:30 pm Coffee Break

5:30 – 7:00 pm Symposium Demonstration Session

## Wednesday January 16, 2019

10:00 am – 3:30 pm Industry Exhibition

10:10 – 11:00 am Coffee Break

12:30 – 2:00 pm Lunch

### Wednesday Plenary

**2:00 – 3:00 pm**
Grand Peninsula Ballroom D

**Light Fields and Light Stages for Photoreal Movies, Games, and Virtual Reality,** *Paul Debevec, senior scientist, Google (United States)*

Paul Debevec will discuss the technology and production processes behind "Welcome to Light Fields", the first downloadable virtual reality experience based on light field capture techniques which allow the visual appearance of an explorable volume of space to be recorded and reprojected photorealistically in VR enabling full 6DOF head movement. The lightfields technique differs from conventional approaches such as 3D modelling and photogrammetry. Debevec will discuss the theory and application of the technique. Debevec will also discuss the Light Stage computational illumination and facial scanning systems which use geodesic spheres of inward-pointing LED lights as have been used to create digital actor effects in movies such as Avatar, Benjamin Button, and Gravity, and have recently been used to create photoreal digital actors based on real people in movies such as Furious 7, Blade Runner: 2049, and Ready Player One. The lighting reproduction process of light stages allows omnidirectional lighting environments captured from the real world to be accurately reproduced in a studio, and has recently be extended with multispectral capabilities to enable LED lighting to accurately mimic the color rendition properties of daylight, incandescent, and mixed lighting environments. They have also recently used their full-body light stage in conjunction with natural language processing and automultiscopic video projection to record and project interactive conversations with survivors of the World War II Holocaust.

*Paul Debevec is a senior scientist at Google VR, a member of Google VR's Daydream team, and adjunct research professor of computer science in the Viterbi School of Engineering at the University of Southern California, working within the Vision and Graphics Laboratory at the USC Institute for Creative Technologies. Debevec's computer graphics research has been recognized with ACM SIGGRAPH's first Significant New Researcher Award (2001) for "Creative and Innovative Work in the Field of Image-Based Modeling and Rendering", a Scientific and Engineering Academy Award (2010) for "the design and engineering of the Light Stage capture devices and the image-based facial rendering system developed for character relighting in motion pictures" with Tim Hawkins, John Monos, and Mark Sagar, and the SMPTE Progress Medal (2017) in recognition of his achievements and ongoing work in pioneering techniques for illuminating computer-generated objects based on measurement of real-world illumination and their effective commercial application in numerous Hollywood films. In 2014, he was profiled in* The New Yorker *magazine's "Pixel Perfect: The Scientist Behind the Digital Cloning of Actors" article by Margaret Talbot.*

3:00 – 3:30 pm Coffee Break

## Light Field Imaging and Display — Joint Session

Session Chair: Gordon Wetzstein, Stanford University (United States)

**3:30 – 5:30 pm**
Grand Peninsula Ballroom D

*This session is jointly sponsored by the EI Steering Committee.*

3:30 EISS-706
**Light fields - From shape recovery to sparse reconstruction (Invited),** *Ravi Ramamoorthi, University of California, San Diego (United States)*

*Prof. Ravi Ramamoorthi is the Ronald L. Graham Professor of Computer Science, and Director of the Center for Visual Computing, at the University of California, San Diego. Ramamoorthi received his PhD in computer science (2002) from Stanford University. Prior to joining UC San Diego, Ramamoorthi was associate professor of EECS at the University of California, Berkeley, where he developed the complete graphics curricula. His research centers on the theoretical foundations, mathematical representations, and computational algorithms for understanding and rendering the visual appearance of objects, exploring topics in frequency analysis and sparse sampling and reconstruction of visual appearance datasets a digital data-driven visual appearance pipeline; light-field cameras and 3D photography; and physics-based computer vision. Ramamoorthi is an ACM Fellow for contributions to computer graphics rendering and physics-based computer vision, awarded Dec. 2017, and an IEEE Fellow for contributions to foundations of computer graphics and computer vision, awarded Jan. 2017.*

4:10 EISS-707
**The beauty of light fields (Invited),** *David Fattal, LEIA Inc. (United States)*

*Dr. David Fattal is co-founder and CEO at LEIA Inc., where he is in charge of bringing their mobile holographic display technology to market. Fattal received his PhD in physics from Stanford University (2005). Prior to founding LEIA Inc., Fattal was a research scientist with HP Labs, HP Inc. At LEIA Inc., the focus is on immersive mobile, with screens that come alive in richer, deeper, more beautiful ways. Flipping seamlessly between 2D and lightfields, mobile experiences become truly immersive: no glasses, no tracking, no fuss. Alongside new display technology LEIA Inc. is developing Leia Loft™ — a whole new canvas.*

4:30 EISS-708
**Light field insights from my time at Lytro (Invited),** *Kurt Akeley, Google Inc. (United States)*

*Dr. Kurt Akeley is a distinguished engineer at Google Inc. Akeley received his PhD in stereoscopic display technology from Stanford University (2004), where he implemented and evaluated a stereoscopic display that passively (e.g., without eye tracking) produces nearly correct focus cues. After Stanford, Akeley worked with OpenGL at NVIDIA Incorporated, was a principal researcher at Microsoft Corporation, and a consulting professor at Stanford University. In 2010, he joined Lytro Inc. as CTO. During his seven-year tenure as Lytro's CTO, he guided and directly contributed to the development of two consumer light-field cameras and their related display systems, and also to a cinematic capture and processing service that supported immersive, six-degree-of-freedom virtual reality playback.*

4:50 EISS-709
**Quest for immersion (Invited),** *Kari Pulli, Stealth Startup (United States)*

*Dr. Kari Pulli has spent two decades in computer imaging and AR at companies such as Intel, NVIDIA and Nokia. Before joining a stealth startup, he was the CTO of Meta, an augmented reality company in San Mateo, heading up computer vision, software, displays, and hardware, as well as the overall architecture of the system. Before joining Meta, he worked as the CTO of the Imaging and Camera Technologies Group at Intel, influencing the architecture of future IPU's in hardware and software. Prior, he was vice president of computational imaging at Light, where he developed algorithms for combining images from a heterogeneous camera array into a single high-quality image. He previously led research teams as a senior director at NVIDIA Research and as a Nokia fellow at Nokia Research, where he focused on computational photography, computer vision, and AR. Pulli holds computer science degrees from the University of Minnesota (BSc), University of Oulu (MSc, Lic. Tech), and University of Washington (PhD), as well as an MBA from the University of Oulu. He has taught and worked as a researcher at Stanford, University of Oulu, and MIT.*

5:10 EISS-710
**Industrial scale light field printing (Invited),** *Matthew Hirsch, Lumii Inc. (United States)*

*Dr. Matthew Hirsch is a co-founder and chief technical officer of Lumii. He worked with Henry Holtzman's Information Ecology Group and Ramesh Raskar's Camera Culture Group at the MIT Media Lab, making the next generation of interactive and glasses-free 3D displays. Hirsch received his bachelors from Tufts University in computer engineering, and his Masters and Doctorate from the MIT Media Lab. Between degrees, he worked at Analogic Corp. as an imaging engineer, where he advanced algorithms for image reconstruction and understanding in volumetric x-ray scanners. His work has been funded by the NSF and the Media Lab consortia, and has appeared in SIGGRAPH, CHI, and ICCP. Hirsch has also taught courses at SIGGRAPH on a range of subjects in computational imaging and display, with a focus on DIY.*

## Computational Imaging XVII Interactive Posters Session

**5:30 – 7:00 pm**
The Grove

*The following works will be presented at the EI 2019 Symposium Interactive Papers Session.*

COIMG-141
**Adaptive loss regression for flexible graph-based semi-supervised embedding,** *Fadi Dornaika and Youssof El Traboulsi, University of the Basque Country (Spain)*

COIMG-142
**An efficient motion correction method for frequency-domain images based on Fast Robust Correlation,** *Yuan Bian[1], Stanley Reeves[1], and Ronald Beyers[2]; [1]Auburn University and [2]Auburn University MRI Research Center (United States)*

COIMG-143
**Compton camera imaging with spherical movement,** *Kiwoon Kwon[1] and Sungwhan Moon[2]; [1]Dongguk University and [2]Kyungpook National University (Republic of Korea)*

# Thursday January 17, 2019

**Medical Imaging - Computational** JOINT SESSION

**8:50 – 10:10 am**
Grand Peninsula Ballroom A

*This medical imaging session is jointly sponsored by: Computational Imaging XVII, Human Vision and Electronic Imaging 2019, and Imaging and Multimedia Analytics in a Web and Mobile World 2019.*

8:50 IMAWM-145
**Smart fetal care,** *Jane You[1], Qin Li[2], Qiaozhu Chen[3], Zhenhua Guo[4], and Hongbo Yang[5]; [1]The Hong Kong Polytechnic University (Hong Kong), [2]Shenzhen Institute of Information Technology (China), [3]Guangzhou Women and Children Medical Center (China), [4]Tsinghua University (China), and [5]Suzhou Institute of Biomedical Engineering and Technology, Chinese Academy of Sciences (China)*

9:10 COIMG-146
**Self-contained, passive, non-contact, photoplethysmography: Real-time extraction of heart rates from live view within a Canon Powershot,** *Henry Dietz, Chadwick Parrish, and Kevin Donohue, University of Kentucky (United States)*

9:30 COIMG-147
**Edge-preserving total variation regularization for dual-energy CT images,** *Sandamali Devadithya and David Castañón, Boston University (United States)*

9:50 COIMG-148
**Fully automated dental panoramic radiograph by using internal mandible curves of dental volumetric CT,** *Sanghun Lee[1], Seongyoun Woo[1], Joonwoo Lee[2], Jaejun Seo[2], and Chulhee Lee[1]; [1]Yonsei University and [2]Dio Implant (Republic of Korea)*

10:10 – 11:00 am Coffee Break

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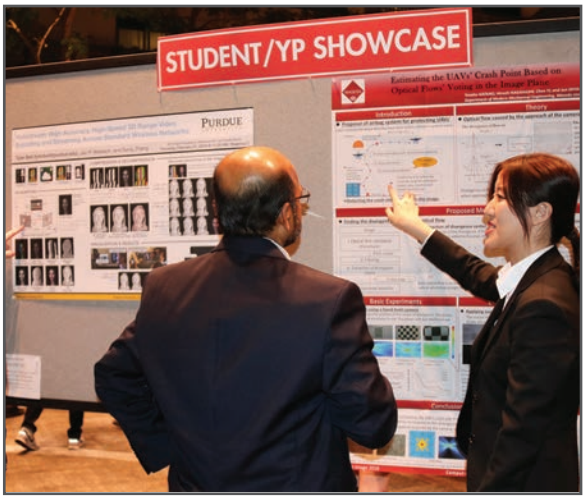


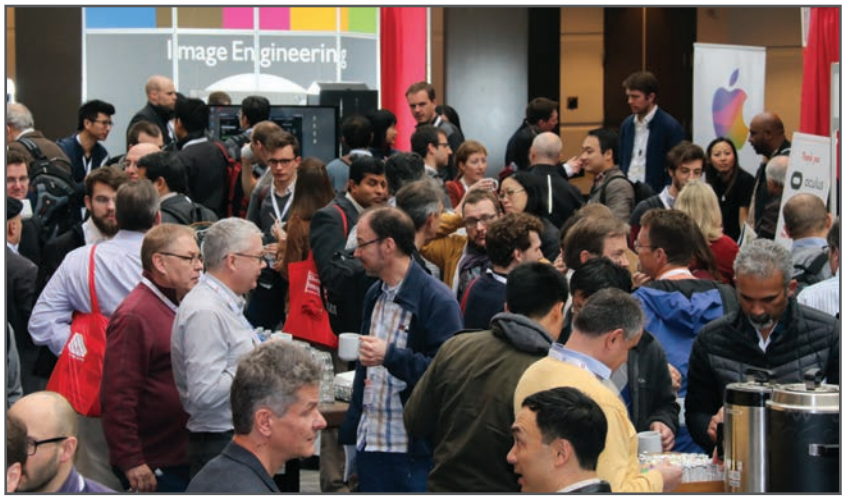


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