PROCEEDINGS

IS&T International Symposium on

Electronic Imaging

SCIENCE AND TECHNOLOGY

#%January 201+ – 1) S`gSck 201+ • Burlingame, CA, USA

Autonomous Vehicles and Machines 201+

Editors: **Patrick Denny,** Valeo (Ireland),
Robin Jenkin, Nvidia Corporation (United States),
Buyue Zhang, Intel Corporation (United States)

Autonomous Vehicles and Machines 2019

Conference overview

Advancements in sensing, computing, imaging processing, and computer vision technologies are enabling unprecedented growth and interest in autonomous vehicles and intelligent machines, from self-driving cars to unmanned drones to personal service robots. These new capabilities have the potential to fundamentally change the way people live, work, commute, and connect with each other and will undoubtedly provoke entirely new applications and commercial opportunities for generations to come.

Successfully launched in 2017, Autonomous Vehicles and Machines (AVM) considers a broad range of topics as it relates to equipping vehicles and machines with the capacity to perceive dynamic environments, inform human participants, demonstrate situational awareness, and make unsupervised decisions on self-navigating. The conference seeks high-quality papers featuring novel research in areas intersecting sensing, imaging, vision and perception with applications including, but not limited to, autonomous cars, ADAS (advanced driver assistance system), drones, robots, and industrial automation. AVM welcomes both academic researchers and industrial experts to join the discussion. In addition to the main technical program, AVM will include interactive sessions / open forum between AVM speakers, committee members and conference participants.

Award

Best Paper Award given to the author(s) of a proceedings paper presented at the conference, selected by the Organizing Committee.

Conference Chairs: **Buyue Zhang,** Apple Inc. (United States), **Patrick Denny,** Valeo (Ireland); and **Robin Jenkin,** NVIDIA Corporation (United States)

Program Committee: **Umit Batur,** Rivian Automotive (United States); **Zhigang Fan,** Apple Inc. (United States); **Ching Hung,** NVIDIA Corporation (United States); **Darnell Moore,** Texas Instruments (United States); **Bo Mu,** Quanergy, Inc. (United States); **Binu Nair,** United Technologies Research Center (United States); **Dietrich Paulus,** Universität Koblenz-Landau (Germany); **Pavan Shastry,** Continental (Germany); **Peter van Beek,** Intel Corporation (United States); **Luc Vincent,** Lyft (United States); **Weibao Wang,** Xmotors. ai (United States); and **Yi Zhang,** Argo AI, LLC (United States)

Conference Sponsor

AutoSens

AVM

AUTONOMOUS VEHICLES AND MACHINES 2019

Monday January 14, 2019

Automotive Image Quality — JOINT SESSION

Session Chairs: Patrick Denny, Valeo (Ireland); Stuart Perry, University of Technology Sydney (Australia); and Peter van Beek, Intel Corporation (United States)

8:50 – 10:10 am
Grand Peninsula Ballroom D

This session is jointly sponsored by: Autonomous Vehicles and Machines 2019, and Image Quality and System Performance XVI.

8:50   AVM-026
Updates on the progress of IEEE P2020 Automotive Imaging Standards Working Group, *Robin Jenkin, NVIDIA Corporation (United States)*

9:10   AVM-027
Signal detection theory and automotive imaging, *Paul Kane, ON Semiconductor (United States)*

9:30   AVM-029
Digital camera characterisation for autonomous vehicles applications, *Paola Iacomussi and Giuseppe Rossi, INRIM (Italy)*

9:50   AVM-030
Contrast detection probability - Implementation and use cases, *Uwe Artmann[1], Marc Geese[2], and Max Gäde[1]; [1]Image Engineering GmbH & Co. KG and [2]Robert Bosch GmbH (Germany)*

10:10 – 10:50 am Coffee Break

Recognition, Detection, and Tracking

Session Chairs: Binu Nair, United Technologies Research Center (UTRC) (United States) and Buyue Zhang, Apple Inc. (United States)

10:50 am – 12:30 pm
Grand Peninsula Ballroom FG

10:50   AVM-031
Hyperspectral shadow detection for semantic road scene analysis, *Christian Winkens, Veronika Adams, and Dietrich Paulus, University of Koblenz-Landau (Germany)*

11:10   AVM-032
Integration of advanced stereo obstacle detection with perspectively correct surround views, *Christian Fuchs and Dietrich Paulus, University of Koblenz-Landau (Germany)*

11:30   AVM-033
Real-time traffic sign recognition using deep network for embedded platforms, *Raghav Nagpal, Chaitanya Krishna Paturu, Vijaya Ragavan, Navinprashath R R, Radhesh Bhat, and Dipanjan Ghosh, PathPartner Technology Pvt. Ltd. (India)*

11:50   AVM-034
From stixels to asteroids: A collision warning system using stereo vision, *Willem Sanberg, Gijs Dubbelman, and Peter de With, Eindhoven University of Technology (the Netherlands)*

12:10   AVM-035
An autonomous drone surveillance and tracking architecture, *Eren Unlu and Emmanuel Zenou, ISAE-SUPAERO (France)*

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

AVM

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

Production and Deployment I

Session Chair: Robin Jenkin, NVIDIA Corporation (United States)
8:50 – 9:50 am
Grand Peninsula Ballroom FG

AVM-036

KEYNOTE: AI and perception for automated driving – From concepts towards production, *Wende Zhang, General Motors (United States)*

Dr. Wende Zhang is currently the Technical Fellow on Sensing Systems at General Motors (GM). Zhang has led GM's Next Generation Perception Systems team, guiding a cross-functional global Engineering and R&D team focused on identifying next generation perception systems for automated driving and active safety since 2010. He was BFO of Lidar Systems (2017) and BFO of Viewing Systems (2014-16) at GM. Zhang's research interests include perception and sensing for automated driving, pattern recognition, computer vision, artificial intelligence, security, and robotics. He established GM's development, execution and sourcing strategy on Lidar systems and components and transferred his research innovation into multiple industry-first applications such as Rear Camera Mirror, Redundant Lane Sensing on MY17 Cadillac Super Cruise, Video Trigger Recording on MY16 Cadillac CT6 and Front Curb Camera System on MY 16 Chevrolet Corvette. Zhang was the technical lead on computer vision and the embedded researcher in the GM-CMU autonomous driving team that won the DARPA Urban Challenge in 2007. He has 75+ US patents, 35+ publications in sensing and viewing systems and received the GM highest technical awards (Boss Kettering Award) 3 times in 2015, 2016, 2017. Zhang has a doctoral degree in electrical and computer engineering from Carnegie Mellon University and an MBA from Indiana University.

Production and Deployment II

Session Chair: Robin Jenkin, NVIDIA Corporation (United States)
9:50 – 10:20 am
Grand Peninsula Ballroom FG

AVM-037

Self-driving cars: Massive deployment of production cars and artificial intelligence evolution (Invited), *Junli Gu, Xmotors.ai (United States)*

10:00 am – 7:00 pm Industry Exhibition

10:10 – 10:50 am Coffee Break

Navigation and Mapping

Session Chairs: Binu Nair, United Technologies Research Center (UTRC) (United States) and Peter van Beek, Intel Corporation (United States)
10:50 am – 12:30 pm
Grand Peninsula Ballroom FG

10:50   AVM-038
HD map for every mobile robot: A novel, accurate, efficient mapping approach based on 3D reconstruction and deep learning, *Chang Yuan, Foresight AI Inc. (United States)*

11:10   AVM-039
Pattern and frontier-based, efficient and effective exploration of autonomous mobile robots in unknown environments, *Hiroyuki Fujimoto, Waseda University (Japan)*

11:30   AVM-040
Autonomous navigation using localization priors, sensor fusion, and terrain classification, *Zachariah Carmichael, Benjamin Glasstone, Frank Cwitkowitz, Kenneth Alexopoulos, Robert Relyea, and Ray Ptucha, Rochester Institute of Technology (United States)*

11:50   AVM-041
Autonomous highway pilot using Bayesian networks and hidden Markov models, *Kurt Pichler, Sandra Haindl, Daniel Reischl, and Martin Trinkl, Linz Center of Mechatronics GmbH (Austria)*

12:10   AVM-042
DriveSpace: Towards context-aware drivable area detection, *Sunil Chandra, Ganesh Sistu, Senthil Yogamani, and Ciaran Hughes, Valeo (Ireland)*

12:30 – 2:00 pm Lunch

AVM

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

Image Processing and Imaging Pipes for Automotive

Session Chairs: Patrick Denny, Valeo (Ireland) and Robin Jenkin, NVIDIA Corporation (United States)

3:30 – 4:50 pm
Grand Peninsula Ballroom FG

3:30   AVM-043
Image-based compression of LiDAR sensor data, *Peter van Beek, Intel Corporation (United States)*

3:50   AVM-044
Optimization of ISP parameters for object detection algorithms, *Lucie Yahiaoui, Jonathan Horgan, Brian Deegan, Patrick Denny, Senthil Yogamani, and Ciaran Hughes, Valeo (Ireland)*

4:10   AVM-045
Learning based demosaicing and color correction for RGB-IR patterned image sensors, *Navinprashath R R and Radhesh Bhat, PathPartner Technology Pvt. Ltd. (India)*

4:30   AVM-046
Color correction for RGB sensors with dual-band filters for in-cabin imaging applications, *Orit Skorka, Paul Kane, and Radu Ispasoiu, ON Semiconductor (United States)*

5:30 – 7:00 pm Symposium Demonstration Session

Wednesday January 16, 2019

Deep Neural Net Optimization I

Session Chair: Buyue Zhang, Apple Inc. (United States)
8:50 – 9:50 am
Grand Peninsula Ballroom FG

       AVM-047
KEYNOTE: Perception systems for autonomous vehicles using energy-efficient deep neural networks, *Forrest Iandola, DeepScale (United States)*
Forrest Iandola completed his PhD in electrical engineering and computer science at UC Berkeley, where his research focused on improving the efficiency of deep neural networks (DNNs). His best-known work includes deep learning infrastructure such as FireCaffe and deep models such as SqueezeNet and SqueezeDet. His advances in scalable training and efficient implementation of DNNs led to the founding of DeepScale, where he has been CEO since 2015. DeepScale builds vision/perception systems for automated vehicles.

Deep Neural Net Optimization II

Session Chair: Buyue Zhang, Apple Inc. (United States)

9:50 – 10:30 am
Grand Peninsula Ballroom FG

9:50   AVM-048
Yes we GAN: Applying adversarial techniques for autonomous driving, *Michal Uricar, Pavel Krizek, Ibrahim Sobh, David Hurych, Senthil Yogamani, and Patrick Denny, Valeo (Ireland)*

10:10   AVM-049
Deep dimension reduction for spatial-spectral road scene classification, *Christian Winkens, Florian Sattler, and Dietrich Paulus, University of Koblenz-Landau (Germany)*

10:00 am – 3:30 pm Industry Exhibition

10:10 – 10:50 am Coffee Break

AVM

Automotive Image Sensing I — Joint Session

Session Chairs: Kevin Matherson, Microsoft Corporation (United States); Arnaud Peizerat, CEA (France); and Peter van Beek, Intel Corporation (United States)

10:50 am – 12:10 pm
Grand Peninsula Ballroom D

This session is jointly sponsored by: Autonomous Vehicles and Machines 2019, Image Sensors and Imaging Systems 2019, and Photography, Mobile, and Immersive Imaging 2019.

10:50   IMSE-050
KEYNOTE: Recent trends in the image sensing technologies, *Vladimir Koifman, Analog Value Ltd. (Israel)*

Vladimir Koifman is a founder and CTO of Analog Value Ltd. Prior to that, he was co-founder of Advasense Inc., acquired by Pixim/ Sony Image Sensor Division. Prior to co-founding Advasense, Koifman co-established the AMCC analog design center in Israel and led the analog design group for three years. Before AMCC, Koifman worked for 10 years in Motorola Semiconductor Israel (Freescale) managing an analog design group. He has more than 20 years of experience in VLSI industry and has technical leadership in analog chip design, mixed signal chip/system architecture and electro-optic device development. Koifman has more than 80 granted patents and several papers. Koifman also maintains Image Sensors World blog.

11:30   AVM-051
KEYNOTE: Solid-state LiDAR sensors: The future of autonomous vehicles, *Louay Eldada, Quanergy Systems, Inc. (United States)*

Louay Eldada is CEO and co-founder of Quanergy Systems, Inc. Eldada is a serial entrepreneur, having founded and sold three businesses to Fortune 100 companies. Quanergy is his fourth start-up. Eldada is a technical business leader with a proven track record at both small and large companies and with 71 patents, is a recognized expert in quantum optics, nanotechnology, photonic integrated circuits, advanced optoelectronics, sensors and robotics. Prior to Quanergy, he was CSO of SunEdison, after serving as CTO of HelioVolt, which was acquired by SK Energy. Eldada was earlier CTO of DuPont Photonic Technologies, formed by the acquisition of Telephotonics where he was founding CTO. His first job was at Honeywell, where he started the Telecom Photonics business and sold it to Corning. He studied business administration at Harvard, MIT and Stanford, and holds a PhD in optical engineering from Columbia University.

Automotive Image Sensing II — Joint Session

Session Chairs: Kevin Matherson, Microsoft Corporation (United States); Arnaud Peizerat, CEA (France); and Peter van Beek, Intel Corporation (United States)

12:10 – 12:50 pm
Grand Peninsula Ballroom D

This session is jointly sponsored by: Autonomous Vehicles and Machines 2019, Image Sensors and Imaging Systems 2019, and Photography, Mobile, and Immersive Imaging 2019.

12:10   PMII-052
Driving, the future – The automotive imaging revolution (Invited), *Patrick Denny, Valeo (Ireland)*

12:30   AVM-053
A system for generating complex physically accurate sensor images for automotive applications, *Zhenyi Liu[1,2], Minghao Shen[1], Jiaqi Zhang[3], Shuangting Liu[3], Henryk Blasinski[2], Trisha Lian[2], and Brian Wandell[2]; [1]Jilin University (China), [2]Stanford University (United States), and [3]Beihang University (China)*

12:50 – 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

AVM

Interaction with People

Session Chair: Robin Jenkin, NVIDIA Corporation (United States)

3:30 – 4:30 pm
Grand Peninsula Ballroom FG

3:30   AVM-054
Today is to see and know: An argument and proposal for integrating human cognitive intelligence into autonomous vehicle perception, *Mónica López-González, La Petite Noiseuse Productions (United States)*

3:50   AVM-055
Pupil detection and tracking for AR 3D under various circumstances, *Dongwoo Kang, Jingu Heo, Byongmin Kang, and Dongkyung Nam, Samsung Advanced Institute of Technology (Republic of Korea)*

4:10   AVM-056
Driver behavior recognition using recurrent neural network in multiple depth cameras environment, *Ying-Wei Chuang[1], Chien-Hao Kuo[1], Shih-Wei Sun[2], and Pao-Chi Chang[1]; [1]National Central University and [2]Taipei National University of the Arts (Taiwan)*

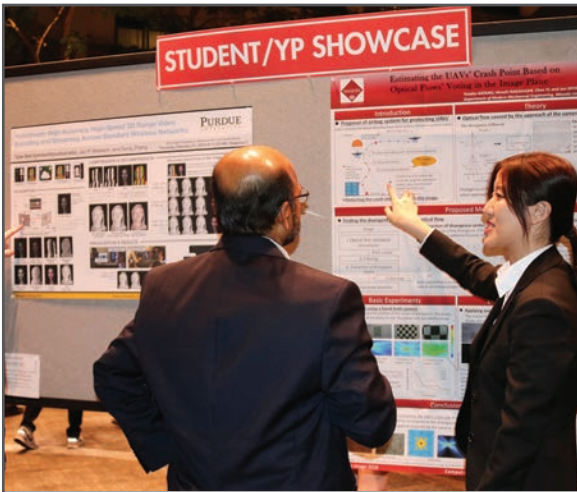> 5:30 – 7:00 pm Symposium Interactive Papers (Poster) Session

AVM