

IS&T International Symposium on

Electronic Imaging

SCIENCE AND TECHNOLOGY

29 January 2017 – 2 February 2017 • Burlingame, CA, USA

PROCEEDINGS

Autonomous Vehicles and Machines 2017

Editors: Patrick Denny, Valeo (Ireland),
Darnell Moore, Texas Instruments (United States)
Buyue Zhang, Intel Corporation (United States)

These papers represent the program of Electronic Imaging 2017,
held January 29 – February 2, 2017, at the Hyatt Regency San Francisco Airport in Burlingame, CA.

Copyright 2017

Society for Imaging Science and Technology
7003 Kilworth Lane • Springfield, VA 22151 USA
703/642-9090; 703/642-9094 fax
info@imaging.org; www.imaging.org

All rights reserved. These proceedings, or parts thereof, may not be reproduced in any form without the written permission of the Society.

ISSN 2470-1173

<https://doi.org/10.2352/ISSN.2470-1173.2017.19.AVM-A>

Manuscripts are reproduced from PDFs as submitted and approved by authors; no editorial changes have been made.

Autonomous Vehicles and Machines 2017

Symposium Chairs

Nitin Sampat, Rochester Institute of Technology (United States)
Joyce Farrell, Stanford University (United States)

Symposium Short Course Chairs

Mohamed-Chaker Larabi, University of Poitiers (France)
Jonathan B. Phillips, Google, Inc. (United States)

At-large Conference Chair Representative

Adnan Alattar, Digimarc (United States)

Past Symposium Chair

Choon-Woo Kim, Inha University (Republic of Korea)

Conference Chairs

Patrick Denny, Valeo (Ireland)
Darnell Moore, Texas Instruments (United States)
Buyue Zhang, Intel Corporation (United States)

Conference Committee

Umit Batur, Faraday Future (United States)
Zhigang Fan, Apple Inc. (United States)
Ching Hung, NVIDIA Corporation (United States)
Mustafa I. Jaber, NantVision (United States)
Pavan Shastry, Continental (Germany)
Markus Vill, Intel Corporation (Germany)
Yuqiong (Joan) Wang, Uber Advanced Technologies Center (United States)
Xinzhou Wu, Qualcomm Technologies, Inc. (United States)
Yi Zhang, Ford Research and Innovation Center (United States)

Introduction

On behalf of the Conference Committee, we welcome you to the inaugural conference on *Autonomous Vehicles and Machines* (AVM), a new addition to the 2017 IS&T International Symposium on Electronic Imaging (EI 2017) held this year in Burlingame, California, near San Francisco, January 29th – February 2nd.

The conference program is organized in a single track with three sessions covering the following themes:

- multi-camera and embedded systems for autonomous machines
- functional safety,
- computer vision, machine learning, and image processing

Each session will be introduced by an invited keynote presentation. We are honored to have three outstanding keynote speakers:

- Mr. Jack Weast, Principal Engineer and Chief Systems Engineer for Autonomous Driving Solutions at Intel Corporation, will present "Architectures for Automated Driving."
- Dr. Larry Matthies, Senior Research Scientist at JPL who pioneered the development of algorithms for visual odometry and real-time 3D perception with stereo vision, will present "Autonomous Navigation on Earth and in Space."
- Dr. Justyna Zander, Software Architect and Technical Lead for Autonomous Driving at Intel, will present "Functional Safety in autonomous Systems, Needs and Challenges Analysis."

In addition, AVM features fifteen oral presentations of original research and industrial applications along with some demonstrations.

We want to sincerely thank the conference committee members, all contributing authors, IS&T staff, and our sponsors for helping launch AVM. We hope that you will find this year's program interesting and will consider contributing to next year's program as AVM seeks to grow over the next few years to promote autonomy through imaging.

— Buyue Zhang, Ph.D, Intel
Darnell Moore, Ph.D, Texas Instruments
Patrick Denny, Ph.D, Valeo

AVM 2017 thanks Conference Sponsor



Autonomous Vehicles and Machines 2017

Monday January 30, 2017

KEYNOTE: Key Learnings from Automated Vehicle Development

Session Chair: Buyue Zhang, Intel Corporation (United States)

8:50 – 9:50 AM

Grand Peninsula Ballroom B

Architectures for automated driving, Jack Weast, Intel Corporation (United States) [AVM-009]

Jack Weast is a Principal Engineer and the Chief Systems Engineer for Autonomous Driving Solutions at Intel Corporation. In his 17 year career at Intel, Weast has built a reputation as a change agent in new industries with significant technical and architectural contributions to a wide range of industry-first products and standards that range from one the world's first Digital Media Adapters to complex heterogeneous high performance compute solutions in markets that are embracing high performance computing for the first time. With an End to End Systems perspective, he combines a unique blend of embedded product experience with a knack for elegant Software and Systems design that will accelerate the adoption of Autonomous Driving. Weast is the co-author of "UPnP: Design By Example", an Associate Professor at Portland State University, and the holder of numerous patents with dozens pending.

Multi-Camera and Embedded Systems for Autonomous Machines

Session Chair: Buyue Zhang, Intel Corporation (United States)

9:50 – 10:30 AM

Grand Peninsula Ballroom B

9:50

3D Perception: Multi-camera embedded structure-from-motion prototype for real-time mapping, Martin Mueller¹, Vikram Appia¹, and Umit Batur²; ¹Texas Instruments Inc. and ²Faraday Future (United States) [AVM-010]

10:10

Measuring MTF with wedges: Pitfalls and best practices, Norman Koren, Robert C. Sumner, and Henry Koren, Imatest LLC (United States) [AVM-451]

10:30 – 10:50 AM Coffee Break

Multi-Camera and Embedded Systems for Autonomous Machines (cont.)

Session Chairs: Darnell Moore, Texas Instruments, and Yi Zhang, Ford Research and Innovation Center (United States)

10:50 AM – 12:30 PM

Grand Peninsula Ballroom B

10:50

Free-view multi-camera visualization and harmonization for automotive systems, Vladimir Zlokolica, Brian Deegan, Patrick Denny, Mark Griffin, and Barry Dever, Valeo Vision System (Ireland) [AVM-012]

11:10

Accelerated stereo matching for autonomous vehicles using upright pinhole camera model

Chen Chen¹, Jiangbo Lu², Do-Kyoung Kwon³, Darnell Moore³ and Minh N. Do¹; ¹University of Illinois at Urbana-Champaign (United States), ²Advanced Digital Sciences Center (Singapore), and ³Texas Instruments (United States) [AVM-013]

11:30

Perspectively correct bird's views using stereo vision

Christian Fuchs and Dietrich Paulus, University of Koblenz-Landau (Germany) [AVM-014]

11:50

A sense and avoid algorithm using surround stereo vision for drones

G.M. Dilshan Godaliyadda^{1,2}, Do-Kyoung Kwon², Darnell Moore² and Victor Cheng²; ¹Purdue University and ²Texas Instruments (United States) [AVM-015]

12:10

Real-time flight altitude estimation using phase correlation with gram polynomial decimation

Amir Badshah¹, Aadil Choudhry², and Saadullah Amin²; ¹International Islamic University Islamabad and ²National University of Sciences and Technology (Pakistan) [AVM-011]

12:30 – 2:00 PM Lunch Break

EI 2017 Opening Plenary and Symposium Awards

Session Chairs: Joyce E. Farrell, Stanford University, and Nitin Sampat, Rochester Institute of Technology (United States)

2:00 – 3:00 PM

Grand Peninsula Ballroom D

Giga-scale 3D computational microscopy

Laura Waller, University of California, Berkeley (United States)
 Laura Waller is the Ted Van Duzer Endowed Assistant Professor of Electrical Engineering and Computer Sciences (EECS) at UC Berkeley. She is a Senior Fellow at the Berkeley Institute of Data Science, and received her BS (2004), MEng (2005), and PhD (2010) in EECS from the Massachusetts Institute of Technology (MIT). Waller's talk is on computational imaging methods for fast capture of gigapixel-scale 3D intensity and phase images in a commercial microscope that employs illumination-side and detection-side coding of angle (Fourier) space with simple hardware and fast acquisition. The result is high-resolution reconstructions across a large field-of-view, achieving high space-bandwidth-time product.

3:00 – 3:30 PM Coffee Break

KEYNOTE: Functional Safety and Security in Autonomous System Design

Session Chair: Umit Batur, Faraday Future (United States)

3:30 – 4:30 PM

Grand Peninsula Ballroom B

AVM-016

Needs and challenges analysis for reference architectures in autonomous systems, *Justyna Zander, Intel Corporation (United States)*

Justyna Zander is Software Architect and Technology Lead in autonomous driving at Intel Corporation. Before joining Intel, she spent over a year working on self-driving cars, ADAS, and functional safety as a senior consultant in Germany. She engaged with Fortune 500 companies including most prestigious automotive OEMs. Prior to that, Zander was a postdoctoral research scientist at Harvard University and a senior scientist at the Fraunhofer Institute in Germany. She holds PhD, MSc, and two BSc degrees in computer science and electrical engineering. Her expertise includes modeling, simulation, deep learning, validation, and verification, functional safety, computing platforms, and rapid prototyping with worldwide operations focus. A frequent public speaker, she holds 6 patents, has 8 patent applications at USPTO, and has co-authored more than 40 publications and 3 books. Her publications have been cited more than 550 times. Zander is recognized internationally with countless awards (IEEE, European Union, NIST, etc). She regularly serves as a technical committee member for more than 50 journals and conferences, and is invited by NSF, EU Commission, and national councils to advise on government strategy and research roadmaps.

Functional Safety

Session Chair: Umit Batur, Faraday Future (United States)

4:30 – 4:50 PM

Grand Peninsula Ballroom B

4:30

AVM-017

Enabling functional safety ASIL compliance for autonomous driving software systems, *Kedar Chitnis, Mihir Mody, Pramod Swami, Sivaraj R, Chaitanya Ghone, M G Biju, Badri Narayanan, Yashwant Dutt, Aish Dubey, Texas Instruments (India and United States)*

Kedar Chitnis is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Mihir Mody is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Pramod Swami is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Sivaraj R is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Chaitanya Ghone is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. M G Biju is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Badri Narayanan is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Yashwant Dutt is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Aish Dubey is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety.

5:00 – 6:00 PM All-Conference Welcome Reception, Atrium

Tuesday January 31, 2017

KEYNOTE: Autonomous Vehicle Navigation in Planetary Exploration

Session Chair: Darnell Moore, Texas Instruments (United States)

8:50 – 9:50 AM

Grand Peninsula Ballroom B

AVM-018

Common themes in autonomous navigation on earth and in space, *Larry Matthies, Jet Propulsion Laboratory (United States)*

Larry Matthies received his PhD in computer science from Carnegie Mellon University in 1989, then moved to the Jet Propulsion Laboratory, where he is a Senior Research Scientist and supervisor of the Computer Vision Group. 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 funded by NASA, Army, Navy, DARPA, and commercial sponsors. He and his group have achieved several firsts in computer vision for space exploration, including development of vision algorithms used by rovers and landers in the 2003 Mars Exploration Rover mission. He is an Adjunct Professor of Computer Science at the University of Southern California, a lecturer in computer vision at Caltech, and a member of the editorial boards of the Autonomous Robots journal and the Journal of Field Robotics. 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.

Computer Vision, Machine Learning, and Image Processing

Session Chair: Darnell Moore, Texas Instruments (United States)

9:50 – 10:10 AM

Grand Peninsula Ballroom B

9:50

AVM-019

Milpet – The self-driving wheelchair, *Samuel Echefu, Jacob Lauzon, Suvam Bag, Rasika Kangukar, Amar Bhatt, and Raymond Ptucha, Rochester Institute of Technology (United States)*

Samuel Echefu is a PhD student at the Rochester Institute of Technology, where he is working on his dissertation titled "Milpet: A self-driving wheelchair for the elderly and disabled." He is currently a research assistant at the Center for Intelligent and Robotic Systems. Jacob Lauzon is a PhD student at the Rochester Institute of Technology, where he is working on his dissertation titled "A self-driving wheelchair for the elderly and disabled." He is currently a research assistant at the Center for Intelligent and Robotic Systems. Suvam Bag is a PhD student at the Rochester Institute of Technology, where he is working on his dissertation titled "A self-driving wheelchair for the elderly and disabled." He is currently a research assistant at the Center for Intelligent and Robotic Systems. Rasika Kangukar is a PhD student at the Rochester Institute of Technology, where he is working on his dissertation titled "A self-driving wheelchair for the elderly and disabled." He is currently a research assistant at the Center for Intelligent and Robotic Systems. Amar Bhatt is a PhD student at the Rochester Institute of Technology, where he is working on his dissertation titled "A self-driving wheelchair for the elderly and disabled." He is currently a research assistant at the Center for Intelligent and Robotic Systems. Raymond Ptucha is a PhD student at the Rochester Institute of Technology, where he is working on his dissertation titled "A self-driving wheelchair for the elderly and disabled." He is currently a research assistant at the Center for Intelligent and Robotic Systems.

10:00 AM – 7:30 PM Industry Exhibition

10:10 – 10:40 AM Coffee Break

Computer Vision, Machine Learning, and Image Processing (cont.)

Session Chairs: Markus Vill, Intel Corporation (Germany), and Buyue Zhang, Intel Corporation (United States)

10:40 AM – 12:40 PM

Grand Peninsula Ballroom B

10:40

AVM-020

Efficient pre-processor for CNN, *Mihir Mody, Manu Mathew, and Shyam Jagannathan, Texas Instruments India Ltd. (India)*

Mihir Mody is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Manu Mathew is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety. Shyam Jagannathan is a Senior Software Architect at Texas Instruments, where he leads the functional safety team for automotive applications. He has a PhD in Computer Science from the University of Texas at Dallas and has worked on autonomous driving software for over 10 years. He is a frequent speaker at industry conferences and has published several papers on functional safety.

11:00	54
Free-space detection with self-supervised and online trained fully convolutional networks , Willem P. Sanberg, Gijs Dubbelman, and Peter H.N. De With, Eindhoven University of Technology (the Netherlands) [AVM-021]	
11:20	62
Motion estimation using visual odometry and deep learning localization , Suvam Bag, Vishwas Venkatachalapathy, and Raymond Ptucha, Rochester Institute of Technology (United States) [AVM-022]	
11:40	70
Deep reinforcement learning framework for autonomous driving , Ahmad El Sallab, Mohammed Abdou, Etienne Perot, and Senthil Yogamani, Valeo (Ireland) [AVM-023]	
12:00	77
Automatic glare detection via photometric, geometric, and global positioning information , Mehran Andalibi ¹ and Damon M. Chandler ² ; ¹ Embry-Riddle Aeronautical University (United States) and ² Shizuoka University (Japan) [AVM-024]	
12:20	83
Face pose estimation from rigid face landmarks for driver monitoring systems , Bhawani Shankar, Dakala Jayachandra, and Kalyan Kumar Hati, Path Partner Technology Pvt Ltd. (India) [AVM-025]	

12:40 – 2:00 PM Lunch Break

El 2017 Tuesday Plenary and Symposium Awards

Session Chairs: Joyce E. Farrell, Stanford University, and Nitin Sampat, Rochester Institute of Technology (United States)

2:00 – 3:00 PM

Grand Peninsula Ballroom D

VR 2.0: Making virtual reality better than reality, Gordon Wetzstein, Stanford University (United States)

Gordon Wetzstein is an Assistant Professor of Electrical Engineering and, by courtesy, of Computer Science, at Stanford University, and leads the Stanford Computational Imaging Group. He received a PhD in computer science from the University of British Columbia (2011) where his doctoral dissertation focused on computational light modulation for image acquisition and display. In his talk, Wetzstein explores the frontiers of VR systems engineering. Eventually, VR/AR systems will redefine communication, entertainment, education, collaborative work, simulation, training, telesurgery, and basic vision research, as next-generation computational near-eye displays evolve to deliver visual experiences that are better than the real world.

3:00 – 3:30 PM Coffee Break

5:30 – 7:30 PM Symposium Demonstration Session, Grand Peninsula Ballroom E

Thursday February 2, 2017

KEYNOTE: History and Standards for Automotive Vision Systems Performance Joint Session

Session Chairs: Arnaud Darmont, APHESA SPRL (Belgium); Ralf Widenhorn, Portland State University (United States); and Buyue Zhang, Intel Corporation (United States)

11:50 AM – 12:30 PM

Harbour

This session is jointly sponsored by: Image Sensors and Imaging Systems 2017 and Autonomous Vehicles and Machines 2017.

Automotive imaging, Patrick Denny, Valeo (Ireland) [IMSE-196]

Patrick Denny is a Senior Research Engineer and a Valeo Senior Expert and has worked for the last 15 years at Valeo Vision Systems, Ireland. He received his PhD in physics (2000) from the National University of Ireland, Galway, where he is also Adjunct Professor of Automotive Electronics. Denny has in excess of 20 years experience in scientific and technological development internationally, designing, innovating and developing automotive imaging technologies for BMWV, Jaguar Land Rover, Daimler, VW and other OEMs. His research interests include several aspects of automotive vision system image quality, sensor components, algorithmic design, systems, machine learning and data analytics.

12:30 – 2:00 PM Lunch Break

3:00 – 5:00 PM Meet the Future: A Showcase of Student and Young Professionals Research, Grand Peninsula Ballroom E