FINAL PROGRAM

JUNE 19 – 22, 2016
GOTHENBURG, SWEDEN

IV16 GOTHENBURG SWEDEN

2016 IEEE
INTELLIGENT
VEHICLES
SYMPOSIUM

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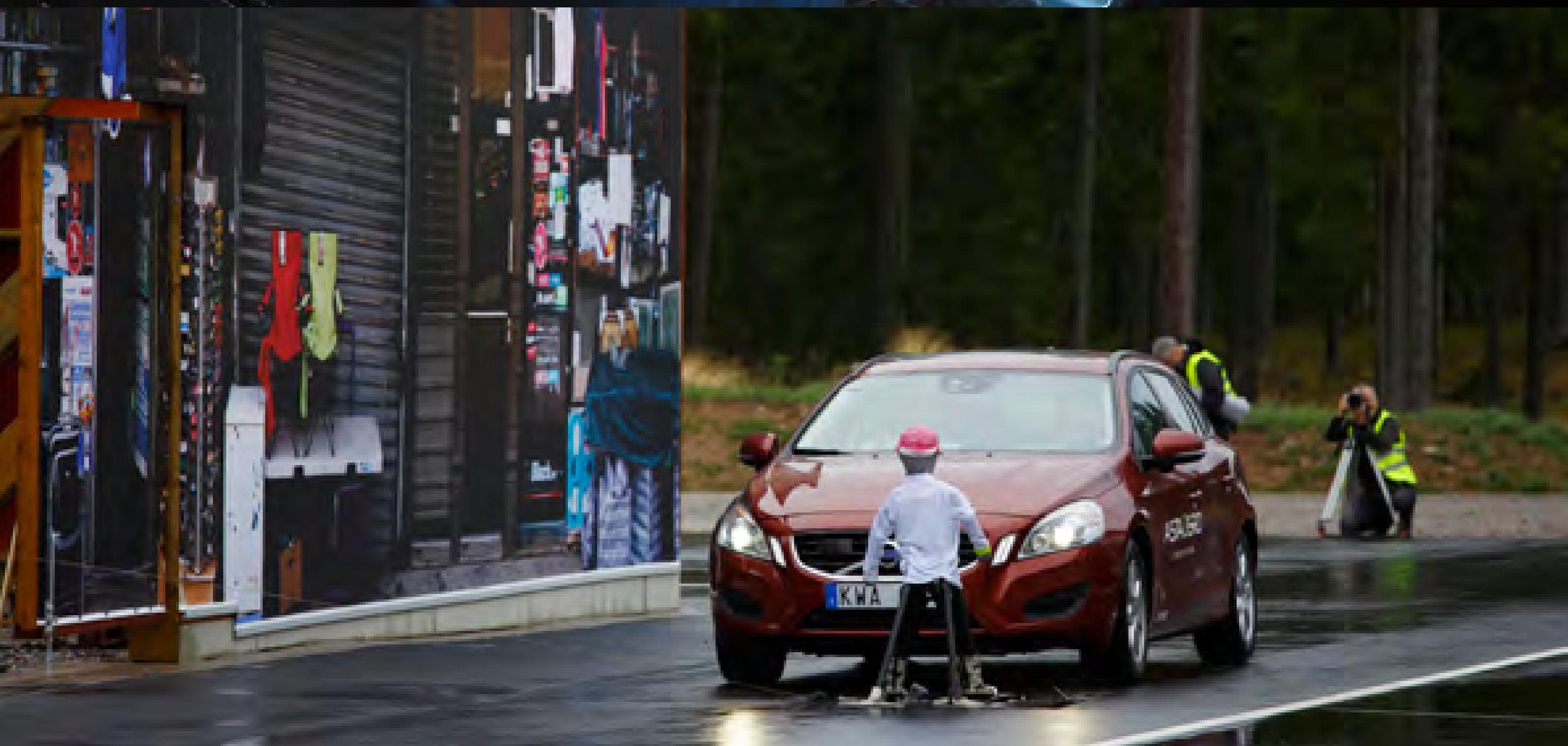
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2016 IEEE INTELLIGENT VEHICLES SYMPOSIUM

June 19-22, 2016

Lindholmen Conference Centre Gothenburg Sweden

The Intelligent Vehicles Symposium (IV'16) is a premier forum sponsored by the IEEE Intelligent Transportation Systems Society (ITSS). Researchers, engineers, practitioners, and students, from industry, universities and government agencies are invited to present their latest work and to discuss research and applications for Intelligent Vehicles and Vehicle-Infrastructure Cooperation. Technical sessions, workshops, poster sessions, exhibition, and technical visits will be organized.

The IV'16 is hosted by Chalmers University of Technology and SAFER Vehicle and Traffic Safety Centre. Gothenburg is a perfect city for the symposium because it is the centre of automotive industry in Sweden, with headquarters of Volvo Trucks, Volvo Cars, and the supplier Autoliv, and where many international companies and academia have their development and research base. The brand new proving ground for active safety testing – AstaZero – is very close.

http://iv2016.org

WORDS OF WELCOME

Dear Colleagues,

On behalf of the organizing committee, it is our pleasure to welcome you to Gothenburg, Sweden and the 2016 IEEE Intelligent Vehicles symposium.

We are happy to have been trusted with the responsibility to organize the 2016 symposium that takes place at Lindholmen Conference Centre at Lindholmen Science Park. The Science Park is dedicated to intelligent transport and mobile internet and the major stakeholders from industry, academia and society are present here. The symposium is co-organized by Chalmers University of Technology and SAFER Vehicle and Traffic Safety Centre at Chalmers, which is a competence centre based in Lindholmen Science Park, consisting of 34 partners from the academy, society and industry.

From the joint competence platform of Chalmers and SAFER, the symposium has been organized in close collaboration with IEEE guaranteeing an interesting program and continuation of the traditions from the earlier symposia. We have also a great workshop program and a technical demo at our world-class proving ground AstaZero. You will get the chance to see some spectacular applications of intelligent vehicle technologies!

The quality of the symposium builds on important contributions from many people. To all symposium participants who have submitted technical papers, to keynote speakers, to the Program Committee, and the Organizing Committee – you have all done a great job.

You will be visiting Gothenburg at a great time of the year and we hope that you will enjoy the symposium and the city!

Warm welcome!

JONAS SJÖBERG
Professor
Chalmers University of Technology
General Chair of IV'16

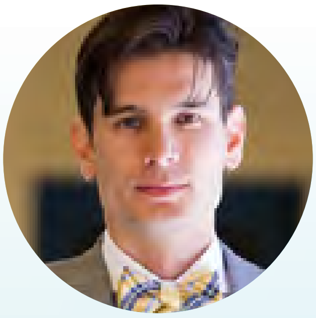
ANNA NILSSON-EHLE
PhD h c
SAFER Vehicle and Traffic
Safety Centre
General Host of IV'16

WELCOME MESSAGE FROM INTERNATIONAL PROGRAM COMMITTEE CHAIR

Dear Colleagues,

It is my great pleasure to welcome you to the 2016 IEEE Intelligent Vehicles Symposium – IV'16 – in Gothenburg, Sweden. It is my great honor to serve as Program Chair for this prestigious meeting in a time when intelligent vehicles are transitioning out of academia and industry and into the public forefront.

After thorough review the Program Committee has organized a technical program comprising of 210 papers (acceptance rate of 51 %) with 28 oral (13.3 %) and 182 poster presentations. This resulted in 742 total authors from 29 different countries. In addition, 31 more papers were accepted through 10 workshops which broadly cover IV topics.



BRENDAN MORRIS
Assistant Professor
University of Nevada
Program Chair of IV'16

As is tradition, the conference is a single-track poster-heavy format over three days with an additional day of workshops to start the meeting. This year, two new policies were implemented to further promote active interactions between authors and attendees. First, the oral presentations will also be found in the poster sessions for more detailed discussion. Second, each Poster Session will begin with a short 1-minute spotlight presentation. This provides poster presenters a forum to highlight their work in front of larger audience.

The conference received a grand total of 412 paper submissions which set a new record. IV is truly an international conference with submissions from 37 countries with clear strength in Europe, the United States of America, and Asia. It is exciting to see contributions from less represented countries such as Iran, Iraq, Malaysia, Qatar, and Thailand as a testament to the growth of the meeting.

I would like to thank everybody that took part in the review process for IV'16. The meeting would not be possible without the efforts of many dedicated individuals from our community. In particular, I am indebted to the 84 members of the International Program Committee (IPC) that served as Associate Editor during the review process. It was a substantial task for the IPC to solicit and mange reviews to ensure the quality of our program. I also would like to send my sincere gratitude to all the 790 reviewers that accounted for 1082 reviews with distinction for the small set of reviewers that provided emergency last minute reviews in only a few days.

Finally, I would like to thank all of the organizing team for their hard work putting together this meeting. I commend my Program Co-Chairs, Sergiu Nedevschi, Chunzhao Guo, Luiz Goes, and Dariu Gavrila, for their support and to Cristina Olaverri Monreal for all her efforts to organize the workshops.

On behalf of the Program Committee, I hope you are able to encounter interesting new work, have engaging conversations, make new friends, and enjoy your visit to Gothenburg for IV'16.

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Professor, Chalmers University of Technology, Sweden

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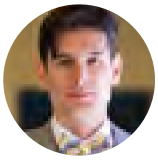

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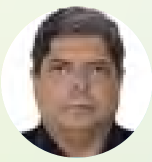

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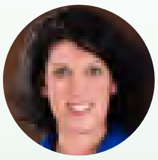

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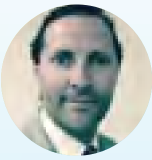

MIGUEL ÁNGEL SOTELO
Full Professor, University of Alcalá, Spain

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PROGRAM AT A GLANCE

SUNDAY, JUNE 19, 2016

09:00-17:30	Workshops
18:30-20:00	**Welcome Reception**

MONDAY, JUNE 20, 2016

08:30-08:45	Opening **Room:** Conference Hall		
08:45-09:15	Keynote: Volvo Group **Room:** Conference Hall		
09:15-10:25	Oral: Vision Sensing and Perception **Room:** Conference Hall		
10:25-10:40	Invited Talk: IAV **Room:** Conference Hall		
10:40-11:10	Coffee Break		
11:10-12:20	Oral: Self-Driving Vehicles **Room:** Conference Hall		
12:20-13:20	**Lunch**		
13:20-14:45	**Poster 1**		
	ADAS & Collision Avoidance **Room:** Open Arena	Lidar & Fusion & Self-Driving Vehicles **Room:** Pascal	Vision Sensing and Perception **Room:** Conference Hall
14:45-15:55	Oral: Cooperative Systems (V2X) **Room:** Conference Hall		
15:55-16:25	Coffee Break		
16:25-17:50	**Poster 2**		
	Driver State/Intention & Situation Analysis/Planning **Room:** Open Arena	Energy Efficiency & Mapping **Room:** Pascal	V2X and Control **Room:** Conference Hall
18:00-21:00	**Student Activity: Volvo Networking Event**		

TUESDAY, JUNE 21, 2016

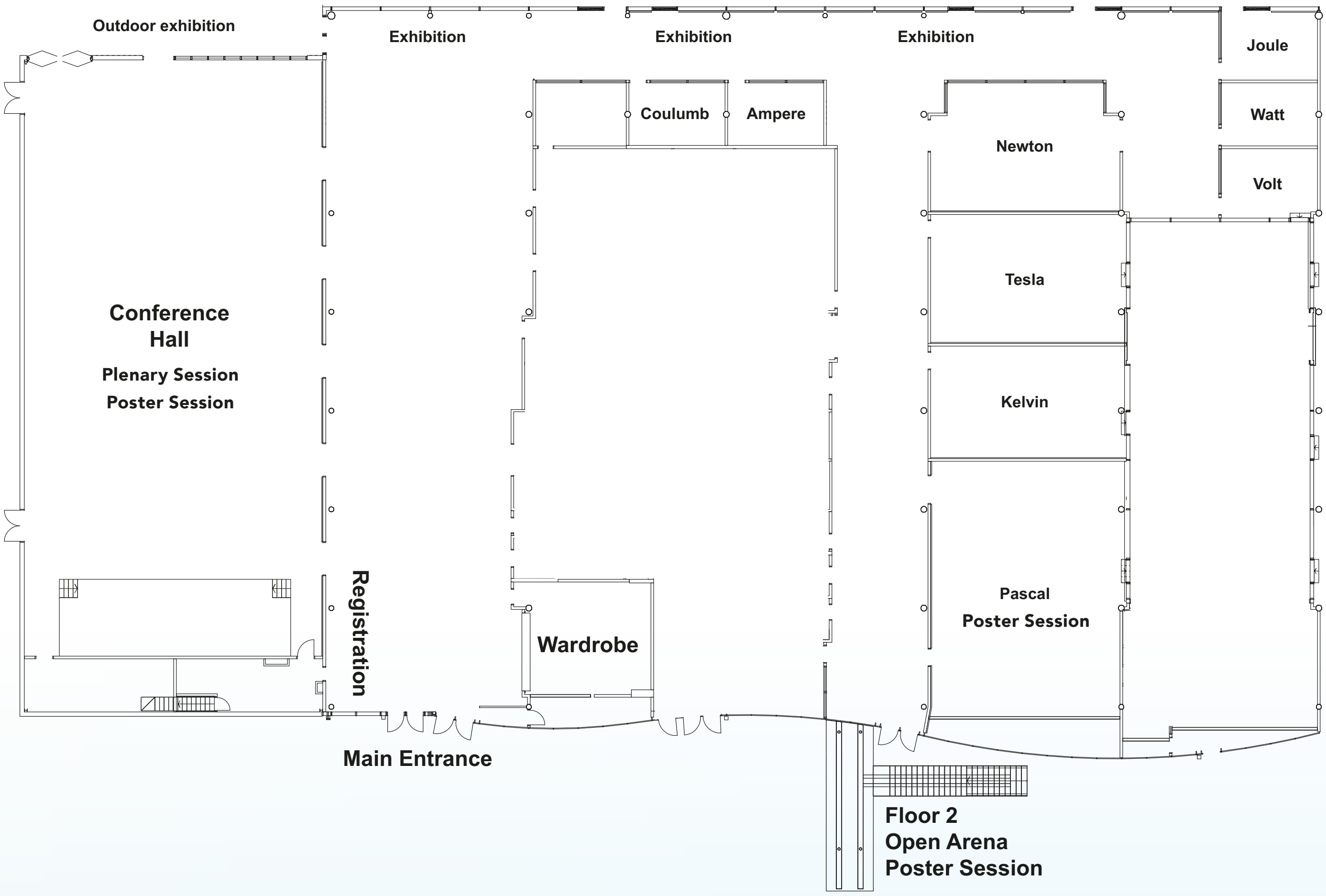
08:30-09:15	Keynote: Highway Loss Data Institute **Room:** Conference Hall		
09:15-10:25	Oral: Sensor and Data Fusion **Room:** Conference Hall		
10:25-10:40	Invited Talk: Volvo Cars **Room:** Conference Hall		
10:40-11:10	Coffee Break		
11:10-12:20	Oral: Vehicle Control **Room:** Conference Hall		
12:20-13:20	**Lunch**		
13:20-14:45	**Poster 3**		
	Lidar & Sensor Fusion **Room:** Open Arena	Self-Driving Vehicles **Room:** Pascal	Vehicle Control & Collision Avoidance **Room:** Conference Hall
14:45-15:55	Oral: Mapping and Localization **Room:** Conference Hall		
15:55-16:25	Coffee Break		
16:25-17:50	**Poster 4**		
	Mapping and Localization **Room:** Open Arena	Vision Sensing and Perception **Room:** Pascal	V2X & Eco-Driving & Traffic Flow **Room:** Conference Hall

18:00-19:30	**Guided boat transfer to the Conference Banquet**
19:30-23:00	**Conference Banquet**

WEDNESDAY, JUNE 22, 2016

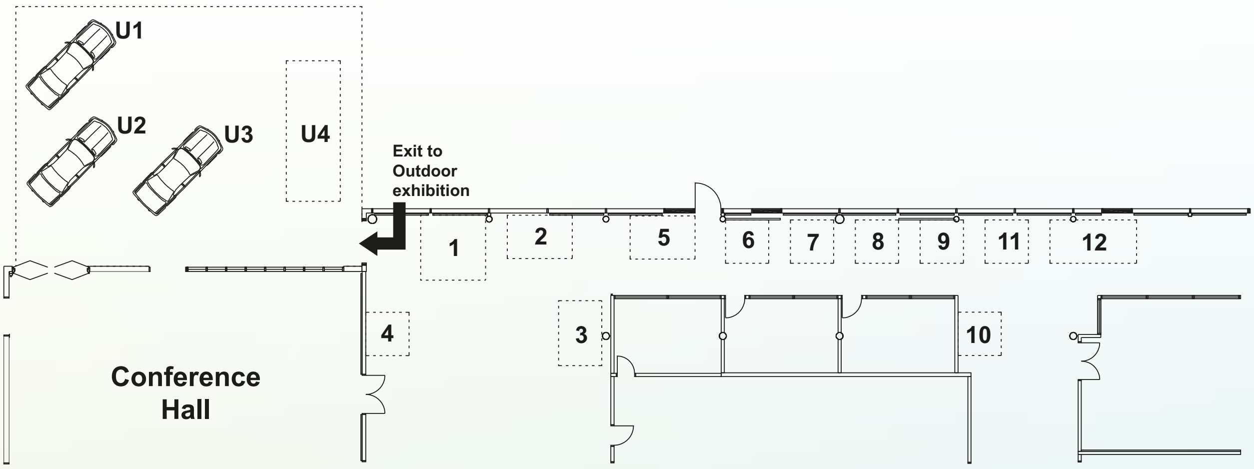
08:45-09:30	Keynote: TNO **Room:** Conference Hall		
09:30-10:40	Advanced Driver Assistance Systems **Room:** Conference Hall		
10:40-11:00	Coffee Break		
11:00-12:25	**Poster 5**		
	Advanced Driver Assistance Systems **Room:** Open Arena	Situation Analysis and Planning **Room:** Pascal	HMI and Factors & Driver State and Intent **Room:** Conference Hall
12:25-12:40	Closing session **Room:** Conference Hall		
13:00-17:15	Technical Demos at AstaZero		

CONFERENCE SITE FLOOR PLAN



EXHIBITION FLOOR PLAN & LIST OF EXHIBITORS

1 & U4	Volvo Group
2 & U2	Volvo Car Group
3 & U3	IAV GmbH
4 & U1	SAFER & Chalmers
5	AUTOLIV
6	Fengco Real Time Control
7	Vector Scandinavia
8	H2020 HIGHTS - HIgh Precision positioning for comperative TIS
9	AstaZero
10	VTI
11	Uniquesec AB
12	TASS International



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KEYNOTE SPEAKERS

MR. ANDERS KELLSTRÖM,
DR. CHRISTIAN GRANTE
Volvo Group, Sweden

Automation will completely redefine commercial transport solutions

MR. MATT MOORE
Highway Loss Data Institute, USA

Conclusions on autonomous emergency braking systems and other advanced driver assistance technologies

DR. JEROEN PLOEG
TNO, The Netherlands

i-GAME: From platooning to cooperative automated maneuvering

INVITED PLENARY SPEAKERS

DR. HADJ HAMMA TADJINE
DIPL.-ING. BENEDIKT SHONLAU
IAV, Germany

Connected and Autonomous Vehicles: challenges & opportunities

DR. ERIK COELINGH
Volvo Cars, Sweden

Self-driving cars in the hands of real customers on normal roads – safety and comfort

DATE: Monday, June 20, 2016 **TIME:** 08:45-09:15

Automation will completely redefine commercial transport solutions

MR. ANDERS KELLSTRÖM & DR. CHRISTIAN GRANTE
Volvo Group, Sweden

Volvo Group is redefining commercial transport solutions in daily life through automation and we strongly believe that automation is, and will be, part of new ways of working. As a company with global presence and many different product areas, the Volvo Group sees a great potential for automation in many types of transport scenarios and application areas, opening up for new business opportunities by providing added value services. The future is now within our reach. Our innovations are created to serve our customers, society and the environment in terms of: Productivity, Energy, Fuel Efficiency and Safety. First we showcased our innovations within platooning, now we are showcasing the autonomous tuck which will revolutionise productivity in future mining. Join us to hear Anders Kellström's (Senior Product Planner) insights about the platooning project and Christian Grante's (Volvo Group Technical Specialist – Preventive Safety and Automation) insights about the autonomous truck.

Anders Kellström, received his M.Sc in innovation, organization and economics at Halmstad University, Sweden, in 1993. After selling his start-up company Viscon AB, he joined the SCUBA-diving equipment manufacturer Poseidon Diving Systems, Sweden, as a Technical Director. In 2005, Anders came to the Volvo Group and were responsible for strategic planning of the commercial offers in the area of alternative fuels; liquid, gaseous, and electromobility. Appointed to Senior Product Planner, today's position is to ensure the strategic and commercial effectiveness of the early stages of product development.

Christian Grante, received his PhD on Fluid and Mechatronic Systems at Linköping University in 2004, his M.Sc. from Georgia Institute of Technology in 1999 and his Civilingenjör from Chalmers University of Technology in 1998. Christian joined Volvo Cars in 1999 as function developer of active safety features. Active safety system is also the area where he applied his research. Christian have held roles as function owner, project manager and business coordinator within development and research of active vehicle systems. Christian joined the Viktoria Institute as R&D Manager for Active Safety and Cooperative Systems early 2009. Late 2010 Christian joined Volvo Group Truck Technology as Program Manager for Vehicle Automation and Vehicle Dynamics and is since 2013 Volvo Group Technical Specialist – Preventive Safety and Automation.

DATE: Tuesday, June 21, 2016 TIME: 08:30-09:15

Conclusions on autonomous emergency braking systems and other advanced driver assistance technologies

MR. MATT MOORE
Highway Loss Data Institute, USA

On March 17, 2016 the Insurance Institute for Highway Safety and the U.S. Department of Transportation's National Highway Traffic Safety Administration announced a historic commitment by 20 automakers representing more than 99 percent of the U.S. auto market to make automatic emergency braking a standard feature on virtually all new cars no later than NHTSA's 2022 reporting year. This presentation will review research, real world results and on track testing from the Insurance Institute for Highway Safety and the Highway Loss Data Institute that served as a catalyst for the agreement. In addition to covering autonomous emergency braking systems the presentation will include results for other advanced driver assistance technologies and projected timelines for the fitment of these technologies in the U.S. fleet.

Matt Moore is vice president of the Highway Loss Data Institute, where he oversees much of HLDI's research. He is the author of numerous research papers published by HLDI on topics such as crash avoidance technologies, vehicle horsepower, motorcycles and distracted driving. He also supervises loss data processing, collection of vehicle information and data services for member companies. Mr. Moore joined HLDI in 1999 as a programmer. Before coming to HLDI, Mr. Moore worked in higher education, conducting institutional research, designing data systems and creating web sites. He holds an M.B.A. and a bachelor's degree from Saint Francis University in Pennsylvania.

DATE: Wednesday, June 22, 2016 **TIME:** 08:45-09:30

i-GAME: From platooning to cooperative automated maneuvering

DR. JEROEN PLOEG
TNO, The Netherlands

i-GAME is an international project, supported by the European Commission in the scope of the 7th Framework Programme, with consortium members being TNO (The Netherlands), Eindhoven University of Technology (The Netherlands), Viktoria Swedish ICT (Sweden), and IDIADA (Spain). The i-GAME project aims to facilitate development and real-life implementation of automated driving with a focus on cooperation supported by wireless communication between vehicles and between vehicles and road-side equipment. To this end, an event is organized as part of the project, in which international teams are challenged to cooperatively perform a number of traffic scenarios, among which the automated merging of two platoons into one, and the automated execution of a T-crossing. The specific scenarios are presented in some detail, after which the most relevant requirements for participation in the challenge are summarized, including the methods used to assess the team vehicles, both regarding hardware and software.

The execution of the selected traffic scenarios does not only require vehicle-level control systems for longitudinal and lateral automation, but also interaction protocols, prescribing the message-action sequence so as to safely and successfully execute the scenario at hand. This presentation will provide ample insight in the interaction protocol design as performed by the consortium members, the implementation thereof by the consortium in their benchmark vehicles, and the various implementations by the teams. The main results, obtained during the challenge, will be illustrated by measurements and movies. In addition, the message sets used in i-GAME will be presented, which clearly indicates that the standardized messages need to be extended in order to support complex traffic scenarios.

In summary, this presentation will provide insight into the technological backgrounds of cooperative automated maneuvering, while illustrating that automated vehicles need to show cooperative behavior, supported by wireless communications, in order to jointly perform complex maneuvers.

Jeroen Ploeg received the M.Sc. degree in mechanical engineering from Delft University of Technology, Delft, The Netherlands, in 1988 and the Ph.D. degree in dynamics and control from Eindhoven University of Technology, Eindhoven, The Netherlands, in 2014.

From 1989 to 1999 he was affiliated with Koninklijke Hoogovens (currently Tata Steel), IJmuiden, The Netherlands, where his interest was the development and implementation of dynamic process control systems for large-scale industrial plants. Since 1999 he has been a Senior Research Scientist with the Integrated Vehicle Safety department, TNO, Helmond, The Netherlands, where he is currently heading the Cooperative Vehicle Systems group.

His research interests include control system design for cooperative and automated vehicles, and motion control of wheeled mobile robots. In particular, he focusses on the controller design for vehicular platooning and cooperative adaptive cruise control, with specific interest in string stability, both in longitudinal and in lateral sense. This research is executed in close cooperation with the department of Mechanical Engineering, Eindhoven University of Technology, Eindhoven, The Netherlands.
Dr. Ploeg is currently an Associate Editor for the IEEE Transactions on Intelligent Transportation Systems.

DATE: Monday, June 20, 2016 **TIME:** 10:25–10:40

Connected and Autonomous Vehicles: challenges & opportunities

DR. HADJ HAMMA TADJINE & DIPL.-ING. BENEDIKT SHONLAU
IAV, Germany

All large vehicle manufacturers and many Tier1 suppliers are making substantial investments in connected and autonomous vehicle technology. An examination how these innovative vehicles will transform our vision, our industrial base, improving safety and congestion, driving up productivity and freeing up space usually devoted to vehicles in our urban areas will be discussed.

It is clear that new vehicles will be connected. To facilitate a variety of driving functions and other enhanced features, a powerful communications capabilities will be built in to automotive systems designed. Data will be exchanged via complex internal networks based on different internal control systems; other applications that interface with drivers through dashboard displays and devices could share information with other connected vehicles; they could also exchange data with connected roadside entities, such as streetlights, that are also linked-in to the Internet of Things.

As well as opportunities, the advent of the 'connected' vehicle brings several major challenges, and will affect the operating models of OEMs, distributors, dealers and mechanics, road infrastructure managers, law-makers, and of course drivers and their passengers. In the public domain verifiable information about automotive cyber security risk levels is scattered, and can tend toward the sensationalist. How far OEM'S have gone, and still have to go.

Dr. Hadj Hamma Tadjine received his engineer degree, D.E.A (Diplome d'Etude Approfondie), and the Third cycle degree, in Electrical engineering from the technical university of Blida in 1994, 1995 and respectively 1998. In 2004, he received his PhD in Computer science from the technical university of Clausthal Zellerfeld (Germany). From 2000 to 2004 he was professor assistant at the technical university of Clausthal (Germany). From 2004 through to 2006 Dr. Hadj Hamma Tadjine has been professor assistant at CUTEC institute GmbH (Germany). And from 2006 to 2008 he was responsible for Advanced Driver Assistance Systems at Hella Aglaia (Germany). From 2008 till 2010 he has been responsible for Advanced Driver Assistance Systems and Park Assistance Systems for IAV GmbH (Germany). Currently he is responsible for technical strategy in the area of integrated safety and driver support at IAV. He has a track record of fundamental research on these topics which is documented by numerous publications by IEEE, VDI and SAE. He is the editor and editor in chief of different international journals.

Dr. Hadj Hamma Tadjine is fellow Member of IACSIT (International Association of Computer Science and Information Technology), and SCIEI (Science and Engineering Institute. Furthermore he is advisory board member by SDIWC (The Society of Digital Information and Wireless Communications), WSEA (World scientific and Engineering Academy and Society), SAI (Science and Information Organization), and WASET (World Academy of Science, Engineering and Technology) and AICIT (The International Association for Information, Culture, Human and Industry Technology). He is Chair, Technical co-chair and Publication chair of different international conferences on computer engineering and computer vision.

Benedikt Schonlau finished his degree in Mechatronics in 2005 at the Ostwestfalen-Lippe University of Applied Sciences (Germany). Starting in the field of function development for Driver Assistance and Active Safety he has been working for IAV in Chemnitz for over 10 years now. Between 2007 and 2011 Mr. Schonlau worked as project manager on the topic PreCrash. Since 2012 he is Head of Department Active Safety and Lighting Functions. In this role he is responsible for the worldwide establishment of IAV competencies in this field. He has a track record of fundamental research on these topics which is documented by numerous publications by IEEE, VDI and SAE. He is a member in Car2Car communication consortium as well as in ITS Niedersachsen.

DATE: Tuesday, June 21, 2016 TIME: 10:25-10:40

Self-driving cars in the hands of real customers on normal roads – safety and comfort

DR. ERIK COELINGH
Volvo Cars, Sweden

Autonomous – or self-driving – vehicles have long been part of an utopian vision of the future, because they will free people from the boring aspects of driving and open up exciting new ways to travel. They also have the potential to make the road transportation system more sustainable in terms of safety, energy efficiency and transport efficiency. This presentation will provide a quick review of the challenges in the Drive Me program in which we try to bring the benefits of self-driving to real customers on the public road.

For more information look at: www.volvocars.com/autopilot

Erik Coelingh is Senior Technical Leader for Safety and Driver Support Technologies with the Volvo Car Corporation and adjunct professor at Chalmers University of Technology, Gothenburg. He received the M.Sc. and Ph.D. degrees in electrical engineering from the University of Twente, Enschede, The Netherlands, in 1995 and 2000, respectively. After his studies he joined Volvo Car Corporation and worked in several projects on vehicle control and active safety. He was responsible for Volvo's first application of Automatic Emergency Braking in 2006 and led the advanced engineering activities for Pedestrian Detection with Full Auto Brake. He works actively in research and development of various collision avoidance and automated driving features.

WORKSHOP OVERVIEW & PROGRAMS

Sunday

June 19th

The following Workshops and Tutorials are given on Sunday June 19th at the same venue as the main conference: Lindholmen Conference Centre. There are five full day workshops and five half day workshops.

The IV'16 offers the opportunity for participation in several workshops and tutorials, which cover a specific topic of interest in the ITS area. Workshops aim to foster discussion on issues related to the field, emphasizing the interaction between the presenter and the audience. Each workshop will have a number of paper presentations and/or invited talks without paper submission.

Full day	Workshops
09:00-17:30	**1.** Deep-driving: learning representations for intelligent vehicles **Room:** Pascal
09:30–16:45	**2.** Workshop on holistic interfaces for environmental fusion models **Room:** Newton
09:15-16:30	**3.** Workshop on Cooperative Communication and Positioning (CCP) **Room:** Aktiviteten, Lindholmen 3
09:00-16:45	**4.** Workshop on Human Factors in Intelligent Vehicles (HFIV'16) **Room:** Tesla
09:30-15:30	**5.** Extended Object Tracking: Theory and Applications **Room:** Aktiviteten, Lindholmen 12

Half day	Workshops
09:00-13:00	**6.** Vision for Intelligent Vehicles and Application (VIVA) 2016: Workshop and Challenges **Room:** Kelvin
09:15-12:30	**7.** Tutorial: Intelligent Vehicles and Energy Efficiency **Room:** Ampere
09:00-12:30	**8.** 3rd Workshop on Naturalistic Driving Data Analytics **Room:** Aktiviteten, Lindholmen 13
14:00-17:20	**9.** Cooperative autonomous intelligent vehicles are advanced robotic systems of systems: current trends and challenges **Room:** Kelvin
14:00-16:30	**10.** Workshop on Autonomous Vehicles in Off-Road Scenarios **Room:** Aktiviteten, Lindholmen 13

1. Deep-driving: learning representations for intelligent vehicles

Website: http://iv2016.berkeleyvision.org
Room: Pascal

Program

09:05-9:45	Invited Talk of Uwe Franke (Daimler AG, Germany) TBD
09:45-10:30	Invited Talk of Trevor Darrell (EECS UC Berkeley) "The Berkeley DeepDrive Initiative"
10:30-11:00	Coffee Break
11:00-11:45	Invited Talk of Roger D. Melen (Toyota ITC USA) TBD
11:45-12:30	Poster Session (accepted abstracts)
12:30-14:00	Lunch break
14:00-14:45	Invited Talk of Raquel Urtasun (University of Toronto) "Towards affordable self-driving cars"
15:00-15:30	Coffee Break
16:00-16:45	Caffe Tutorial (Evan Shelhamer)
16:45-17:30	Invited talk / Panel Session TBD
17:30	Workshop closing

Organizers: José M. Alvarez, Lars Petersson, Uwe Franke, Trevor Darrell, Carl Henrik Ek, Erik Rodner

2. Workshop on holistic interfaces for environmental fusion models

Website: http://www.ofp-projekt.de/ofp-project/de/Wissenschaftliche-Veroffentlichungen-307.html
Room: Newton

Program

09:30-10:00	Welcome and introduction: "Holistic Interfaces in an Open Fusion Platform", Michael Schilling (Hella)
10:00-10:30	Invited talk: "Measuring the World: Designing Robust Vehicle Localization for Autonomous Driving", Frank Schuster, Martin Haueis, Christoph G. Keller (Daimler)
10:30-11:00	Coffee break
11:00-11:30	Contributed paper: "The need for a sensor fusion to address all ASIL levels at the time", Rolf Johansson (SPTR), Jonas Nilsson (Volvo Cars)
11:30-12:00	Invited talk: "Examining Pedestrian Intentions at Urban Crosswalks", Benjamin Voelz (Bosch)
12:00-12:30	Invited talk: "Towards purposeful intention prediction of pedestrians", Dennis Ludl, David Randler, Björn Browatzki, Cristóbal Curio (Reutlingen University)
12:30-14:00	Lunch
14:00-14:30	Invited talk: "Developing software architectures for autonomous vehicles", Sebastian Ohl (Elektrobit)
14:30-15:00	Invited talk: "Predictive Video Processing for ADAS", Rudolf Mester, VSI Lab (Frankfurt University)
15:00-15:30	Coffee break
15:30-16:00	Invited talk: "Challenges in vision-based fully automated valet parking", Ulrich Schwesinger (ETH-Zürich)
16:00-16:30	Discussion Round with all Speakers, Moderators: Cristóbal Curio & Michael Schilling
16:30-16:45	Workshop closing

Organizers: Michael Schilling, Cristobal Curio

3. Workshop on Cooperative Communication and Positioning (CCP)

Website: http://ccp-iv.eurecom.fr/
Room: Aktiviteten, Lindholmen 3

Program

09:15-10:00	Keynote by Fredrik Tufvesson, Lund University, Title to be confirmed.
10:00-10:20	Invited Presentation on the "EU H2020 HIGHTS project: High precision Positioning for Cooperative-ITS" by Stefano Severi, Jacobs University
10:30-11:00	Coffee break
11:00-11:20	Invited Presentation on the "EU H2020 TIMON project: Enhanced real time services for an optimised multimodal mobility relying on cooperative networks and open data" by Karsten Roscher, Fraunhofer ESK and H2020 TIMON.
11:20-11:40	"Localization in V2X Communication Networks" by Alireza Ghods, Stefano Severi, Giuseppe Abreu
11:40-12:00	"On Prototyping IEEE802.11p Channel Estimators in Real-World Environments Using GNURadio", by Razvan-Andrei Stoica, Stefano Severi, Giuseppe Abreu
12:00-12:20	Invited Presentation on "Cooperative ITS research at Chalmers" by Henk Wymeersch, Chalmers University of Technology
12:30-14:00	Lunch
14:00-14:45	Keynote by Katrin Sjöberg, Volvo AB: "The connected and automated vehicle"
15:00-15:30	Coffee break
15:30:15:50	"Static and Dynamic Performance Evaluation of Low-Cost RTK GPS Receivers", by Martin Skoglund, Thomas Petig, Benjamin Vedder, Henrik Eriksson, Elad Schiller
15:50-16:10	"On Communication Aspects of Particle-Based Cooperative Positioning in GPS-aided VANETs ", by Gia-Minh Hoang, Denis Benoit, Jerome Haerri, Dirk Slock
16:10-16:30	Invited talk on "Heterogeneous Networking for Cooperative Applications" by Karsten Roscher, Fraunhofer ESK and H2020 TIMON.

Organizers: Henk Wymeersch

4. Workshop on Human Factors in Intelligent Vehicles (HFIV'16)

Website: http://hfiv.net/
Room: Tesla

Program

09:00-10:00	Invited Talk "Human Factors in the Automotive Industry", IAV
10:00-10:30	"Automatic and Manual Driving Paradigms: Cost-Efficient Mobile Application for the Assessment of Driver Inattentiveness and Detection of Road Conditions""; Arman Allamehzadeh and Cristina Olaverri Monreal"
10:30-11:00	Coffee break
11:00-11:30	"Evaluating Interactions with Non-existing Automated Vehicles: Three Wizard of Oz Approaches"; A. Habibovic, J. Andersson, M. Nilsson, V. Malmsten Lundgren"
11:30-12:00	"Analyzing driver-pedestrian interaction at crosswalks: A contribution to autonomous driving in urban environments ", Friederike Schneemann Schneemann, Irene Gohl
12:00-12:30	"Mobile based Pedestrian Detection with Accurate Tracking "; Fernando Garcia, Jesus Urdiales, Juan Carmona, David Martin Gomez, José María Armingol Moreno
12.30-14:00	Lunch
14:00-14:30	"Risk Predictive Shared Deceleration Control: Its Functionality and Effectiveness of an Early Intervention Support"; Yuichi Saito, Pongsathorn Raksincharoensak
14:30-15:00	"JLR Heart: Employing Wearable Technology in Non-Intrusive Driver State Monitoring. Preliminary Study"; Vadim Melnicuk, Stewart Birrell, Panos Konstantopoulos, Elizabeth Crundall, Paul Jennings
15:00-15:30	Coffee break
15:30-16:00	"Embedded system for driver behavior analysis based on GMM "; Juan Carmona, Fernando Garcia, Miguel Angel de Miguel, Arturo de la Escalera
16:00-16:30	"Study of the Capabilities of the Yellow Flashing Arrow Traffic Signal and Driver Response"; Samy El-Tawab, Matthew Phelan, Mohammad Almalag, puya Ghazizadeh
16:30-16:45	Conclusions & Wrap up

Organizers: Cristina Olaverri Monreal

5. Extended Object Tracking: Theory and Applications

Room: Aktiviteten, Lindholmen 12

Program:

09:30-09:45	Introduction and Motivation for Extended Object Tracking; Workshop organisers
09:45-10:30	Invited Talk "Single extended object modelling"; Marcus Baum
10:30-11:00	Coffee break
11:00-11:45	Invited Talk "Multiple extended object tracking"; Karl Granström
11:45-12:30	Invited Talk "Applications of extended target methods"; Stephan Reuter
12:30-14:00	Lunch
14:00-14:30	Accepted paper "Online Learning based Multiple Pedestrians Tracking in Thermal Imagery for Safe Driving at Night"; Byoung Chul Ko, Joon Young Kwak, Jae Yeal Nam
14:30-15:00	Accepted paper "Dynamical Tracking of Surrounding Objects for Road Vehicles using Linearly-Arrayed Ultrasonic Sensors "; Jailing Yu, Shengbo Li, Chang Liu, Bo Cheng
15:00	Workshop closing, coffee break

Organizers: Karl Granstrom, Stephan Reuter, Marcus Baum

Half day Workshops

6. Vision for Intelligent Vehicles and Application (VIVA) 2016: Workshop and Challenges

Website: http://cvrr.ucsd.edu/vivachallenge/
Room: Kelvin

Program:

09:00-09:30	Introduction and opening remarks, Professor Mohan M. Trivedi
09:30-10:00	Invited talk "Looking-Inside: Faces"; Ms. Sujitha Martin
10:00-10:30	Invited talk "Looking-Inside: Hands"; Mr. Eshed Ohn-Bar
10:30-11:00	Coffee Break; Poster Session
11:00-11:45	Keynote talk by Professor Raquel Urtasun, University of Toronto, Title to be confirmed
11:45-12:15	Invited talk "Looking-Outside: Signs and Signals"; Mr. Mark Philipsen, Mr. Morten Jensen, Dr. Andreas Moegel-mose
12:15-12:45	Invited talk "Looking-Outside: Vehicles and Trajectories"; Mr. Miklas Kristoffer-sen, Mr. Jacob Dueholm, Mr. Eshed Ohn-bar, Dr. Ravi Satzoda
12:45-13:00	Awards, discussion and closing remarks
13:00-14:00	Lunch; Poster Session

Organizers: Sujitha Martin, Eshed Ohn-Bar, Ravi Kumar Satzoda, Andreas Møgelmose, Mark Philip Philipsen, Morten Jensen, Mohan M. Trivedi

7. Tutorial: Intelligent Vehicles and Energy Efficiency

More information: http://iv2016.org/wp-content/uploads/2016/04/EnergyEfficiency.pdf
Room: Ampere

Program

09:15-10:30	Talk 1: "Energy efficiency with Intelligent Vehicular Technology", Prof. Sousso Kelouwani
10:30-11:00	Coffee break
11:00-12:30	Talk 2: "Soft-Computing Techniques for Intelligent Vehicular Technology ", Prof. Hicham Chaoui
12:30-14:00	Lunch

Learning Outcome:
At the end of the tutorial, the audience should be able to understand the link between intelligent vehicle and energy efficiency:

1. different vehicle power train architectures
2. different sensing technologies to achieve high power flow efficiency
3. role of GIS (Geographical Information System) when dealing with single on-board energy source or hybrid on-board energy sources
4. various well-known driving cycles
5. brief optimisation of driving behaviour in conjunction with road condition (road sensing) and GIS data
6. link between driving security, autonomous driving and energy efficiency
7. soft-computing techniques for intelligent transportation

Organizers: Sousso Kelouwani, Hicham Chaoui

8. 3rd Workshop on Naturalistic Driving Data Analytics

Program and abstracts: http://iv2016.org/wp-content/uploads/2016/04/Programme_and_abstracts_3rd-Workshop-on-Naturalistic-Driving-Data-Analytics_20160418.pdf
Room: Aktiviteten, Lindholmen 13

Program

09:00-09:05	Welcome
09:05-09:40	Analysis of non-critical left turns at intersections and LTAP/OD crashes/near-crashes using naturalistic driving data from EuroFOT and SHRP2. Speaker: Emma Tivesten (Volvo Cars, Sweden)
09:40-10:05	Brake Response Time under Near-crash Cases with Cyclist. Authors: Mingyang Chen, Xichan Zhu, Zhixiong Ma, Lin Li, Dazhi Wang, and Junyong Liu (Tongji University and SAIC Motor Technical Center, China)
10:05-10:30	A graph database for modelling and analysis of naturalistic driving data. Speaker: Camelia Elena Ciolac (Chalmers, Sweden)
10:30-11:00	Coffee break
11:00 11:30	Driving Characteristics from NDS data – Challenges and Approaches to Manage, Extract Features, Analyze, and Predict Behaviors. Speaker: Pujitha Gunaratne (Toyota Collaborative Safety Research Center, USA)
11:30-11:55	Prediction of Individual Driving Behavior on Highway Curves. Speaker: Naren Bao (Nagoya University, Japan)
11:55-12:20	The Australian Naturalistic Driving Study (ANDS). Speaker: Ann Williamson (University of New South Wales, Australia)
12:20-12:30	Closing
12:30-14:00	Lunch

Organizers: Selpi Selpi, Helena Gellerman, Chiyomi Miyajima

9. Cooperative autonomous intelligent vehicles are advanced robotic systems of systems: current trends and challenges

Room: Kelvin

Program

12:30-14:00	Lunch & Poster setup
14:00-14:15	Welcome & introduction (15 min)
14:15-15:00	ITS Invited Talk: Prof Eduardo Nebot "Cooperative Situation Awareness in Intelligent Transportation Systems" (30 min talk + 15 min discussion)
15:00-15:30	Coffee break & Poster session
15:30-15:50	ITS Accepted Paper: Florent Altché, Arnaud de La Fortelle "Analysis of Optimal Solutions to Robot Coordination Problems to Improve Autonomous Intersection Management Policies" (15 min talk + 5 min discussion)
15:50-16:35	MRS Invited Talk: Prof Patrick Doherty "Collaboration framework and mission planning for UAVs in Search and Rescue (30 min talk + 15 min discussion)
16:35-16:55	Poster session (ctd.) or MRS presentation (TBD)
16:55-17:15	Round table discussion on research roadmap and open questions (20 min) • How can we increase collaborations between fields? • What are common research questions in MRS & ITS? • Can we set up a joint research road map for MRS & ITS?
17:15-17:20	Conclusions & Wrap up (5 min)

Organizers: Johan Philips, KU Leuven, Belgium
Alejandro Mosteo, Centro Universitario de la Defensa in Zaragoza, Spain
Danilo Tardioli, Centro Universitario de la Defensa in Zaragoza, Spain
Sazalinsyah Razali, Universiti Teknikal Malaysia Melaka, Malaysia
Lorenzo Sabattini, University of Modena and Reggio Emilia, Italy
IEEE RAS Technical Committee on Multi-Robot Systems

10. Workshop on Autonomous Vehicles in Off-Road Scenarios

Website: http://portal.uc3m.es/portal/page/portal/dpto_ing_sistemas_automatica/investigacion/IntelligentSystemsLab/events/IV16Workshop
Room: Aktiviteten, Lindholmen 13

Program

12:30-14:00	Lunch
14:00-14:15	Welcome
14:15-14:40	"Monocular Vision-Based Obstacle Detection/Avoidance for Unmanned Aerial Vehicles" ; Abdulla Al-Kaff, Qinggang Meng, David Martin Gomez, Arturo de la Escalera, José María Armingol Moreno
14:40-15:00	"Autonomous Vehicle for Surveillance Missions in off-road Environment"; Jose Naranjo, Miguel Clavijo, Felipe Jiménez, Oscar Gómez Casado, José Luis Rivera, Manuel Anguita.
15:00-15:30	Coffee break
15:30-15:55	"Autonomous Off-Road Navigation using Stereo Vision and Laser Rangefinder Fusion for Outdoor Obstacle Detection"; Ahmed Hussein, Pablo Marin Plaza, David Martin Gomez, Arturo de la Escalera, José María Armingol Moreno
15:55-16:20	"A Skyline Detection Algorithm for Use in Different Weather and Environmental Conditions"; Chung-Cheng Chiu, Yun Jiun Liu, Sheng Yi Chiu, Hsing-Chien Chang, Chia-Lun Hsu
16:20-16:30	Closing

Organizers: Fernando Garcia, David Martin Gomez, José María Armingol Moreno, Arturo de la Escalera

TECHNICAL PROGRAM

Technical Program for Monday June 20, 2016

Opening	Conference Hall
Opening Session (Plenary Session)	
Chair: Sjoberg, Jonas	Chalmers Univ
Co-Chair: Morris, Brendan	Univ. of Nevada, Las Vegas
08:30-08:45	
Opening Speeches	
Viberg, Mats	Chalmers Univ
Sjoberg, Jonas	Chalmers Univ
Morris, Brendan	Univ. of Nevada, Las Vegas

MoKeynoteP	Conference Hall
Keynote: Volvo Group (Plenary Session)	
Chair: Sjoberg, Jonas	Chalmers Univ
Co-Chair: Morris, Brendan	Univ. of Nevada, Las Vegas
08:45-09:15	MoKeynoteP.1
*Automation Will Completely Redefine Commercial Transport Solutions**.	
Kellstrom, Anders	Volvo AB
Grante, Christian	Volvo GTT, Advanced Tech. & Res

MoOralAT	Conference Hall
Vision Sensing and Perception (Regular Session)	
Chair: Sanchez-Medina, Javier J.	ULPGC
Co-Chair: Stiller, Christoph	Karlsruhe Inst. of Tech
09:15-09:32	MoOralAT.1
Semantic Stixels: Depth Is Not Enough, pp. 110-117.	
Schneider, Lukas	Daimler, ETH Zurich
Cordts, Marius	Daimler AG, TU Darmstadt
Rehfeld, Timo	MBRDNA
Pfeiffer, David	Daimler AG
Enzweiler, Markus	Daimler AG
Franke, Uwe	Daimler AG
Pollefeys, Marc	ETH Zurich
Roth, Stefan	TU Darmstadt
09:32-09:49	MoOralAT.2
Map-Supervised Road Detection, pp. 118-123.	
Laddha, Ankit	Carnegie Mellon Univ
Kocamaz, Mehmet	Carnegie Mellon Univ
Navarro-Serment, Luis	Carnegie Mellon Univ
Hebert, Martial	Carnegie Mellon Univ
09:49-10:06	MoOralAT.3
A Closer Look at Faster R-CNN for Vehicle Detection, pp. 124-129.	
Fan, Quanfu	IBM T. J. Watson Res. Center
10:06-10:23	MoOralAT.4
Hierarchical CNN for Traffic Sign Recognition, pp. 130-135.	
Mao, Xuehong	Cadence Design Systems
Hijazi, Samer	Cadence Design Systems
Casas, Rual	Cadence Design Systems
Kaul, Piyush	Cadence Design Systems
Kumar, Rishi	Cadence Design Systems
Rowen, Chris	Cadence Design Systems

MoInvitedP	Conference Hall
Invited Talk: AIV (Plenary Session)	
Chair: Stiller, Christoph	Karlsruhe Inst. of Tech
Co-Chair: Sanchez-Medina, Javier J.	ULPGC
10:25-10:40	MoInvitedP.1
*Connected and Autonomous Vehicles: Challenges & Opportunities**.	
Tadjine, Hadj Hamma	IAV GmbH
Schonlau, Benedikt	IAV GmbH

MoOralBT	Conference Hall
Self-Driving Vehicles (Regular Session)	
Chair: Mårtensson, Jonas	KTH Royal Inst. of Tech
Co-Chair: Olaverri Monreal, Cristina	UAS Tech. Wien
11:10-11:27	MoOralBT.1
Visual Autonomous Road Following by Symbiotic Online Learning, pp. 136-143.	
Öfjäll, Kristoffer	Linköping Univ
Felsberg, Michael	Linköping Univ
Robinson, Andreas	Linköping Univ
11:27-11:44	MoOralBT.2
Testing and Validating High Level Components for Automated Driving: Simulation Framework for Traffic Scenarios, pp. 144-150.	
Zofka, Marc René	FZI Forschungszentrum Informatik
Klemm, Sebastian	FZI Forschungszentrum Informatik
Kuhnt, Florian	FZI Forschungszentrum Informatik
Schamm, Thomas	FZI Forschungszentrum Informatik
Zöllner, J. Marius	FZI Res. Center for Information Tech. KIT Karlsruhe In
11:44-12:01	MoOralBT.3
A Dynamic Programming Approach for Nonholonomic Vehicle Maneuvering in Tight Environments, pp. 151-156.	
Schildbach, Georg	Univ. of California at Berkeley
Borrelli, Francesco	Univ. of California, Berkeley
12:01-12:18	MoOralBT.4
Automated Valet Parking and Charging for E-Mobility Results of the V-Charge Project, pp. 157-164.	
Schwesinger, Ulrich	ETH Zurich
Bürki, Mathias	Autnomous Systems Lab, ETH Zürich
Timpner, Julian	Tech. Univ. Braunschweig
Rottmann, Stephan	Tech. Univ. Braunschweig
Wolf, Lars	Tech. Univ. Braunschweig
Paz, Lina Maria	Univ. of Oxford
Grimmet, Hugo	Univ. of Oxford
Posner, Ingmar	Oxford Univ
Newman, Paul	Univ. of Oxford
Häne, Christian	ETHZ
Heng, Lionel	DSO National Lab
Lee, Gim Hee	National Univ. of Singapore
Sattler, Torsten	ETH Zurich
Pollefeys, Marc	ETH Zurich
Allodi, Marco	VisLab Srl
Valenti, Francesco	Univ. Degli Studi Di Parma
Mimura, Keiji	Robert Bosch GmbH

Göbelsmann, Bernd	Robert Bosch GmbH
Derendarz, Wojciech	Volkswagen AG
Muehlfellner, Peter	Volkswagen AG, Halmstad Univ
Wonneberger, Stefan	Volkswagen AG
Waldmann, Rene	Volkswagen AG
Last, Carsten	Volkswagen AG
Siegwart, Roland	ETH Zurich

MoPosterAT1 Open Arena
Poster I: ADAS & Collision Avoidance (Poster Session)
Chair: Murgovski, Nikolce — Chalmers Univ. of Tech

13:20-14:45 MoPosterAT1.1
Predictive Safety Based on Track-Before-Detect for Teleoperated Driving through Communication Time Delay, pp. 165-172.

Hosseini, Amin	Tech. Univ. of Munich
Lienkamp, Markus	Tech. Univ. München

13:20-14:45 MoPosterAT1.2
Fast Decision Making Using Ontology-Based Knowledge Base, pp. 173-178.

Zhao, Lihua	National Inst. of Advanced Industrial Science and Tech
Ichise, Ryutaro	National Inst. of Informatics
Sasaki, Yutaka	Toyota Tech. Inst
Liu, Zheng	Univ. of British Columbia Okanagan
Yoshikawa, Tatsuya	AISIN SEIKI Co., Ltd

13:20-14:45 MoPosterAT1.3
Monocular Parking Slots and Obstacles Detection and Tracking, pp. 179-185.

Allodi, Marco	VisLab Srl
Castangia, Luca	Univ. of Parma
Cionini, Alessandro	VisLab Srl
Valenti, Francesco	Univ. Degli Studi Di Parma

13:20-14:45 MoPosterAT1.4
Extensions for the Foresighted Driver Model: Tactical Lane Change, Overtaking and Continuous Lateral Control, pp. 186-193.

Damerow, Florian	Tech. Univ. of Darmstadt
Flade, Benedict	Honda Res. Inst. (HRI)
Eggert, Julian	Honda Res. Inst. Europe GmbH

13:20-14:45 MoPosterAT1.5
Road Network Reconstruction Using Reversible Jump MCMC Simulated Annealing Based on Vehicle Trajectories from Fleet Measurements, pp. 194-201.

Roeth, Oliver Bertin	Robert Bosch GmbH
Zaum, Daniel	Robert Bosch GmbH
Brenner, Claus	Inst. of Cartography and Geoinformatics, Leibniz Univ

13:20-14:45 MoPosterAT1.6
Trajectory Planning for Collision Avoidance in Urban Area, pp. 202-207.

Ferdinand, Jens	Adam Opel AG
Yi, Boliang	Adam Opel AG

13:20-14:45 MoPosterAT1.7
Estimation and Prediction of Vehicle Dynamics States Based on Fusion of OpenStreetMap and Vehicle Dynamics Models, pp. 208-213.

Jiang, Kun	Univ. of Tech. of Compiegne
Correa Victorino, Alessandro	Univ. De Tech. De Compiègne (UTC)
Charara, Ali	Univ. De Tech. De Compiègne

13:20-14:45 MoPosterAT1.8
Vehicle Speed Tracking Using Chassis Vibrations, pp. 214-219.

Lindfors, Martin	Linköping Univ
Hendeby, Gustaf	Linköping Univ
Gustafsson, Fredrik	Linköping Univ
Karlsson, Rickard	Linköping Univ

13:20-14:45 MoPosterAT1.9
Analytical Derivation of Performance Bounds of Autonomous Emergency Brake Systems, pp. 220-226.

Stellet, Jan Erik	Robert Bosch GmbH
Vogt, Patrick	Univ. of Darmstadt
Schumacher, Jan	Robert Bosch GmbH
Branz, Wolfgang	Robert Bosch GmbH
Zöllner, J. Marius	FZI Res. Center for Information Tech. KIT Karlsruhe In

13:20-14:45 MoPosterAT1.10
Driver Lane Keeping Behavior in Normal Driving Using 100-Car Naturalistic Driving Study Data, pp. 227-232.

Johnson, Taylor	Virginia Tech
Sherony, Rini	Toyota Motor Engineering and Manufacturing North America
Gabler, Hampton Clay	Virginia Tech

13:20-14:45 MoPosterAT1.11
A Collision Avoidance System at Intersections Using Robust Model Predictive Control, pp. 233-238.

Schildbach, Georg	Univ. of California at Berkeley
Soppert, Matthias	Hamburg Univ. of Tech
Borrelli, Francesco	Univ. of California, Berkeley

13:20-14:45 MoPosterAT1.12
Driver Perception and Reaction in Collision Avoidance: Implications for ADAS Development and Testing, pp. 239-245.

Sieber, Markus	Univ. Der Bundeswehr München
Färber, Berthold	Univ. Der Bundeswehr

13:20-14:45 MoPosterAT1.13
3D Motion Planning of UAVs in GPS-Denied Unknown Forest Environment, pp. 246-251.

Liao, Fang	National Univ. of Singapore
Lai, Shupeng	National Univ. of Singapore
Hu, Yuchao	National Univ. of Singapore
Cui, Jinqiang	National Univ. of Singapore
Wang, Jianliang	Nanyang Tech. Univ
Teo, Rodney	DSO National Lab
Lin, Feng	National Univ. of Singapore

MoPosterAT2 Pascal
Poster I: Lidar & Fusion & Self-Driving Vehicles (Poster Session)
Chair: Wymeersch, Henk — Chalmers

13:20-14:45 MoPosterAT2.1
Multi-Sensor Tracking with SPRT in an Autonmous Vehicle, pp. 252-257.

Stess, Marek	Volkswagen AG
Schildwächter, Christian	Tech. Univ. Braunschweig
Mersheeva, Vera	Otto-Von-Guericke Univ. Magdeburg
Ortmeier, Frank	Otto-Von-Guericke Univ. Magdeburg
Wagner, Bernardo	Leibniz Univ. Hannover,

13:20-14:45 MoPosterAT2.2
Why the Association Log-Likelihood Distance Should Be Used for

Measurement-To-Track Association, pp. 258-265.

Altendorfer, Richard — Zf Trw
Wirkert, Sebastian — DKFZ (German Cancer Res. Center)

13:20-14:45 — MoPosterAT2.3

Locally Adaptive Discounting in Multi Sensor Occupancy Grid Fusion, pp. 266-271.

Seeger, Christoph — BMW Group
Manz, Michael — BMW Group
Matters, Patrick — BMW Group
Hornegger, Joachim — Friedrich-Alexander-Univ. Erlangen-Nürnberg

13:20-14:45 — MoPosterAT2.4

A New Geometric 3D LiDAR Feature for Model Creation and Classification of Moving Objects, pp. 272-278.

Kusenbach, Michael — Univ. of the Bundeswehr Munich
Himmelsbach, Michael — Univ. of the Bundeswehr, Munich
Wuensche, Hans Joachim Joe — Univ. Bw Munich

13:20-14:45 — MoPosterAT2.5

Probabilistic Rectangular-Shape Estimation for Extended Object Tracking, pp. 279-285.

Broßeit, Peter — Daimler AG
Rapp, Matthias — Ulm Univ
Appenrodt, Nils — Daimler AG
Dickmann, Jürgen — Mercedes-Benz AG

13:20-14:45 — MoPosterAT2.6

Modeling and Simulation of Rain for the Test of Automotive Sensor Systems, pp. 286-291.

Hasirlioglu, Sinan — Tech. Hochschule Ingolstadt
Doric, Igor — Tech. Hochschule Ingolstadt
Lauerer, Christian — CARISSMA, Tech. Hochschule Ingolstadt
Brandmeier, Thomas — Ingolstadt Univ. of Applied Sciences

13:20-14:45 — MoPosterAT2.7

Integration of a Dynamic Model in a Driving Simulator to Meet Requirements of Various Levels of Automatization, pp. 292-297.

Gauerhof, Lydia — Tech. Univ. München
Bilic, Anito — Tech. Univ. München
Knies, Christian — Tech. Univ. München
Diermeyer, Frank — Tech. Univ. München

13:20-14:45 — MoPosterAT2.8

A Direct Scattering Model for Tracking Vehicles with High-Resolution Radars, pp. 298-303.

Knill, Christina — Ulm Univ
Scheel, Alexander — Univ. of Ulm
Dietmayer, Klaus — Univ. of Ulm

13:20-14:45 — MoPosterAT2.9

Functional System Architectures towards Fully Automated Driving, pp. 304-309.

Tas, Omer Sahin — FZI Res. Center for Information Tech
Kuhnt, Florian — FZI Forschungszentrum Informatik
Zöllner, J. Marius — FZI Res. Center for Information Tech. KIT Karlsruhe In
Stiller, Christoph — Karlsruhe Inst. of Tech

MoPosterAT3 — Conference Hall

Poster I: Vision Sensing and Perception (Poster Session)

Chair: Charalambous, Themistoklis — Chalmers Univ

13:20-14:45 — MoPosterAT3.1

Monocular 3D Shape Reconstruction Using Deep Neural Networks, pp. 310-315.

Rao, Qing — Daimler AG
Krüger, Lars — Daimler AG
Dietmayer, Klaus — Univ. of Ulm

13:20-14:45 — MoPosterAT3.2

Additional Traffic Sign Detection Using Learned Corner Representations, pp. 316-321.

Wenzel, Thomas — Robert Bosch Car Multimedia GmbH
Brueggert, Steffen — Robert Bosch GmbH
Denzler, Joachim — Friedrich-Schiller-Univ. Jena

13:20-14:45 — MoPosterAT3.3

Robust Pedestrian Attribute Recognition for an Unbalanced Dataset Using Mini-Batch Training with Rarity Rate, pp. 322-327.

Fukui, Hiroshi — Chubu Univ
Yamashita, Takayoshi — Chubu Univ
Yamauchi, Yuji — Chubu Univ
Fujiyoshi, Hironobu — Chubu Univ
Murase, Hiroshi — Nagoya Univ

13:20-14:45 — MoPosterAT3.4

Fast Traffic Scene Segmentation Using Multi-Range Features from Multi-Resolution Filtered and Spatial Context Channels, pp. 328-334.

Costea, Arthur Daniel — Tech. Univ. of Cluj-Napoca
Nedevschi, Sergiu — Tech. Univ. of Cluj-Napoca

13:20-14:45 — MoPosterAT3.5

Improving Stereo Reconstruction by Sub-Pixel Correction Using Histogram Matching, pp. 335-341.

Vancea, Cristian Cosmin — Tech. Univ. of Cluj-Napoca
Miclea, Vlad — Tech. Univ. of Cluj-Napoca
Nedevschi, Sergiu — Tech. Univ. of Cluj-Napoca

13:20-14:45 — MoPosterAT3.6

DeepTLR: A Single Deep Convolutional Network for Detection and Classification of Traffic Lights, pp. 342-348.

Weber, Michael — FZI Res. Center for Information Tech
Wolf, Peter — FZI Res. Center for Information Tech
Zöllner, J. Marius — FZI Res. Center for Information Tech. KIT Karlsruhe In

13:20-14:45 — MoPosterAT3.7

Directional-DBSCAN: Parking-Slot Detection Using a Clustering Method in Around-View Monitoring System, pp. 349-354.

Lee, Soomok — Seoul National Univ
Hyeon, Daejin — Seoul National Univ
Park, Gikwang — Seoul National Univ
Baek, Il-joo — LG Electronics
Kim, Seong-Woo — Seoul National Univ
Seo, Seungwoo — Seoul National Univ

13:20-14:45 — MoPosterAT3.8

Combined 2d/3d Traffic Signs Recognition and Distance Estimation, pp. 355-360.

Ben Romdhane, Nadra — MIRACL Lab
Mliki, Hazar — MIRACL Lab
Elbeji, Rabii — National Engineering School of Gabes
Hammami, Mohamed — MIRACL Lab

MoOralCT	Conference Hall
Cooperative Systems (V2X) (Regular Session)	
Chair: Gavrila, Dariu M.	Daimler AG
Co-Chair: Fidan, Baris	Univ. Ofg Waterloo

14:45-15:02 MoOralCT.1

Cooperative Adaptive Cruise Control: An Artificial Potential Field Approach, pp. 361-367.

Semsar-Kazerooni, Elham	TNO
Verhaegh, Jan	TNO
Ploeg, Jeroen	TNO
Alirezaei, Mohsen	TNO

15:02-15:19 MoOralCT.2

V2V Communication for Analysis of Lane Level Dynamics for Better EV Traversal, pp. 368-375.

Agarwal, Akash	International Inst. of Information Tech. Hyderabad
Paruchuri, Praveen	International Inst. of Information Tech. Hyderabad

15:19-15:36 MoOralCT.3

A Hierarchical Model Predictive Control Framework for On-Road Formation Control of Autonomous Vehicles, pp. 376-381.

Qian, Xiangjun	MINES ParisTech
de La Fortelle, Arnaud	Mines ParisTech
Moutarde, Fabien	Mines ParisTech

15:36-15:53 MoOralCT.4

Vehicular Platooning: Multi-Layer Consensus Seeking, pp. 382-387.

Fusco, Mauro	TNO
Semsar-Kazerooni, Elham	TNO
Ploeg, Jeroen	TNO
van de Wouw, Nathan	Eindhoven Univ. of Tech

MoPosterBT1	Open Arena
Poster II: Driver State/Intention & Situation Analysis/Planning (Poster Session)	
Chair: Williamson, Ann	Univ. of New South Wales
Co-Chair: Murgovski, Nikolce	Chalmers Univ. of Tech

16:25-17:50 MoPosterBT1.1

Study on Estimating Driver Awareness of Pedestrians While Turning Right at Intersection Based on Vehicle Behavior Utilizing Driving Simulator, pp. 388-393.

Tateiwa, Kei	Meijo Univ
Nakamura, Akinori	Meijo Univ
Yamada, Keiichi	Meijo Univ

16:25-17:50 MoPosterBT1.2

Detection of Driver Cognitive Distraction: An SVM Based Real-Time Algorithm and Its Comparison Study in Typical Driving Scenarios, pp. 394-399.

Liao, Yuan	State Key Lab of Automotive Safety and Energy, Department of Aut
Li, Shengbo	Dept of Automotive Eng., Tsinghua Univ
Li, Guofa	Tsinghua Univ
Wang, Wenjun	Tsinghua Univ
Cheng, Bo	State Key Lab. of Automotive Safety and Energy, Tsinghua U
Chen, Fang	Chalmers Univ. of Tech

16:25-17:50 MoPosterBT1.3

Driver Drowsiness and Behavior Detection in Prolonged Conditionally Automated Drives, pp. 400-405.

Schmidt, Jürgen	Daimler AG
Braunagel, Christian	Daimler AG
Stolzmann, Wolfgang	Daimler AG
Karrer-Gauss, Katja	Tech. Univ. Berlin

16:25-17:50 MoPosterBT1.4

Developing a Model of Driver's Uncertainty in Lane Change Situations for Trustworthy Lane Change Decision Aid Systems, pp. 406-411.

Yan, Fei	Univ. of Oldenburg
Eilers, Mark	OFFIS E.v
Luedtke, Andreas	OFFIS-Inst. for Information Tech
Baumann, Martin	Ulm Univ

16:25-17:50 MoPosterBT1.5

Predicting Lane Keeping Behaviour of Visually Distracted Drivers Using Inverse Suboptimal Control, pp. 412-418.

Schmitt, Felix	Robert Bosch GmbH
Bieg, Hans-Joachim	Robert Bosch GmbH
Manstetten, Dietrich	Robert Bosch GmbH
Herman, Michael	Robert Bosch GmbH
Stiefelhagen, Rainer	Karlsruhe Inst. of Tech

16:25-17:50 MoPosterBT1.6

Monitoring Driver Cognitive Load Using Functional Near Infrared Spectroscopy in Partially Autonomous Cars, pp. 419-425.

Sibi, Srinath	Stanford Univ
Ayaz, Hasan	Drexel Univ
Kuhns, David	Intel Corp
Sirkin, David	Stanford Univ
Ju, Wendy	Stanford Univ

16:25-17:50 MoPosterBT1.7

Predicting Pedestrian Crossing Using Quantile Regression Forests, pp. 426-432.

Voelz, Benjamin	Robert Bosch GmbH
Mielenz, Holger	Robert Bosch Group
Siegwart, Roland	ETH Zurich
Nieto, Juan Ignacio	ETH Zurich

16:25-17:50 MoPosterBT1.8

Adaptive Learning Based on Guided Exploration for Decision Making at Roundabouts, pp. 433-440.

Gritschneder, Franz	Univ. of Ulm
Hatzelmann, Patrick	Inst. of Measurement, Control and Microtechnology
Thom, Markus	Univ. of Ulm
Kunz, Felix	Univ. Ulm
Dietmayer, Klaus	Univ. of Ulm

16:25-17:50 MoPosterBT1.9

Optimizing a Driving Strategy by Its Sensor Coverage of Relevant Environment Information, pp. 441-446.

Heinrich, Steffen	Freie Univ. Berlin
Stubbemann, Jannes	Univ. of Paderborn
Rojas, Raúl	Berlin Univ

16:25-17:50 MoPosterBT1.10

Tactical Cooperative Planning for Autonomous Highway Driving Using Monte-Carlo Tree Search, pp. 447-453.

Lenz, David	Fortiss GmbH
Kessler, Tobias	Fortiss GmbH
Knoll, Alois	Tech. Univ. München

16:25-17:50 MoPosterBT1.11

Driver and Pedestrian Awareness-Based Collision Risk Analysis, pp. 454-459.

Roth, Markus	Daimler R&D

Flohr, Fabian — Daimler AG
Gavrila, Dariu M. — Daimler AG

MoPosterBT2 — Pascal
Poster II: Energy Efficiency & Mapping (Poster Session)
Chair: Garcia, Fernando — Univ. Carlos III De Madrid
Co-Chair: Wymeersch, Henk — Chalmers

16:25-17:50 — MoPosterBT2.1
*New High-Efficiency Architecture for Regenerative Braking Systems**.
Saci, Samir — Tsinghua Univ
Zhang, Junzhi — Tsinghua Univ
Li, Yutong — Tsinghua Univ. Department of Automotive Engineering - Beij

16:25-17:50 — MoPosterBT2.2
An Adaptive Equivalent Consumption Minimization Strategy for Parallel Hybrid Electric Vehicle Based on Fuzzy PI, pp. 460-465.
Zhang, Fengqi — Beijing Inst. of Tech
Xi, JunQiang — Beijing Inst. of Tech
Langari, Reza — Texas A&M Univ

16:25-17:50 — MoPosterBT2.3
Online MPC Based PHEV Energy Management Using Conic Interior-Point Methods, pp. 466-471.
Sangili Vadamalu, Raja — TU Darmstadt
Beidl, Christian — TU Darmstadt

16:25-17:50 — MoPosterBT2.4
Performance of Current Eco-Routing Methods, pp. 472-477.
Kubicka, Matej — Lab. of Signals and Systems, CNRS, Supélec and Paris-Sud U
Klusáček, Jan — Brno Univ. of Tech
Sciarretta, Antonio — IFP
Cela, Arben — ESIEE Paris
Mounier, Hugues — LSS
Laurent, Thibault — IFPEN
Niculescu, Silviu-Iulian — Lab. De Signaux Et Systemes (L2S, UMR CNRS 8506)

16:25-17:50 — MoPosterBT2.5
How to Distinguish Inliers from Outliers in Visual Odometry for High-Speed Automotive Applications, pp. 478-483.
Buczko, Martin — Tech. Univ. of Darmstadt
Willert, Volker — TU Darmstadt

16:25-17:50 — MoPosterBT2.6
*Monocular Self Localization in an Urban Environment Using a Prior-Based Soft Optimization Robust Estimation Method**.
Dekel, Shay — General Motors Advanced Tech. Center Israel
Levi, Dan — General Motors, Advanced Tech. Center, Israel
Slutsky, Michael — General Motors Advanced Tech. Center Israel
Shimshoni, Ilan — Univ. of Haifa

16:25-17:50 — MoPosterBT2.7
FastSLAM Filter Implementation for Indoor Autonomous Robot, pp. 484-489.
Buonocore, Luciano — Federal Univ. of Maranhão
Barros dos Santos, Sergio Ronaldo — Federal Univ. of Maranhão
de Almeida Neto, Areolino — Federal Univ. of Maranhão
Nascimento Junior, Cairo Lucio — Inst. Tecnologico De Aeronautica

16:25-17:50 — MoPosterBT2.8
Reliable Scale Estimation and Correction for Monocular Visual Odometry, pp. 490-495.
Zhou, Dingfu — Australian National Univ
Dai, Yuchao — The Australian National Univ
Li, Hongdong — Australian National Univ

MoPosterBT3 — Conference Hall
Poster II: V2X and Control (Poster Session)
Co-Chair: Charalambous, Themistoklis — Chalmers Univ

16:25-17:50 — MoPosterBT3.1
*A Freeway Speed Harmonization Experiment Using I2V Communication with Connected, Automated Vehicles**.
Dailey, Daniel J. — Univ. of Washington
Jagannathan, Ramesh — Regional Municipality of Durham
Lochrane, Taylor — U.S. Department of Transportation - Federal Highway Administrati

16:25-17:50 — MoPosterBT3.2
Cooperative Localization of Vehicles Sharing GNSS Pseudoranges Corrections with No Base Station Using Set Inversion, pp. 496-501.
Lassoued, Khaoula — Univ. of Tech. of Compiegne
Bonnifait, Philippe — Univ. of Tech. of Compiegne
Fantoni, Isabelle — Univ. of Tech. of Compiègne, CNRS

16:25-17:50 — MoPosterBT3.3
Towards a Safety Mechanism for Platooning, pp. 502-507.
Van Nunen, Ellen — TNO
Tzempetzis, Dimitrios — Eindhoven Univ. of Tech
Koudijs, Gerald — TNO
Nijmeijer, Henk — Eindhoven Univ. of Tech
van den Brand, Mark — Eindhoven Univ. of Tech

16:25-17:50 — MoPosterBT3.4
Visible Light Inter-Vehicle Communication for Platooning of Autonomous Vehicles, pp. 508-513.
Abualhoul, Mohammad — INRIA Paris-Rocquencourt
Shagdar, Oyunchimeg — INRIA, Paris-Rocquencourt
Nashashibi, Fawzi — INRIA

16:25-17:50 — MoPosterBT3.5
Design and Validation of an MPC-Based Torque Blending and Wheel Slip Control Strategy, pp. 514-520.
Satzger, Clemens Wolfgang — DLR
de Castro, Ricardo — Faculdade De Engenharia Da Univ. Do Porto
Knoblach, Andreas — German Aerospace Center (DLR)
Brembeck, Jonathan — German Aerospace Center (DLR)

16:25-17:50 — MoPosterBT3.6
Parameter Identification for a Multi-Body Vehicle Model, pp. 521-526.
Traub, Lukas — Tech. Univ. München
Butakov, Vadim — Univ. of Southern California
Simpson, Robin — Volkswagen Group of America

16:25-17:50 — MoPosterBT3.7
Combined Lateral and Longitudinal CACC for a Unicycle-Type Platoon, pp. 527-532.
Bayuwindra, Anggera — Eindhoven Univ. of Tech
Aakre, Øyvind Løberg — Norwegian Univ. of Science and Tech

Ploeg, Jeroen	TNO
Nijmeijer, Henk	Eindhoven Univ. of Tech

16:25-17:50	MoPosterBT3.8

Road Friction Estimation Using Recursive Total Least Squares, pp. 533-538.

Shao, Liang	Graz Univ. of Tech
Lex, Cornelia	Graz Univ. of Tech
Hackl, Andreas	Graz Univ. of Tech
Eichberger, Arno	TU Graz

16:25-17:50	MoPosterBT3.9

Experimental Validation of Geometric Path Following Control with Demand Supervision on an Overactuated Robotic Vehicle, pp. 539-545.

Ritzer, Peter	German Aerospace Center
Winter, Christoph	German Aerospace Center
Brembeck, Jonathan	German Aerospace Center (DLR)

16:25-17:50	MoPosterBT3.10

Vehicle Stability Enhancement by an Energy Optimal Control Approach, pp. 546-551.

Arslan, M. Selçuk	Yildiz Tech. Univ

16:25-17:50	MoPosterBT3.11

Lane Keeping System Based on Kinematic Model with Road Friction Coefficient Adaptation, pp. 552-557.

Kang, Chang Mook	Hanyang Univ
Lee, Seung-Hi	Hanyang Univ
Chung, Chung Choo	Hanyang Univ

Technical Program for Tuesday June 21, 2016

TuKeynoteP Conference Hall
Keynote: Highway Loss Data Institute (Plenary Session)

Chair: Nilsson-Ehle, Anna — SAFER
Co-Chair: Takeda, Kazuya — Nagoya Univ

08:30-09:15 TuKeynoteP.1

*Conclusions on Autonomous Emergency Braking Systems and Other Advanced Driver Assistance Technologies**.

Moore, Matt — Highway Loss Data Inst

TuOralAT Conference Hall
Sensor and Data Fusion (Regular Session)

Chair: Cherfaoui, Véronique — Univ. DE Tech. DE COMPIEGNE
Co-Chair: Fredriksson, Jonas — Chalmers Univ. of Tech

09:15-09:32 TuOralAT.1

Multi-Sensor Multi-Object Tracking of Vehicles Using High-Resolution Radars, pp. 558-565.

Scheel, Alexander — Univ. of Ulm
Knill, Christina — Ulm Univ
Reuter, Stephan — Univ. of Ulm
Dietmayer, Klaus — Univ. of Ulm

09:32-09:49 TuOralAT.2

Robust Estimation of Vehicle Longitudinal Dynamics Parameters, pp. 566-571.

Altmannshofer, Simon — Tech. Hochschule Ingolstadt
Endisch, Christian — Tech. Hochschule Ingolstadt
Martin, Jan — Tech. Hochschule Ingolstadt
Gerngroß, Martin — Tech. Univ. München
Limbacher, Reimund — Audi Ag

09:49-10:06 TuOralAT.3

Manoeuvre Segmentation Using Smartphone Sensors, pp. 572-577.

Woo, Christopher — Univ. of Waterloo
Kulic, Dana — Univ. of Waterloo

10:06-10:23 TuOralAT.4

Energy Harvesting System for Intelligent Tyre Sensors, pp. 578-583.

Jousimaa, Otso Jeremias — Aalto Univ
Xiong, Yi — Aalto Univ
Niskanen, Arto Juhani — Aalto Univ. School of Engineering
Tuononen, Ari Juhani — Aalto Univ

TuInvitedP Conference Hall
Invited Talk: Volvo Cars (Plenary Session)

Chair: Fredriksson, Jonas — Chalmers Univ. of Tech

10:25-10:40 TuInvitedP.1

*Self-Driving Cars in the Hands of Real Customers on Normal Roads – Safety and Comfort**.

Coelingh, Erik — Volvo Car Corp

TuOralBT Conference Hall
Vehicle Control (Regular Session)

Chair: Borrelli, Francesco — Univ. of California, Berkeley
Co-Chair: Axehill, Daniel — Linköping Univ

11:10-11:27 TuOralBT.1

Real Time Integrated Vehicle Dynamics Control and Trajectory Planning with MPC for Critical Maneuvers, pp. 584-589.

Yi, Boliang — Adam Opel AG
Gottschling, Stefan — Adam Opel AG
Ferdinand, Jens — Adam Opel AG
Simm, Norbert — Adam Opel AG
Bonarens, Frank — Adam Opel AG
Stiller, Christoph — Karlsruhe Inst. of Tech

11:27-11:44 TuOralBT.2

Coordination of Motion Actuators in Heavy Vehicles Using Model Predictive Control Allocation, pp. 590-596.

Sinigaglia, Andrea — Chalmers Univ. of Tech
Tagesson, Kristoffer — Volvo GTT & Chalmers Uni. of Tech
Falcone, Paolo — Chalmers Univ. of Tech
Jacobson, Bengt J H — Chalmers Univ. of Tech

11:44-12:01 TuOralBT.3

Simultaneous Stabilization and Tracking of Basic Automobile Drifting Trajectories, pp. 597-602.

Goh, Jonathan Y. — Stanford Univ
Gerdes, J Christian — Stanford Univ

12:01-12:18 TuOralBT.4

Nonlinear Lateral Vehicle Control in Combined Emergency Steering and Braking Maneuvers, pp. 603-610.

Kranz, Tobias — Univ. of Applied Sciences Aschaffenburg
Hahn, Stefan — Univ. of Applied Sciences Aschaffenburg
Zindler, Klaus — Univ. of Applied Sciences Hochschule Aschaffenburg

TuPosterAT1 Open Arena
Poster III: Lidar & Sensor Fusion (Poster Session)

Chair: Falcone, Paolo — Chalmers Univ. of Tech

13:20-14:45 TuPosterAT1.1

Understanding the Data-Processing Challenges in Intelligent Vehicular Systems, pp. 611-618.

Costache, Stefania — IBM
Gulisano, Vincenzo — Chalmers Univ. of Tech
Papatriantafilou, Marina — Chalmers Univ. of Tech

13:20-14:45 TuPosterAT1.2

Wireless Energy Autonomous Light Sensor for Automotive Applications, pp. 619-624.

Haider, Majumder — City Univ. Bremen
Kanning, Bastian — Hella Fahrzeugkomponenten GmbH Bremen
Peik, Soeren F. — City Univ. Bremen

13:20-14:45 TuPosterAT1.3

Towards the Friction Potential Estimation: A Model-Based Approach to Utilizing In-Tyre Accelerometer Measurements, pp. 625-629.

Niskanen, Arto Juhani — Aalto Univ. School of Engineering
Xiong, Yi — Aalto Univ
Tuononen, Ari Juhani — Aalto Univ

13:20-14:45 TuPosterAT1.4

Multisensor Simultaneous Vehicle Tracking and Shape Estimation, pp. 630-635.

Elfring, Jos — TNO
Appeldoorn, Rein — TNO
Kwakkernaat, Maurice — TNO

13:20-14:45	TuPosterAT1.5

Accuracy and Robustness of Road Observers with Uncertainties for Reconstruction of the Road Elevation Profile, pp. 636-641.

Noll, Andreas	Audi AG and (Univ. of Augsburg)

13:20-14:45	TuPosterAT1.6

Integrating Driving Behavior and Traffic Context through Signal Symbolization, pp. 642-647.

Yamazaki, Suguru	Nagoya Univ
Miyajima, Chiyomi	Nagoya Univ
Yurtsever, Ekim	Nagoya Univ
Takeda, Kazuya	Nagoya Univ
Mori, Masataka	DENSO Corp
Hitomi, Kentarou	DENSO Corp
Egawa, Masumi	DENSO Corp

13:20-14:45	TuPosterAT1.7

Machine Learning in Tracking Associations with Stereo Vision and Lidar Observations for an Autonomous Vehicle, pp. 648-653.

Allodi, Marco	VisLab Srl
Broggi, Alberto	Univ. of Parma
Giaquinto, Domenico	Univ. Di Parma
Patander, Marco	VisLab - Parma Univ
Prioletti, Antonio	Univ. of Parma

13:20-14:45	TuPosterAT1.8

Model-Based Rail Detection in Mobile Laser Scanning Data, pp. 654-661.

Stein, Denis	FZI Res. Center for Information Tech
Spindler, Max	Karlsruhe Inst. of Tech. (KIT)
Lauer, Martin	Karlsruher Inst. Für Tech

13:20-14:45	TuPosterAT1.9

Automatic Detection of Vehicles at Road Intersections Using a Compact 3D Velodyne Sensor Mounted on Traffic Signals, pp. 662-667.

Aijazi, Ahmad Kamal	Pascal Inst. Univ. Blaise Pascal
Checchin, Paul	Univ. Blaise Pascal - Clermont-Ferrand - FRANCE
Malaterre, Laurent	Inst. Pascal
Trassoudaine, Laurent	Univ. of Clermont-Ferrand

13:20-14:45	TuPosterAT1.10

Efficient Automotive Grid Maps Using a Sensor Ray Based Refinement Process, pp. 668-675.

Jungnickel, Ruben	Ibeo Automotive Systems GmbH
Köhler, Michael	Ibeo Automotive Systems GmbH
Korf, Franz	Hamburg Univ. of Applied Sciences

13:20-14:45	TuPosterAT1.11

Track-Before-Detect Approach on LIDAR Signal Processing for Low SNR Target Detection, pp. 676-682.

Ogawa, Takashi	DENSO Corp
Wanielik, Gerd	Chemnitz Univ. of Tech

13:20-14:45	TuPosterAT1.12

Robust Virtual Scan for Obstacle Detection in Urban Environments, pp. 683-690.

Mengwen, He	Nagoya Univ
Takeuchi, Eijiro	Nagoya Univ
Ninomiya, Yoshiki	Nagoya Univ
Kato, Shinpei	Nagoya Univ

TuPosterAT2	Pascal

Poster III: Self-Driving Vehicles (Poster Session)

Chair: Lidberg, Mathias	Chalmers Univ. of Tech

13:20-14:45	TuPosterAT2.1

Identification of Potential Hazardous Events for an Unmanned Protective Vehicle, pp. 691-697.

Bagschik, Gerrit	Tech. Univ. Braunschweig
Reschka, Andreas	Tech. Univ. Braunschweig
Stolte, Torben	Inst. of Control Engineering, Tech. Univ. Braunsc
Maurer, Markus	TU Braunschweig

13:20-14:45	TuPosterAT2.2

Dynamic Carbon Emissions Minimization for Autonomous Vehicles in the Context of On-Demand Transportation Systems, pp. 698-703.

Fatnassi, Ezzeddine	Higher Inst. of Management of Tunis
Chaouachi, Jouhaina	Inst. of Advanced Business Studies of Carthage

13:20-14:45	TuPosterAT2.3

Using Plug&Play Control for Stable ACC-CACC System Transitions, pp. 704-709.

Navas, Francisco	INRIA
Milanés, Vicente	INRIA
Nashashibi, Fawzi	INRIA

13:20-14:45	TuPosterAT2.4

Experimental Evaluation of Economic Model Predictive Control for an Autonomous Truck, pp. 710-715.

Russo de Almeida Lima, Pedro Filipe	KTH Royal Inst. of Tech
Trincavelli, Marco	Scania CV AB
Nilsson, Mattias	Scania CV AB
Mårtensson, Jonas	KTH Royal Inst. of Tech
Wahlberg, Bo	KTH Royal Inst. of Tech

13:20-14:45	TuPosterAT2.5

Human-Like Planning of Swerve Maneuvers for Autonomous Vehicles, pp. 716-721.

Gu, Tianyu	Carnegie Mellon Univ
Dolan, John	Carnegie Mellon Univ
Lee, Jin-Woo	General Motors Res. and Development

13:20-14:45	TuPosterAT2.6

Realization of Different Driving Characteristics for Autonomous Drive by Using Model Predictive Control, pp. 722-728.

Koga, Ayame	Nagoya Univ
Okuda, Hiroyuki	Nagoya Univ
Tazaki, Yuichi	Nagoya Univ
Suzuki, Tatsuya	Nagoya Univ
Haraguchi, Kentaro	TOYOTA Tech. DEVELOPMENT Corp
Kang, Zibo	TOYOTA Tech. DEVELOPMENT Corp

13:20-14:45	TuPosterAT2.7

The Worst-Time-To-Collision Metric for Situation Identification, pp. 729-734.

Wachenfeld, Walther	Tech. Univ. Darmstadt, Mechanical Engineering
Junietz, Philipp	TU Darmstadt
Wenzel, Raphael	TU Darmstadt, Inst. of Automotive Engineering
Winner, Hermann	Tech. Univ. Darmstadt

13:20-14:45	TuPosterAT2.8

Cross Datasets Vegetation Detection with Spatial Prior and Local Context, pp. 735-740.

Fan, Heng	Temple Univ
Mei, Xue	Toyota Res. Inst. North America
Prokhorov, Danil	Toyota Res. Inst. NA
Ling, Haibin	Temple Univ

13:20-14:45 TuPosterAT2.9

Decoupled Cooperative Trajectory Optimization for Connected Highly Automated Vehicles at Urban Intersections, pp. 741-746.

Krajewski, Robert	Inst. Für Kraftfahrzeuge, RWTH Aachen Univ
Themann, Philipp	Inst. Für Kraftfahrzeuge, RWTH Aachen Univ
Eckstein, Lutz	RWTH Aachen Univ

13:20-14:45 TuPosterAT2.10

Reactive Trajectory Planning and Tracking for Pedestrian-Aware Autonomous Driving in Urban Environments, pp. 747-754.

Cofield, Robert	Auburn Univ
Gupta, Rakesh	Honda Res. Inst. USA Inc

13:20-14:45 TuPosterAT2.11

Human-Driver Speed Profile Modeling for Autonomous Vehicle's Velocity Strategy on Curvy Paths, pp. 755-760.

Geng, Xinli	Univ. of Science and Tech. of China
Liang, Huawei	Inst. of Applied Tech. Hefei Inst. of Physical Sc
Xu, Hao	Univ. of Nevada, Reno
Yu, Biao	Inst. of Advanced Manufacturing Tech
Zhu, Maofei	The Inst. of Advanced Manufacturing Tech. Chinese Acad

TuPosterAT3 Conference Hall

Poster III: Vehicle Control & Collision Avoidance (Poster Session)

Chair: Sjoberg, Jonas	Chalmers Univ

13:20-14:45 TuPosterAT3.1

String Stability of Heterogeneous Leader-Following Vehicle Platoons Based on Constant Spacing Policy, pp. 761-766.

Guo, Xianggui	Nanyang Tech. Univ
Wang, Jianliang	Nanyang Tech. Univ
Liao, Fang	National Univ. of Singapore
Teo, Rodney	DSO National Lab

13:20-14:45 TuPosterAT3.2

High-Precision Motion Control Method and Practice for Autonomous Driving in Complex Off-Road Environments, pp. 767-773.

Sun, Zhenping	National Univ. of Defense Tech
Huang, Zhenhua	National Univ. of Defense Tech
Zhu, Qi	Coll. of Mechatronics and Automation, National Univ. of D
Li, Xiaohui	National Univ. of Defense Tech
Liu, Daxue	National Univ. of Defense Tech

13:20-14:45 TuPosterAT3.3

Hail-A-Drone: Enabling Teleoperated Taxi Fleets, pp. 774-781.

d'Orey, Pedro M.	Inst. De Telecomunicações, Univ. of Porto
Hosseini, Amin	Tech. Univ. of Munich
Azevedo, José	Inst. De Telecomunicações, Univ. Do Porto
Diermeyer, Frank	Tech. Univ. München
Ferreira, Michel	Inst. De Telecomunicações (VAT Nr: PT 502 854 200)
Lienkamp, Markus	Tech. Univ. München

13:20-14:45 TuPosterAT3.4

Direct Homography Control for Vision-Based Platooning, pp. 782-789.

Schaub, Alexander	German Aerospace Center (DLR) - Robotics Mechatronics Center
de Castro, Ricardo	Faculdade De Engenharia Da Univ. Do Porto
Burschka, Darius	Tech. Univ. Munich

13:20-14:45 TuPosterAT3.5

Model-Based Design and Control of Long Heavy Vehicle Combinations, pp. 790-795.

Sundström, Peter	Modelon AB
Andreasson, Johan	Modelon Ab

13:20-14:45 TuPosterAT3.6

Active Trailer Braking System Design with Linear Matrix Inequalities Based Multi-Objective Robust LQR Controller for Vehicle-Trailer Systems, pp. 796-801.

Sever, Mert	Yildiz Tech. Univ
Kaya, Ece Ebru	Yildiz Tech. Univ
Arslan, M. Selçuk	Yildiz Tech. Univ
Yazici, Hakan	Yildiz Tech. Univ

13:20-14:45 TuPosterAT3.7

Scenario Model Predictive Control for Robust Adaptive Cruise Control in Multi-Vehicle Traffic Situations, pp. 802-807.

Schmied, Roman	Johannes Kepler Univ. Linz
Moser, Dominik	Johannes Kepler Univ. Linz
Waschl, Harald	Johannes Kepler Univ. Linz
del Re, Luigi	Johannes Kepler Univ. Linz

13:20-14:45 TuPosterAT3.8

The Modeling of Transfer of Steering between Automated Vehicle and Human Driver Using Hybrid Control Framework, pp. 808-814.

Kaustubh, Mani	AVL LIST GmbH
Willemsen, Dehlia	TNO
Mazo Jr, Manuel	Tech. Univ. of Delft

13:20-14:45 TuPosterAT3.9

Appearance-Based Brake-Lights Recognition Using Deep Learning and Vehicle Detection, pp. 815-820.

Wang, Jian-Gang	Inst. for Infocomm Res
Zhou, Lubing	Inst. for Infocomm Res. A*STAR, Singapore
Pan, Yu	Inst. for Infocomm Res. A*STAR
Lee, Serin	Inst. for Infocomm Res. A*STAR
Song, Zhiwei	Inst. for Infocomm Res. (I2R), Agency for Science, Tech
Han, Boon Siew	Inst. for Infocomm Res. (I2R), Agency for Science, Tech
Saputra, Vincensius Billy	Inst. for Infocomm Res

13:20-14:45 TuPosterAT3.10

Data Veracity in Intelligent Transportation Systems: The Slippery Road Warning Scenario, pp. 821-826.

Staron, Miroslaw	Univ. of Gothenburg
Scandariato, Riccardo	Univ. of Gothenburg

13:20-14:45 TuPosterAT3.11

Longitudinal and Lateral Motion Planning Method for Avoidance of Multi-Obstacles in Urban Environments Based on Inverse Collision Probability, pp. 827-832.

Akagi, Yasuhiro	Tokyo Univ. of Agriculture and Tech
Raksincharoensak, Pongsathorn	Tokyo Univ. of Agriculture and Tech

13:20-14:45 TuPosterAT3.12

*Anticipation Based on a Bi-Level Bi-Objective Modeling for the Decision-Making in the Car-Following Behavior**.

Bennajeh, Anouer	Stratégies d'optimisation et informatique intelligente
Kebair, Fahem	Higher Inst. of Computer Science of Tunis
Ben Said, Lamjed	Higher Inst. of Computer Science of Tunis
Akinine, Samir	Univ. Claude Bernard Lyon 1

13:20-14:45 TuPosterAT3.13

Trajectory Prediction of Cyclists Using a Physical Model and an Artificial Neural Network, pp. 833-838.

Zernetsch, Stefan	Univ. of Applied Sciences Aschaffenburg
Kohnen, Sascha-Marcel	Aschaffenburg Univ. of Applied Sciences
Goldhammer, Michael	Univ. of Applied Sciences Aschaffenburg
Doll, Konrad	Univ. of Applied Sciences Aschaffenburg
Sick, Bernhard	Univ. of Kassel

TuOralCT Conference Hall

Mapping and Localization (Regular Session)

Chair: Nedevschi, Sergiu	Tech. Univ. of Cluj-Napoca
Co-Chair: Sörstedt, Joakim	Volvo Car Group

14:45-15:02 TuOralCT.1

Robust Localization Based on Radar Signal Clustering, pp. 839-844.

Schuster, Frank	Daimler AG
Wörner, Marcus	Daimler AG
Keller, Christoph Gustav	Daimler AG
Haueis, Martin	Daimler AG
Curio, Cristobal	Reutlingen Univ. & Max Planck Inst. for Biological Cybe

15:02-15:19 TuOralCT.2

Towards Online Mobile Mapping Using Inhomogeneous Lidar Data, pp. 845-850.

Vlaminck, Michiel	IPI - Ghent Univ. - Iminds
Luong, Hiep	IPI - Ghent Univ. - Iminds
Goeman, Werner	Grontmij
Philips, Wilfried	Ghent Univ. IMinds
Veelaert, Peter	Ghent Univ

15:19-15:36 TuOralCT.3

A Compact Representation of the Environment and Its Frontiers for Autonomous Vehicle Navigation, pp. 851-857.

Lopez, Eduardo	Univ. of Alicante
Martinez-Marin, Tomas	Univ. De Alicante

15:36-15:53 TuOralCT.4

Vehicle Localization with Tightly Coupled GNSS and Visual Odometry, pp. 858-863.

Schreiber, Markus	FZI Res. Center for Information Tech
Königshof, Hendrik	FZI Res. Center for Information Tech
Hellmund, André-Marcel	FZI Res. Center for Information Tech
Stiller, Christoph	Karlsruhe Inst. of Tech

TuPosterBT1 Open Arena

Poster IV: Mapping and Localization (Poster Session)

Chair: Nedevschi, Sergiu	Tech. Univ. of Cluj-Napoca
Co-Chair: Falcone, Paolo	Chalmers Univ. of Tech

16:25-17:50 TuPosterBT1.1

Vehicle Localization with Low Cost Radar Sensors, pp. 864-870.

Ward, Erik	KTH Royal Inst. of Tech
Folkesson, John	KTH -Royal Inst. of Tech

16:25-17:50 TuPosterBT1.2

Vehicle Localization Using an AVM Camera for an Automated Urban Driving, pp. 871-876.

Park, Sungyoul	Seoul National Univ
Kim, Dongwook	Seoul National Univ
Yi, Kyongsu	Seoul National Univ

16:25-17:50 TuPosterBT1.3

Track-Constrained GNSS/Odometer-Based Train Localization Using a Particle Filter, pp. 877-882.

Liu, Jiang	Beijing Jiaotong Univ
Cai, Baigen	Beijing Jiaotong Univ
Wang, Jian	Beijing Jiaotong Univ

16:25-17:50 TuPosterBT1.4

Road DNA Based Localization for Autonomous Vehicles, pp. 883-888.

Li, Liang	Shanghai Jiao Tong Univ
Yang, Ming	Shanghai Jiao Tong Univ
Wang, Chunxiang	Shanghai Jiao Tong Univ
Wang, Bing	Shanghai Jiao Tong Univ. SEIEE

16:25-17:50 TuPosterBT1.5

Lane-Level Positioning with Sparse Visual Cues, pp. 889-895.

Kogan, Victoria	Univ. of Haifa
Shimshoni, Ilan	Univ. of Haifa
Levi, Dan	General Motors, Advanced Tech. Center, Israel

16:25-17:50 TuPosterBT1.6

Ego-Lane Estimation for Lane-Level Navigation in Urban Scenarios, pp. 896-901.

Rabe, Johannes	Daimler AG
Necker, Marc	Daimler AG
Stiller, Christoph	Karlsruhe Inst. of Tech

16:25-17:50 TuPosterBT1.7

3D Occupancy Grid Mapping Using Statistical Radar Models, pp. 902-908.

Degerman, Johan	SafeRadar Res. Sweden
Thomas, Pernstål	SafeRadar Res. Sweden
Alenljung, Klas	DENSO International Europe

16:25-17:50 TuPosterBT1.8

Ego Lane Estimation Using Vehicle Observations and Map Information, pp. 909-914.

Svensson, Daniel	Volvo Car Corp
Sörstedt, Joakim	Volvo Car Group

16:25-17:50 TuPosterBT1.9

A Robust Terrain-Based Road Vehicle Localization Algorithm, pp. 915-920.

Li, Tianyi	Shanghai Jiao Tong Univ
Yang, Ming	Shanghai Jiao Tong Univ
Zhou, Xujin	Shanghai Jiao Tong Univ
Wang, Chunxiang	Shanghai Jiao Tong Univ

16:25-17:50 TuPosterBT1.10

Using a Single Band GNSS Receiver to Improve Relative Positioning in Autonomous Cars, pp. 921-926.

Stenborg, Erik	Chalmers Univ. of Tech. Volvo

Car Corp
Hammarstrand, Lars — Chalmers Univ. of Tech

16:25-17:50 — TuPosterBT1.11

Vehicle Self-Localization Using 3D Building Map and Stereo Camera, pp. 927-932.

Bao, Jiali — The Univ. of Tokyo
Gu, Yanlei — The Univ. of Tokyo
Hsu, Li-Ta — The Univ. of Tokyo
Kamijo, Shunsuke — The Univ. of Tokyo

16:25-17:50 — TuPosterBT1.12

Keypoint Trajectory Estimation Using Propagation Based Tracking, pp. 933-939.

Fanani, Nolang — Goethe Univ. Frankfurt
Ochs, Matthias — Goethe Univ. Frankfurt Am Main
Bradler, Henry — Goethe Univ. Frankfurt Am Main
Mester, Rudolf — Univ. Frankfurt

16:25-17:50 — TuPosterBT1.13

Landmark Based Localization : LBA Refinement Using MCMC-Optimized Projections of RJMCMC-Extracted Road Marks, pp. 940-947.

Soheilian, Bahman — Univ. Paris-Est, IGN/SR, MATIS
Qu, Xiaozhi — Univ. Paris-Est
Brédif, Mathieu — IGN

TuPosterBT2 — Pascal

Poster IV: Vision Sensing and Perception (Poster Session)

Chair: Bergasa, Luis M. — Univ. of Alcala
Co-Chair: Lidberg, Mathias — Chalmers Univ. of Tech

16:25-17:50 — TuPosterBT2.1

Geodesic Distance Transform-Based Salient Region Segmentation for Automatic Traffic Sign Recognition, pp. 948-953.

Fu, Keren — Chalmers Univ. of Tech
Gu, Irene Y.H. — Chalmers Univ. of Tech
Odblom, Anders — Active Safety CAE, Volvo Cars Corp. Dept. Volvo Cars AB, S
Liu, Feng — Active Safety CAE, Volvo Cars Corp. Department, Volvo Car

16:25-17:50 — TuPosterBT2.2

Online Vehicle Detection Using Deep Neural Networks and Lidar Based Preselected Image Patches, pp. 954-959.

Lange, Stefan, Stefan — Freie Univ. Berlin
Ulbrich, Fritz — Freie Univ. Berlin
Goehring, Daniel — Freie Univ. Berlin

16:25-17:50 — TuPosterBT2.3

A Ground Truth Building Approach for Evaluation of Grid Based Discretization Techniques in Automotive Scenarios, pp. 960-965.

Valenti, Francesco — Univ. Degli Studi Di Parma
Ghidini, Francesca — Vislab Srl
Patander, Marco — VisLab - Parma Univ
Broggi, Alberto — Univ. of Parma

16:25-17:50 — TuPosterBT2.4

Continuous Extrinsic Online Calibration for Stereo Cameras, pp. 966-971.

Mueller, Georg Rupert — Univ. of the Bundeswehr Munich
Wuensche, Hans Joachim Joe — Univ. Bw Munich

16:25-17:50 — TuPosterBT2.5

Parts Selective DPM for Detection of Pedestrians Possessing an Umbrella, pp. 972-977.

Shimbo, Yuto — Nagoya Univ
Kawanishi, Yasutomo — Nagoya Univ
Deguchi, Daisuke — Nagoya Univ
Ide, Ichiro — Nagoya Univ
Murase, Hiroshi — Nagoya Univ

16:25-17:50 — TuPosterBT2.6

Thermal-Infrared Based Drivable Region Detection, pp. 978-985.

Yoon, Jae Shin — KOREA ADVANCED Inst. OF SCIENCE AND Tech. (KAIST)
Park, Kibaek — KAIST
Hwang, Soonmin — KAIST
Kim, Namil — KAIST
Choi, Yukyung — KAIST
Rameau, Francois — KAIST, RCV Lab
Kweon, In So — KAIST

16:25-17:50 — TuPosterBT2.7

Evaluating Visual ADAS Components on the COnGRATS Dataset, pp. 986-991.

Biedermann, Daniel — Goethe Univ. Frankfurt Am Main
Ochs, Matthias — Goethe Univ. Frankfurt Am Main
Mester, Rudolf — Univ. Frankfurt

16:25-17:50 — TuPosterBT2.8

Robust Localization Via Turning Point Filtering with Road Map, pp. 992-997.

Jin, Yidong — Zhejiang Univ
Xiang, Zhiyu — Zhejiang Univ

16:25-17:50 — TuPosterBT2.9

Real-Time Stereo Vision System at Nighttime with Noise Reduction Using Simplified Non-Local Matching Cost, pp. 998-1003.

Xu, Yuquan — Toyota Tech. Inst
Long, Qian — Toyota Tech. Inst
Mita, Seiichi — Toyota Tech. Inst
Tehrani Nik Nejad, Hossein — DENSO Corp
Ishimaru, Kazuhisa — Nippon Soken Inc
Shirai, Noriaki — DENSO Corp

16:25-17:50 — TuPosterBT2.10

Robust Road Marking Detection Using Convex Grouping Method in Around-View Monitoring System, pp. 1004-1009.

Hyeon, Daejin — Seoul National Univ
Lee, Soomok — Seoul National Univ
Jung, Soonhong — LG Electronics
Kim, Seong-Woo — Seoul National Univ
Seo, Seungwoo — Seoul National Univ

16:25-17:50 — TuPosterBT2.11

Vision for Intelligent Vehicles & Applications (VIVA): Face Detection and Head Pose Challenge, pp. 1010-1014.

Martin, Sujitha — Univ. of California, San Diego
Yuen, Kevan — Univ. of California, San Diego
Trivedi, Mohan M. — Univ. of California at San Diego

16:25-17:50 — TuPosterBT2.12

Safe Maneuverability Zones & Metrics for Data Reduction in Naturalistic Driving Studies, pp. 1015-1021.

Satzoda, Ravi Kumar — Univ. of California San Diego
Trivedi, Mohan M. — Univ. of California at San Diego

16:25-17:50 — TuPosterBT2.13

Vision-Based Pedestrian Monitoring at Intersections Including Behavior & Crossing Count, pp. 1022-1027.

Shokrolah Shirazi, Mohammad — Univ. of Nevada, Las Vegas
Morris, Brendan — Univ. of Nevada, Las Vegas

16:25-17:50	TuPosterBT2.14

A New Benchmark for Vision-Based Cyclist Detection, pp. 1028-1033.

Li, Xiaofei	Tsinghua Univ. Beijing
Flohr, Fabian	Daimler AG
Yang, Yue	Driver Assistance and Chassis Systems, Daimler Greater China Ltd
Xiong, Hui	Beihang Univ. China
Braun, Markus	Daimler AG
Pan, Shuyue	Tech. Univ. of Braunschweig
Li, Keqiang	Tsinghua Univ
Gavrila, Dariu M.	Daimler AG

16:25-17:50	TuPosterBT2.15

Development and Comparison of Homography Based Estimation Techniques for Camera to Road Surface Orientation, pp. 1034-1040.

Westerhoff, Jens	Bergische Univ. Wuppertal
Lessmann, Stephanie	Delphi
Meuter, Mirko	Delphi Electronics & Safety
Jan, Siegemund	Delphi
Kummert, Anton	Univ. of Wuppertal

16:25-17:50	TuPosterBT2.16

Accurate and Robust Lane Detection Based on Dual-View Convolutional Neutral Network, pp. 1041-1046.

He, Bei	Baidu Map
Ai, Rui	Baidu Map
Yan, Yang	Baidu Map
Lang, Xianpeng	Baidu Map

TuPosterBT3	Conference Hall

Poster IV: V2X & Eco-Driving & Traffic Flow (Poster Session)

Chair: Fredriksson, Jonas	Chalmers Univ. of Tech
Co-Chair: Cherfaoui, Véronique	Univ. DE Tech. DE COMPIEGNE

16:25-17:50	TuPosterBT3.1

Platooning at Traffic Lights - a Microscopic Simulation Study, pp. 1047-1053.

Günther, Hendrik-Jörn	Volkswagen Group Res. and Tech. Univ. Braunschwei
Kleinau, Sandra	Volkswagen AG Group Res
Trauer, Oliver	C4c Engineering GmbH Braunschweig
Wolf, Lars	Tech. Univ. Braunschweig

16:25-17:50	TuPosterBT3.2

An Overtaking Decision Algorithm for Networked Intelligent Vehicles Based on Cooperative Perception, pp. 1054-1059.

Vasic, Milos	EPFL
Lederrey, Gael	EPFL
Navarro, Inaki	EPFL
Martinoli, Alcherio	EPFL

16:25-17:50	TuPosterBT3.3

Cooperative Positioning and Radar Sensor Fusion for Relative Localization of Vehicles, pp. 1060-1065.

de Ponte Müller, Fabian	German Aerospace Center (DLR)
Munoz Diaz, Estefania	German Aerospace Center DLR
Rashdan, Ibrahim	German Aerospace Center DLR

16:25-17:50	TuPosterBT3.4

Evaluating the Requirements of Communicating Vehicles in Collaborative Automated Driving, pp. 1066-1071.

Ozbilgin, Guchan	Ohio State Univ
Ozguner, Umit	Ohio State Univ
Altintas, Onur	Toyota InfoTechnology Center
Kremo, Haris	Toyota InfoTechnologies Center
Maroli, John	The Ohio State Univ

16:25-17:50	TuPosterBT3.5

Cooperative Road Condition Estimation for an Adaptive Model Predictive Collision Avoidance Control Strategy, pp. 1072-1077.

Jalalmaab, Mehdi	Univ. of Waterloo
Pirani, Mohammad	Univ. of Waterloo
Fidan, Baris	Univ. Ofg Waterloo
Jeon, Soo	Univ. of Waterloo

16:25-17:50	TuPosterBT3.6

Cooperation of Autonomous Vehicles Using a Hierarchy of Auction-Based and Model-Predictive Control, pp. 1078-1084.

Rewald, Hannes	Univ. of Kassel
Stursberg, Olaf	Univ. of Kassel

16:25-17:50	TuPosterBT3.7

Vehicle Infrastructure Cooperative Localization Using Factor Graphs, pp. 1085-1090.

Gulati, Dhiraj	Fortiss GmbH
Zhang, Feihu	TU Munich
Clarke, Daniel Stephen	Fortiss GmbH - an Inst. of the Tech. Univ. of Munic
Knoll, Alois	Tech. Univ. München

16:25-17:50	TuPosterBT3.8

GPS Spoofing Detection and Mitigation Using Cooperative Adaptive Cruise Control System, pp. 1091-1096.

Carson, Nathaniel	Auburn Univ
Martin, Scott	Auburn Univ
Starling, Joshua	Auburn Univ
Bevly, David	Auburn Univ

16:25-17:50	TuPosterBT3.9

Impact Analysis of AUTOSAR Energy Saving Mechanisms for Automotive Networks, pp. 1097-1102.

Hong, Wei	FZI Res. Center for Information Tech
Viehl, Alexander	Forschungszentrum Informatik Karlsruhe
Lin, Juguang	JEE Automation Equipment Co.LTD
Bringmann, Oliver	Eberhard Karls Univ. Tübingen
Rosenstiel, Wolfgang	Eberhard Karls Univ. Tübingen

16:25-17:50	TuPosterBT3.10

Unified Predictive Fuel Efficiency Optimization Using Traffic Light Sequence Information, pp. 1103-1108.

Guan, Tianyi	Fraunhofer IOSB
Frey, Christian	Fraunhofer IOSB

16:25-17:50	TuPosterBT3.11

Safety, Mobility and Environmental Sustainability of Eco-Approach and Departure Application at Signalized Intersections: A Simulation Study, pp. 1109-1114.

Li, Weixia	Tsinghua Univ
Wu, Guoyuan	Univ. of California-Riverside
Zhang, Yi	Tsinghua Univ
Barth, Matthew	Univ. of California-Riverside

16:25-17:50	TuPosterBT3.12

*The Impacts of Highly Automated Vehicles on Safety and Stability of Freeway Traffic Flow**.

Motamedidehkordi, Nassim	Tech. Univ. of Munich
Margreiter, Martin	Tech. Univ. of Munich

Hoffmann, Silja	Tech. Univ. München, Chair of TrafficEngineering and Control

16:25-17:50	TuPosterBT3.13

Car Type Recognition with Deep Neural Networks, pp. 1115-1120.

Huttunen, Heikki	Tampere Univ. of Tech
Shokrollahi Yancheshmeh, Fatemeh	Tampere Univ. of Tech
Chen, Ke	Tampere Univ. of Tech

16:25-17:50	TuPosterBT3.14

Coping with Non-Recurring Congestion with Distributed Hybrid Routing Strategy, pp. 1121-1127.

Seredynski, Marcin	Luxembourg Inst. of Science and Tech
Grzybek, Agata	Univ. of Luxembourg

Technical Program for Wednesday June 22, 2016

WeKeynoteP Conference Hall
Keynote: TNO (Plenary Session)

Chair: Sotelo, Miguel A. — Univ. of Alcala

08:45-09:30 WeKeynoteP.1

*I-GAME: From Platooning to Cooperative Automated Maneuvering**.

Ploeg, Jeroen — TNO

WeOralAT Conference Hall
Advanced Driver Assistance Systems (Regular Session)

Chair: Vlacic, Ljubo — Griffith Univ
Co-Chair: Selpi, Selpi — Chalmers Univ. of Tech

09:30-09:47 WeOralAT.1

A Bayesian Framework for Preventive Assistance at Road Intersections, pp. 1128-1134.

Armand, Alexandre — Renault SA
Filliat, David — ENSTA ParisTech
Ibanez Guzman, Javier — Renault S.A.S,

09:47-10:04 WeOralAT.2

Preliminary Potential Crash Prevention Estimates for an Intersection Advanced Driver Assistance System in Straight Crossing Path Crashes, pp. 1135-1140.

Scanlon, John Michael — Virginia Tech
Gabler, Hampton Clay — Virginia Tech
Sherony, Rini — Toyota Motor Engineering and Manufacturing North America

10:04-10:21 WeOralAT.3

Probabilistic Situation Assessment Framework for Multiple, Interacting Traffic Participants in Generic Traffic Scenes, pp. 1141-1148.

Klingelschmitt, Stefan — Tech. Univ. of Darmstadt
Damerow, Florian — Tech. Univ. of Darmstadt
Willert, Volker — TU Darmstadt
Eggert, Julian — Honda Res. Inst. Europe GmbH

10:21-10:38 WeOralAT.4

A Model-Based Scenario Specification Method to Support Development and Test of Automated Driving Functions, pp. 1149-1155.

Bach, Johannes — FZI Res. Center for Information Tech
Otten, Stefan — FZI Res. Center for Information Tech
Sax, Eric — FZI Res. Center for Information Tech

WePosterAT1 Open Arena
Poster V: Advanced Driver Assistance Systems (Poster Session)

Chair: Willemsen, Dehlia — TNO
Co-Chair: Sjoberg, Jonas — Chalmers Univ

11:00-12:25 WePosterAT1.1

Path Tracking and Stabilization for a Reversing General 2-Trailer Configuration Using a Cascaded Control Approach, pp. 1156-1161.

Evestedt, Niclas — Linköpings Univ
Ljungqvist, Oskar — Linköping Univ
Axehill, Daniel — Linköping Univ

11:00-12:25 WePosterAT1.2

Integrated Adaptive Cruise Control Design Considering the Optimization of Switching between Throttle and Brake, pp. 1162-1167.

Luo, Lihua — Shanghai Maritime Univ
Chen, Jihong — Shanghai Maritime Univ
Zhang, Fangwei — Shanghai Maritime Univ

11:00-12:25 WePosterAT1.3

Reliable Routing in Stochastic Time-Dependent Network with the Use of Actual and Forecast Information of the Traffic Flows, pp. 1168-1172.

Agafonov, Anton — Samara State Aerospace Univ
Myasnikov, Vladislav — Samara State Aerospace Univ

11:00-12:25 WePosterAT1.4

Using Insurance Claims Data to Evaluate the Collision Avoidance and Crash-Mitigating Effect of Collision Warning and Brake Support with Adaptive Cruise Control, pp. 1173-1178.

Isaksson-Hellman, Irene — If P&C Insurance
Lindman, Magdalena — Volvo Car Corp

11:00-12:25 WePosterAT1.5

A Multi-Domain Simulation Approach to Validate Advanced Driver Assistance Systems, pp. 1179-1184.

Feilhauer, Marius — ETAS GmbH
Häring, Dr. Jürgen — ETAS GmbH

11:00-12:25 WePosterAT1.6

Inferring a Spatial Road Representation from the Behavior of Real World Traffic Participants, pp. 1185-1191.

Casapietra, Edoardo — Bielefeld Univ
Weisswange, Thomas H. — Honda Res. Inst. Europe GmbH
Goerick, Christian — Honda Res. Inst. Europe GmbH
Kummert, Franz — Bielefeld Univ

11:00-12:25 WePosterAT1.7

The Narrow Road Assistant - Evolution towards Highly Automated Driving in Inner City, pp. 1192-1198.

Michalke, Thomas Paul — Robert Bosch GmbH
Gläser, Claudius — Robert Bosch GmbH
Buerkle, Lutz — Robert Bosch GmbH
Niewels, Frank — Robert Bosch GmbH

11:00-12:25 WePosterAT1.8

Probabilistic Distance Estimation for Vehicle Tracking Application in Monocular Vision, pp. 1199-1204.

Lessmann, Stephanie — Delphi
Meuter, Mirko — Delphi Electronics & Safety
Mueller, Dennis — Delphi Electronics & Safety
Pauli, Josef — Univ. Duisburg-Essen

11:00-12:25 WePosterAT1.9

Blurring the Border between Real and Virtual Parking Environments, pp. 1205-1210.

Becker, Daniel — Daimler Center for Automotive Information Tech. Innovations
Munjere, Andrew — Fraunhofer FOKUS
Einsiedler, Jens — Fraunhofer Society
Massow, Kay — Fraunhofer Fokus
Thiele, Fabian — Daimler Center for Automotive Information Tech. Innovations
Radusch, Ilja — Fraunhofer FOKUS

11:00-12:25 WePosterAT1.10

Towards Personalized Automated Driving: Prediction of Preferred ACC Behavior Based on Manual Driving, pp. 1211-1216.

de Gelder, Erwin — TNO
Cara, Irene — TNO
Uittenbogaard, Jeroen — TNO

Kroon, Liselotte	TNO
van Iersel, Sven	TNO
Hogema, Jeroen	TNO

11:00-12:25 WePosterAT1.11

Variable-Sensitivity Road Departure Warning System Based on Static, Mapped, Near-Road Threats, pp. 1217-1223.

Arora, Prashant	The Pennsylvania State Univ
Corbin, David	The Pennsylvania State Univ
Brennan, Sean	The Pennsylvania State Univ

11:00-12:25 WePosterAT1.12

Multi-Level Cooperation between the Driver and an Automated Driving System During Lane Change Maneuver, pp. 1224-1229.

Benloucif, Mohamed Amir	LAMIH, UVHC-CNRS UMR 8201 Univ. of Valenciennes
Popieul, Jean-Christophe	Univ. De Valenciennes
Sentouh, Chouki	LAMIH/CNRS Univ. of Valenciennes

11:00-12:25 WePosterAT1.13

Improving Robustness for Real-Time Vehicle Egomotion Estimation, pp. 1230-1235.

Lessmann, Stephanie	Delphi Electronics & Safety
Siegemund, Jan	Univ. of Bonn
Meuter, Mirko	Delphi Electronics & Safety
Westerhoff, Jens	Bergische Univ. Wuppertal
Pauli, Josef	Univ. Duisburg-Essen

11:00-12:25 WePosterAT1.14

Learning-Based Trajectory Generation for Intelligent Vehicles in Urban Environment, pp. 1236-1241.

Guo, Chunzhao	Toyota Central R&D Labs., Inc
Kidono, Kiyosumi	Toyota Central R&D Labs., Inc
Ogawa, Masaru	Toyota Central R&D Labs., Inc

WePosterAT2 Pascal

Poster V: Situation Analysis and Planning (Poster Session)

Chair: Brennan, Sean	The Pennsylvania State Univ
Co-Chair: Fredriksson, Jonas	Chalmers Univ. of Tech

11:00-12:25 WePosterAT2.1

Combing Task and Motion Planning for Intersection Assistance Systems, pp. 1242-1247.

Chen, Chao	Fortiss GmbH
Rickert, Markus	Fortiss GmbH
Knoll, Alois	Tech. Univ. München

11:00-12:25 WePosterAT2.2

Temporal Logic for Finding Undesired Behaviors of Autonomous Vehicles in a State Space Explored by Dynamic Analysis, pp. 1248-1253.

Minnerup, Pascal	Fortiss GmbH
Knoll, Alois	Tech. Univ. München

11:00-12:25 WePosterAT2.3

A Markov Decision Process-Based Approach for Trajectory Planning with Clothoid Tentacles, pp. 1254-1259.

Mouhagir, Hafida	Heudiasyc-UTC
Talj, Reine	Univ. De Tech. De Compiègne, Heudiasyc
Cherfaoui, Véronique	Univ. DE Tech. DE COMPIEGNE
Guillemard, Franck	PSA Peugeot Citroen, Velizy, France
Aioun, Francois	PSA Peugeot Citroen, Velizy, France

11:00-12:25 WePosterAT2.4

Extracting Path Graphs from Vehicle Trajectories, pp. 1260-1264.

Ulbrich, Fritz	Freie Univ. Berlin
Rotter, Simon	Freie Univ. Berlin
Goehring, Daniel	Freie Univ. Berlin
Raul, Rojas	Freie Univ. Berlin

11:00-12:25 WePosterAT2.5

A Novel Rear-End Collision Warning System Using Neural Network Ensemble, pp. 1265-1270.

An, Jhonhyun	Yonsei Univ
Choi, Baehoon	Yonsei Univ
Hwang, Taehun	Hyundai Mobis
Kim, Euntai	Yonsei Univ

11:00-12:25 WePosterAT2.6

Understanding Interactions between Traffic Participants Based on Learned Behaviors, pp. 1271-1278.

Kuhnt, Florian	FZI Forschungszentrum Informatik
Schulz, Jens	BMW Group Res. and Tech
Schamm, Thomas	FZI Forschungszentrum Informatik
Zöllner, J. Marius	FZI Res. Center for Information Tech. KIT Karlsruhe In

11:00-12:25 WePosterAT2.7

Adaptive Vehicle Longitudinal Trajectory Prediction for Automated Highway Driving, pp. 1279-1284.

Guo, Chunshi	Renault
Sentouh, Chouki	LAMIH/CNRS Univ. of Valenciennes
Soualmi, Boussaad	IRT Systemx
Haue, Jean-Baptiste	UCSD
Popieul, Jean-Christophe	Univ. De Valenciennes

11:00-12:25 WePosterAT2.8

Probability Estimation for Predicted-Occupancy Grids in Vehicle Safety Applications Based on Machine Learning, pp. 1285-1292.

Nadarajan, Parthasarathy	Tech. Hochschule Ingolstadt
Botsch, Michael	Tech. Hochschule Ingolstadt

11:00-12:25 WePosterAT2.9

Wiggling through Complex Traffic: Planning Trajectories Constrained by Predictions, pp. 1293-1300.

Schlechtriemen, Julian	Daimler AG
Wabersich, Kim Peter	Univ. of Stuttgart
Kuhnert, Klaus-Dieter	Univ. of Siegen, Germany

11:00-12:25 WePosterAT2.10

Runtime-Bounded Tunable Motion Planning for Autonomous Driving, pp. 1301-1306.

Gu, Tianyu	Carnegie Mellon Univ
Dolan, John	Carnegie Mellon Univ
Lee, Jin-Woo	General Motors Res. and Development

11:00-12:25 WePosterAT2.11

The Multilayer Perceptron Approach to Lateral Motion Prediction of Surrounding Vehicles for Autonomous Vehicles, pp. 1307-1312.

Yoon, Seungje	KOREA ADVANCED Inst. OF SCIENCE AND Tech. (KAIST)
Kum, Dongsuk	Korea Advanced Inst. of Science & Tech

11:00-12:25 WePosterAT2.12

Driving Word2vec: Distributed Semantic Vector Representation for Symbolized Naturalistic Driving Data, pp. 1313-1320.

Fuchida, Yusuke	Ritsumeikan Univ
Taniguchi, Tadahiro	Ritsumeikan Univ

Takano, Toshiaki	Ritsumeikan Univ
Mori, Takuma	Ritsumeikan Univ
Takenaka, Kazuhito	DENSO Corp
Bando, Takashi	DENSO International America, Inc

11:00-12:25 WePosterAT2.13

SMARTcycling: Assessing Cyclists' Driving Experience, pp. 1321-1326.

Vieira, Pedro Sousa	Inst. Superior Técnico
Costeira, João P.	IST/UTL
Brandao, Susana	Inst. Superior Tecnico
Marques, Manuel	Inst. Superior Técnico

WePosterAT3 Conference Hall

Poster V: HMI and Factors & Driver State and Intent (Poster Session)

Chair: Hammarstrand, Lars	Chalmers Univ. of Tech
Co-Chair: Morris, Brendan	Univ. of Nevada, Las Vegas

11:00-12:25 WePosterAT3.1

Driving Automation & Changed Driver's Task - Effect of Driver-Interfaces on Intervention, pp. 1327-1332.

van den Beukel, Arie Paul	Univ. of Twente
van der Voort, Mascha C.	Univ. of Twente

11:00-12:25 WePosterAT3.2

A Brain Signals-Based Interface between Drivers and In-Vehicle Devices, pp. 1333-1337.

He, Tenghuan	Beijing Inst. of Tech
Bi, Luzheng	Beijing Inst. of Tech
Lian, Jinling	Beijing Inst. of Tech
Sun, Huafei	Beijing Inst. of Tech

11:00-12:25 WePosterAT3.3

Discriminative Dictionary Learning Sparse Coding for Person Re-Identification, pp. 1338-1343.

Sheng, Hao	Beihang Univ
Zhang, Beichen	Beihang Univ
Huang, Yan	Beihang Univ
Zheng, Yanwei	Beihang Univ
Xiong, Zhang	Beihang Univ

11:00-12:25 WePosterAT3.4

Public Perception of V2X-Technology – Evaluation of General Advantages, Disadvantages and Reasons for Data Sharing with Connected Vehicles, pp. 1344-1349.

Schmidt, Teresa	RWTH Aachen Univ
Philipsen, Ralf	RWTH Aachen Univ
Themann, Philipp	Inst. Für Kraftfahrzeuge, RWTH Aachen Univ
Ziefle, Martina	RWTH Aachen Univ

11:00-12:25 WePosterAT3.5

Towards Selecting Robust Hand Gestures for Automotive Interfaces, pp. 1350-1357.

Gupta, Shalini	NVIDIA
Molchanov, Pavlo	NVIDIA
Yang, Xiaodong	NVIDIA
Kim, Kihwan	NVIDIA Res
Tyree, Stephen	NVIDIA
Kautz, Jan	NVIDIA

11:00-12:25 WePosterAT3.6

Take the Wheel: Effects of Available Modalities on Driver Intervention, pp. 1358-1365.

Mok, Brian	Stanford Univ
Johns, Mishel	Stanford Univ
Gowda, Nikhil	Renault Innovation Silicon Valley
Sibi, Srinath	Stanford Univ
Ju, Wendy	Stanford Univ

11:00-12:25 WePosterAT3.7

Enhancing Telepresence During the Teleoperation of Road Vehicles Using HMD-Based Mixed Reality, pp. 1366-1373.

Hosseini, Amin	Tech. Univ. of Munich
Lienkamp, Markus	Tech. Univ. München

11:00-12:25 WePosterAT3.8

Validation of a HMI Concept Indicating the Status of the Traffic Light Signal in the Context of Automated Driving in Urban Environment, pp. 1374-1379.

Kettwich, Carmen	German Aerospace Centre (DLR)
Haus, Raphael	Mobfish GmbH
Temme, Gerald	Organisation
Schieben, Anna	Senior Res

11:00-12:25 WePosterAT3.9

Correlation between Subjective Driver State Measures and Psychophysiological and Vehicular Data in Simulated Driving, pp. 1380-1385.

Schmidt, Elisabeth	Bmw Ag
Decke, Ralf	BMW Forschung Und Tech
Rasshofer, Ralph	BMW Forschung Und Tech. GmbH

11:00-12:25 WePosterAT3.10

Driver State Estimation for Prediction of Vehicle States within Control Systems, pp. 1386-1391.

Fünfgeld, Sebastian	Dr. Ing. H.c. F. Porsche AG
Holzaepfel, Marc	Dr. Ing. H.c. F. Porsche AG
Frey, Michael	Karlsruhe Inst. of Tech. Inst. of Vehicle System T
Gauterin, Frank	Inst. of Vehicle System Tech. Karlsruhe Inst. Te

11:00-12:25 WePosterAT3.11

Towards Hybrid Driver State Monitoring: Review, Future Perspectives and the Role of Consumer Electronics, pp. 1392-1397.

Melnicuk, Vadim	Univ. of Warwick
Birrell, Stewart	Univ. of Warwick
Crundall, Elizabeth	Bright Eyes Scientific Services
Jennings, Paul	WMG, Univ. of Warwick

11:00-12:25 WePosterAT3.12

Fusion of Driver-Information Based Driver Status Recognition for Co-Pilot System, pp. 1398-1403.

Kim, Jinwoo	ETRI
Kim, Ki Tae	Univ. of Science and Tech

11:00-12:25 WePosterAT3.13

Comparing Datasets for Generalizing Models of Driver Intent in Dynamic Environments, pp. 1404-1409.

Driggs-Campbell, Katherine	Univ. of California, Berkeley
Bajcsy, Ruzena	Univ. of California, Berkeley

11:00-12:25 WePosterAT3.14

The Rhythms of Head, Eyes and Hands at Intersections, pp. 1410-1415.

Martin, Sujitha	Univ. of California, San Diego
Rangesh, Akshay	Univ. of California, San Diego
Ohn-Bar, Eshed	Univ. of California San Diego
Trivedi, Mohan M.	Univ. of California at San Diego

Closing Conference Hall

Closing Session (Plenary Session)

12:25-12:40

Closing Speeches

Nilsson-Ehle, Anna	SAFER
Sjoberg, Jonas	Chalmers Univ

BOOK OF ABSTRACTS

Book of Abstracts: Sunday June 19, 2016

SuW1T1 — Pascal

DeepDriving: From Low Level Task to High Level Reasoning (Workshop)

Chair: Alvarez, José M.	NICTA
Organizer: Alvarez, José M.	NICTA
Organizer: Petersson, Lars	NICTA
Organizer: Franke, Uwe	Daimler AG

09:00-09:05 — SuW1T1.1

*Vision, You Can Drive My Car (I)**

Franke, Uwe — Daimler AG

09:45-10:30 — SuW1T1.3

*The Berkeley DeepDrive Initiative (I)**

Darrell, Trevor — UC Berkeley

11:00-11:45 — SuW1T1.5

*Considerations for Future Automated and Autonomous Vehicle Designs (I)**

Melen, Roger D. — Toyota ITC

14:00-14:45 — SuW1T1.8

*Towards Affordable Self-Driving Cars (I)**

Urtasun, Raquel — Univ. of Toronto

15:45-16:45 — SuW1T1.10

*Caffe Tutorial (I)**

Shelhamer, Evan — Univ. of California, Berkeley

SuW2T2 — Newton

Workshop on Holistic Interfaces for Environmental Fusion Models (Workshop)

Chair: Schilling, Michael	HELLA KGaA Hueck & Co
Co-Chair: Curio, Cristobal	Reutlingen Univ. & Max Planck Inst. for Biological Cybernetics
Organizer: Schilling, Michael	HELLA KGaA Hueck & Co
Organizer: Curio, Cristobal	Reutlingen Univ. & Max Planck Inst. for Biological Cybernetics

09:30-10:00 — SuW2T2.1

*Holistic Interfaces in an Open Fusion Platform (I)**

Schilling, Michael — HELLA KGaA Hueck & Co.

10:00-10:30 — SuW2T2.2

*Measuring the World: Designing Robust Vehicle Localization for Autonomous Driving (I)**

Schuster, Frank — Daimler AG
Haueis, Martin — Daimler AG
Keller, Christoph Gustav — Daimler AG

Autonomous vehicles rely on map data for trajectory planning and to extend the knowledge of the environment beyond the sensor range. In order to use the map data, it is essential to solve the localization problem in the map. To address this problem in the real world, different environmental conditions have to be considered. It turns out that a key aspect of localization is to find a suitable representation of the world that can be used for data association between map and sensor measurements.

We show in this presentation in multiple examples that besides choosing a suitable sensor setup and data extraction, the mapping algorithms and furthermore map representation are equally important to achieve high accuracy and reliability. The actual choice of these factors depends on the use case.

As this talk focusses on the mapping process, map representations can be handled differently to incorporate environmental changes and to model changing environments both on a small scale and on large datasets provided by mapping companies.

A case study conducted in a dynamic environment demonstrates such a specific localization design for a radar equipped autonomous prototype.

10:30-11:30 — SuW2T2.3

The Need for an Environment Perception Block to Address All ASIL Levels Simultaneously (I), pp. 1-4

Johansson, Rolf — SP
Nilsson, Jonas — Volvo Car Corp

In order to perform safety assessment of vehicles for highly automated driving, it is critical that the vehicle can be proven to adapt its driving according to the sensed objects that might become a hinder. There is a complicated relation between the confidence of what hinders that might exist coming out of an environment perception block, and the tactical decisions about the driving style done by the autonomous vehicle. A good strategy that enables safety assessment according to ISO26262 implies that the environment perception block should address its safety requirements for all the ASIL attribute values simultaneously. In this paper we argue why every functional safety requirement allocated to an environment perception block should preferable be instantiated four times, each with a different ASIL value.

11:30-12:00 — SuW2T2.4

*Examining Pedestrian Intentions at Urban Crosswalks (I)**

Voelz, Benjamin — Robert Bosch GmbH

A comprehensive scene understanding is crucial for future fully automated vehicles. Especially urban traffic scenarios involving pedestrians remain challenging. This talk will tackle one part of the problem regarding the prediction of pedestrian intentions at urban crosswalks. Due to safety and comfortability reasons it is essential to identify the pedestrians' intentions as early as possible. Particularly cars which approach the crosswalk with a high velocity will be enabled to either adjust their velocity with small accelerations or to avoid an unnecessary stop completely. This talk analyzes the behavior of pedestrians by means of machine learning algorithms based on real world trajectories. A basic intention recognition algorithm, that utilizes a large feature set, is introduced. The algorithms predicts the pedestrians' intention to cross the street at a particular crosswalk. Additionally, the features are analyzed regarding their relevance for this underlying classification task. An evaluation is carried out based on a large dataset containing pedestrian trajectories which have been recorded at different crosswalks. The results will provide a detailed analysis of both typical and challenging (or atypical) pedestrian trajectories and their influence on the prediction performance.

12:00-12:30 — SuW2T2.5

*Towards Purposeful Intention Prediction of Pedestrians (I)**

Ludl, Dennis — Reutlingen Univ
Browatzki, Björn — Reutlingen Univ
Curio, Cristobal — Reutlingen Univ. & Max Planck Inst. for Biological Cybe

Automated driving requires dedicated perception algorithms to infer the intention of weaker traffic participants, especially those of pedestrians, in order to guarantee safe and seamless navigation through urban environments. In scenarios where vehicles and pedestrians operate in a shared space, such as parking lots or residential areas, the incorporation of communication processes between both parties becomes crucial. We present latest work on the development of visual perception methods for an extended interpretation of pedestrian behavior including the understanding of dynamic gestures with consumer-grade hardware such as monocular cameras.

12:30-14:30 SuW2T2.6

*Developing Software Architectures for Autonomous Vehicles (I)**

Ohl, Sebastian — TU Braunschweig

Lately, many companies entered the field of developing autonomous driving functions. Starting this development from scratch is quite some effort and requires highly qualified resources. To easy this process and help the developers to focus on the user experienceable function, we propose a reference architecture for highly automated driving with standardized open software interfaces. Using this architecture and its interfaces, the developer can reuse software components from other projects or from suppliers on the market to develop their brand's special experience.

14:30-15:00 SuW2T2.7

*Predictive Video Processing for ADAS (I)**

Mester, Rudolf — Univ. Frankfurt

Understanding the world around us while we are moving means continuously maintaining a dynamically changing representation of the environment, making predictions about what to see next, and correctly processing those perceptions which were surprising, relative to our predictions. This principle is valid both for animate beings, as well as for technical systems that successfully participate in traffic.

The VSI Lab at Frankfurt University puts special emphasis on this recursive / predictive approach to visual perception in ongoing projects for ADAS and autonomous driving.

In our opinion, this approach leads to particularly efficient systems, since computational resources may be focused on 'surprising' (thus rare) observations, and since this allows for a large reduction of search spaces in typical visual matching and tracking tasks.

Furthermore, since the environment representation is actually closely coupled to the measuring process, and not a distant result at the end of a long processing pipeline, it allows for a simplified fusion of information from different sensors. This implies of course a more tight coupling between sensor data processing and interpretation. The talk will present examples for the such predictive / recursive processing structures and put the pros and cons up to discussion.

15:00-16:00 SuW2T2.8

*Challenges in Vision-Based Fully Automated Valet Parking (I)**

Schwesinger, Ulrich — ETH Zurich

Automated valet parking provides great potential to pave the way for driverless vehicles as it provides immediate benefits to customers and enables us to better adapt the complexity of the environment to the technical possibilities. Yet offering automated valet parking services on parking lots shared with other traffic participants at a reasonable price is still a challenging endeavor. This talk will detail the efforts undertaken in the European project "V-Charge" targeting automated valet parking with close-to-market sensors. Robust visual localization under changing weather- and lighting conditions, 360° object detection from monocular cameras and motion planning in mixed-traffic are among the project's achievements and will be presented together with remaining challenges.

SuW3T3 Aktiviteten, Lindholmen 3

IEEE IV Workshop on Cooperative Communication and Positioning (CCP) (Workshop)

Chair: Wymeersch, Henk — Chalmers

Organizer: Wymeersch, Henk — Chalmers

09:15-10:00 SuW3T3.1

*Channel Characteristics for Cooperative ITS and Positioning (I)**

Tufvesson, Fredrik — Lund Univ.

11:20-11:40 SuW3T3.4

Localization in V2X Communication Networks (I), pp. 5-9

Ghods, Alireza — Jacobs Univ. Bremen
Severi, Stefano — Jacobs Univ. Bremen
Abreu, Giuseppe — Jacobs Univ. Bremen/Ritsumeikan Univ

This paper addresses the problem of vehicle position estimation in dense urban environments, where traditional global positioning system (GPS)-based localisation techniques are severely affected by non line-of-sight (NLOS) signal propagation and multipaths presence. Assuming that GPS signals are fairly received only by a very small fraction of vehicles at the border of the urban environment, we propose a solution based on vehicle to X (V2X) communication to propagate this information to the whole network. As a consequence, this multi hop scheme allows every vehicle to estimate its own position collecting its cumulative distances to border vehicles. Finally we introduce a new analytical framework to verify the fundamental performance of the proposed solution in term of position estimate error bounds, jointly considering the uncertainty introduced by the multihop process and by the GPS localization.

11:40-12:00 SuW3T3.5

On Prototyping IEEE802.11p Channel Estimators in Real-World Environments Using GNURadio (I), pp. 10-15

Stoica, Razvan-Andrei — Jacobs Univ. Bremen
Severi, Stefano — Jacobs Univ. Bremen
Abreu, Giuseppe — Jacobs Univ. Bremen/Ritsumeikan Univ

The current advances in the Intelligent Transportation Systems (ITS) reveal new solutions which are in need of validation in real-world deployments. The practicality, implementability, latency and robustness of such methods are key insights into their wide acceptance, and finally, absorption by standardization organizations. This paper discusses an approach to rapidly prototype newly proposed Wireless Access in Vehicular Environments (WAVE) algorithms based on the open source community and the emergence of Software Defined Radio (SDR). Concretely, this work details the practical deployment of a new adaptive channel estimation method in the context of IEEE 802.11p based vehicular communications. The development steps are illustrated and some challenges involved by real-world deployment (e.g. the phase tracking problem) are treated. Consequently, practical methods to solve the observed impairments are derived and implemented for real-time operation and validation.

14:45-15:50 SuW3T3.8

Static and Dynamic Performance Evaluation of Low-Cost RTK GPS Receivers (I), pp. 16-19

Skoglund, Martin — SP Tech. Res. Inst. of Sweden
Petig, Thomas — Chalmers Univ. of Tech
Vedder, Benjamin — SP Tech. Res. Inst. of Sweden
Eriksson, Henrik — SP Tech. Res. Inst. of Sweden
Schiller, Elad — Chalmers Univ

The performance of low-cost RTK (real-time kinematic) GPS receivers has been compared to a state-of-the-art system as well to each other. Both static and dynamic performances have been compared. The dynamic performance has been evaluated using a vehicle with driving robot on the AstaZero proving ground. The assembly of the low-cost RTK GPS receivers is presented, and the test set-ups described. Besides having a lower data output frequency, two of the low-cost receivers have static and dynamic performance not far from that of the state-of-the-art system.

15:50-16:10 SuW3T3.9

On Communication Aspects of Particle-Based Cooperative Positioning in GPS-Aided VANETs (I), pp. 20-25

Hoang, Gia-Minh	Cea-Leti, Eurecom
Benoit, Denis	CEA-Leti
Haerri, Jerome	EURECOM
Slock, Dirk	EURECOM

Precise location services are seen as key enablers to future Intelligent Transport Systems (ITSs). Relying on Vehicle-to-Vehicle (V2V) communication links, one promising solution consists in performing distributed Cooperative Positioning (CP). More specifically, Cooperative Awareness Message (CAM) broadcasts from neighboring vehicles (seen as "virtual anchors") are used to exchange positional information and to measure V2V radiolocation metrics such as the Received Signal Strength Indicator (RSSI). For the sake of fusing these non-linear hybrid data, Particle Filters (PFs) represent the required positional information by a set of particles with associated weights. However, in a jointly cooperative and distributed context, the transmission of explicit particle clouds (required by receiving neighbors to update their own location estimates) is hardly affordable under limited V2V channel capacity for typical numbers of particles. In this paper we thus combine and compare several solutions in terms of message representation and adaptive transmission policy so as to reduce simultaneously CAM overhead, channel congestion and computational complexity. Proposals are made at both signal processing level (parametric density approximation) and protocol level (jointly adaptive transmission payload, power and rate), showing no impact on channel load in congested scenarios and negligible CP accuracy degradation in comparison with normal CAM transmission at critical rates.

SuW4T4 Tesla

Workshop on Human Factors in Intelligent Vehicles (HFIV'16) (Workshop)

Chair: Olaverri Monreal, Cristina	UAS Tech. Wien
Co-Chair: Garcia, Fernando	Univ. Carlos III De Madrid
Organizer: Olaverri Monreal, Cristina	UAS Tech. Wien

09:00-10:00 SuW4T4.1

*Human Factors in the Automotive Industry (I)**

Schonlau, Benedikt	IAV GmbH
Tadjine, Hadj Hamma	IAV GmbH

10:00-10:30 SuW4T4.2

Automatic and Manual Driving Paradigms: Cost-Efficient Mobile Application for the Assessment of Driver Inattentiveness and Detection of Road Conditions (I), pp. 26-31

Allamehzadeh, Arman	UAS Tech. Wien
Olaverri Monreal, Cristina	UAS Tech. Wien

Assessment of the driver's state and the driving environment is essential in promoting road safety in both manual and automatic driving paradigms where the monitoring tasks are either performed by the driver or by the system. Within this work, we present a cost effective mobile application to measure gaze behavior and analyze road conditions for a request to take vehicle's control in case of an automatic driving or to avoid inattentive driving in a manual driving paradigm. We evaluated the application under daylight conditions. Results showed a high rate of detections in a short period of time.

10:30-11:30 SuW4T4.3

Evaluating Interactions with Non-Existing Automated Vehicles: Three Wizard of Oz Approaches (I), pp. 32-37

Habibovic, Azra	Viktoria Swedish ICT
Andersson, Jonas	Viktoria Swedish ICT
Nilsson, Maria	Viktoria Swedish ICT
Malmsten Lundgren, Victor	Viktoria Swedish ICT
Nilsson, Jan	Semcon Sweden AB

Highly automated test vehicles are rare today, and (independent) researchers have often limited access to them. Also, developing fully functioning system prototypes is time and effort consuming. In this paper, we present three adaptions of the Wizard of Oz technique as a means of gathering data about interactions with highly automated vehicles in early development phases. Two of them address interactions between drivers and highly automated vehicles, while the third one is adapted to address interactions between pedestrians and highly automated vehicles. The focus is on the experimental methodology adaptations and our lessons learned.

11:30-12:00 SuW4T4.4

Analyzing Driver-Pedestrian Interaction at Crosswalks: A Contribution to Autonomous Driving in Urban Environments (I), pp. 38-43

Schneemann, Friederike	Audi Electronics Venture GmbH
Gohl, Irene	Audi AG

In urban environments traffic safety is primarily determined by the successful interaction between road users. In order to define behavioral requirements for future autonomous vehicles, an understanding of these interactions is needed. Therefore this paper analyzes the interaction between drivers and pedestrians at crosswalks from both the driver's and the pedestrian's perspective. A study with driving experiments in real-life traffic was conducted. The study not only investigates how drivers respond to pedestrians who intend to use the crosswalk, but also their response to pedestrians who waive their right-of-way. An analysis of recorded driving and video data identified typical behavior patterns of drivers approaching a crosswalk, as well as of pedestrians crossing on it. Supplemented by questionnaires filled in by drivers and pedestrians, we determined factors which have a relevant impact on successful driver-pedestrian interaction. We confirmed that with higher initial speeds, drivers tend to exhibit more anticipatory driving behavior. Contrary to previous studies, the presented results show a significant influence of the vehicle's speed on the pedestrian's decision process. The gained insights into the driver-pedestrian interaction process provide an opportunity to develop autonomous driving functions with a cooperative driving behavior that conforms to the expectations of both pedestrians and vehicle occupants.

12:00-12:30 SuW4T4.5

Mobile Based Pedestrian Detection with Accurate Tracking (I), pp. 44-48

Garcia, Fernando	Univ. Carlos III De Madrid
Urdiales, Jesus	Univ. Carlos III De Madrid
Carmona, Juan	Univ. Carlos III De Madrid
Martin Gomez, David	Carlos III Univ. of Madrid
Armingol Moreno, José María	Univ. Carlos III De Madrid

This paper presents an innovative smartphone application which takes advantage of the availability of smartphone technologies to develop a highly accurate pedestrian detection and tracking application, based on monocular camera and embedded sensors. Monocular pedestrian detection is performed based on well-known vision approaches, later pose estimation is used to correct the location of the pedestrian, based on the information provided by the mobile device, and finally movement is estimated by means of a Kalman Filter. The information from the internal sensors corrects the distance given by the pin-hole model. Test performed proved the viability of the system as well as its accuracy.

12:30-14:30 SuW4T4.6

Risk Predictive Shared Deceleration Control: Its Functionality and Effectiveness of an Early Intervention Support (I), pp. 49-54

Saito, Yuichi	Tokyo Univ. of Agriculture and Tech
Raksincharoensak,	Tokyo Univ. of Agriculture and

Pongsathorn Tech

ADAS are designed to complement driver capabilities for perception, situation recognition, action selection, and action implementation in a dynamic environment. Today, the machine with artificial-intelligence technology has the ability to determine and implement for trading or sharing of the control authority between the human and the machine. AEB systems have been already introduced to the markets, and humans positively evaluated the functions of AEB. AEB systems avoid collisions with a harsh braking at the last second, when the collision risk becomes imminent. However, such system reaches its limit when there are unexpected moving obstacles appearing suddenly from poor visibility area. Suppose that pedestrians suddenly intends to cross the road with short time margin to collision. Then the AEB may fail to prevent the vehicle-pedestrian collision because of limitations of information acquisition and information analysis functions by the machine. This paper focuses on a parked vehicle overtaking scenario, in such scenario, it is highly possible that pedestrians might cross the road behind the parked vehicle, especially in urban roads. This paper proposes a risk predictive shared deceleration control system based on potential risk prediction of collision with a pedestrian on urban roads. The assistance system performs the shared deceleration control in uncertain situations that a pedestrian might intend to cross the road as well as providing an arousing attention to potential hazard. Under a driving simulator experiment, we investigated its functionality and effectiveness of the proposed early intervention support, and we confirmed that the proposed assistance system can be effective for guiding the drivers to trace the desired velocity.

14:30-15:00 SuW4T4.7

JLR Heart: Employing Wearable Technology in Non-Intrusive Driver State Monitoring. Preliminary Study (I), pp. 55-60

Melnicuk, Vadim — Univ. of Warwick
Birrell, Stewart — Univ. of Warwick
Konstantopoulos, Panos — Jaguar Land Rover
Crundall, Elizabeth — Bright Eyes Scientific Services
Jennings, Paul — WMG, Univ. of Warwick

This paper presents the results from a preliminary study where a wearable consumer electronic device was used to assess driver's state by capturing human physiological response in non-intrusive manner. Majority of state of the art studies have employed medical equipment drivers' state evaluation. Despite the potential gain in road safety this method of measuring physiology is unlikely to be accepted by private vehicle consumers due to its invasiveness, complexity, and high cost. This study was aiming to investigate possibility of employing a consumer grade wearable device to measure physiological parameters related to cognitive workload in real-time while driving i.e., drivers' heart rate. Furthermore, validity of captured heart activity metrics was analyzed to determine if wearable devices could be embedded into driving at its current technological state. The driving context was reproduced in desktop driving simulator, with 14 participants agreeing to take part in the study (μ = 28, σ = 8.5 years). Drivers were exposed to various road types, including pure Motorway, Rural, and Urban scenario modes. An accident was simulated in order to generate sudden cognitive arousal and capture participants' physiological response to the generated distress. It was found that a smartwatch is capable of reliable heart activity tracking in driving context. The results, supporting the relationship between cognitive workload level, generated by various complexity driving tasks, and Heart Rate Variability, were also presented.

15:00-16:00 SuW4T4.8

Embedded System for Driver Behavior Analysis Based on GMM (I), pp. 61-65

Carmona, Juan — Univ. Carlos III De Madrid
Garcia, Fernando — Univ. Carlos III De Madrid
de Miguel, Miguel Angel — Univ. Carlos III De Madrid
de la Escalera, Arturo — Univ. Carlos III De Madrid
Martin Gomez, David — Carlos III Univ. of Madrid

The work presented describes a tool for driver behavior analysis. The proposal offers a contribution based on Gaussian Mixture Model (GMM) modeling technique. GMM is a powerful tool for the statistical modeling. Data are obtained by the in-vehicle sensors using Controller Area Network bus (CAN-bus), an Inertial Measurement Unit (IMU) and a GPS. These data allow to provide driver behavior analysis and aggressive behavior identification. This development has been tested in real-traffic situations

16:00-16:30 SuW4T4.9

Study of the Capabilities of the Yellow Flashing Arrow Traffic Signal and Driver Response (I), pp. 66-71

Almalag, Mohammad — Indiana Univ. Kokomo
El-Tawab, Samy — James Madison Univ
Phelan, Matthew — James Madison Univ
Ghazizadeh, Puya — Millersville Univ

In the United States of America, about half of all car collisions occur at intersections and a third of these crashes that result in fatalities take place at signalized intersections. Several researchers have been working to reduce crashes at signalized intersections, it is necessary to investigate traffic signal phasing for safer alternatives in comparison to the current models. The Yellow Flashing Arrow (YFA) is becoming more widely implemented across USA for protective/permissive left turn phasing, a function most commonly associated with the combination of a green arrow and circular green light (GA/CG). With well-designed research and implementation, the YFA could potentially make signalized intersections more safe and efficient in handling traffic flow. In order to model the YFA, we use AORTA Traffic Simulator, which is a city-scale traffic simulator, to observe and analyze its handling of left turn phasing at signalized intersections in different traffic flow conditions (sparse traffic, normal traffic, and congested traffic). We conduct a survey to gauge people's understanding of the YFA and other traffic signals. We develop a simulation to study the ability of traffic to handle different types of left turn signals. The data collected from the simulation is used to analyze the YFA's handling of the three different traffic conditions. Our results showed that drivers understand easier the YFA concept than the CG. This supports the hypothesis that the YFA causes drivers to be more cautious. Also, our simulation results conclude that with heavier traffic through an area, there will be longer wait times while using YFA.

SuW5T5 Aktiviteten, Lindholmen 12

Extended Object Tracking: Theory and Applications (Workshop)

Chair: Granstrom, Karl — Chalmers Univ. of Tech
Organizer: Granstrom, Karl — Chalmers Univ. of Tech
Organizer: Reuter, Stephan — Univ. of Ulm
Organizer: Baum, Marcus — Univ. of Göttingen

14:00-14:30 SuW5T5.7

Dynamical Tracking of Surrounding Objects for Road Vehicles Using Linearly-Arrayed Ultrasonic Sensors (I), pp. 72-77

Yu, Jiaying — Tsinghua Univ
Li, Shengbo — Dept of Automotive Eng., Tsinghua Univ
Liu, Chang — Univ. of California
Cheng, Bo — State Key Lab. of Automotive Safety and Energy, Tsinghua U

Accurate detection and tracking of traffic participants are crucial to advanced driver assistance systems. This paper presents a centralized object tracking approach for surrounding objects in road traffic environments by using multiple linearly arrayed ultrasonic sensors. An ultrasonic sensor model is specifically developed for traffic environment, which consists of detection scope, chance of detection and ranging error, incorporating factors of object shapes, materials, distances and orientations. A centralized filter is designed to selectively fuse new measurements that are obtained using the Extended Kalman Filter (EKF) from certain sensors to conduct object tracking at each step. The effectiveness of proposed method is validated by simulations, which is found to have superior tracking performance compared to traditional triangle localization method, with more stable and smaller tracking error, especially when the object is entering or leaving the detection area.

14:30-15:00	SuW5T5.8

Online Learning Based Multiple Pedestrians Tracking in Thermal Imagery for Safe Driving at Night (I), pp. 78-79

Ko, Byoung Chul	Keimyung Univ
Kwak, Joon Young	Keimyung Univ
Nam, JaeYeal	Keimyung Univ

Recent advanced driver assistance system (ADAS) has been researching on automatic pedestrian detection and tracking using night vision camera to automatically prevent such accidents. Among the various types of cameras used in such systems, thermal cameras are favorable because they are invariant to illumination changes. Therefore, this tutorial focuses on a pedestrian night-time tracking system with a thermal camera. This tutorial consists of following five topics: (1) we therefore first introduce two models for detecting pedestrians according to the season and weather , (2)we introduce some state-of-the-art real-time online learning algorithms with our online learning based on boosted random ferns (BRFs) in detail, (3)for association checking of multiple pedestrians, we explain the advantages and disadvantages of feed-forward system and global association system, (4)we introduce a few evaluation video sequences for pedestrian tracking, (5)we introduce the evaluation methods to measure the performance of the pedestrian tracking system. As the further research in multiple pedestrians tracking, we will guide the fusion of sensors such as Radio Detection and Ranging (RADAR) sensor or Light Detection and Ranging (LIDAR) sensor with a camera for overcome the limitations occurred in a standalone sensor.

SuW6T6	Kelvin

Vision for Intelligent Vehicles and Application (VIVA) 2016: Workshop and Challenges (Workshop)

Chair: Trivedi, Mohan M.	Univ. of California at San Diego
Co-Chair: Martin, Sujitha	Univ. of California, San Diego
Organizer: Martin, Sujitha	Univ. of California, San Diego
Organizer: Ohn-Bar, Eshed	Univ. of California San Diego
Organizer: Satzoda, Ravi Kumar	Univ. of California San Diego
Organizer: Møgelmose, Andreas	Aalborg Univ
Organizer: Philipsen, Mark Philip	Aalborg Univ
Organizer: Jensen, Morten	Aalborg Univ
Organizer: Trivedi, Mohan M.	Univ. of California at San Diego

09:00-09:30	SuW6T6.1

*VIVA 2016: Introduction and Opening Remarks (I)**

Trivedi, Mohan M.	Univ. of California at San Diego

09:30-10:00	SuW6T6.2

*Looking-Inside: Faces (I)**

Martin, Sujitha	Univ. of California, San Diego

10:00-10:30	SuW6T6.3

*Looking-Inside: Hands (I)**

Ohn-Bar, Eshed	Univ. of California San Diego

11:00-11:45	SuW6T6.5

*TBD (I)**

Urtasun, Raquel	Univ. of Toronto

11:45-12:15	SuW6T6.6

*Looking-Outside: Signs and Signals (I)**

Philipsen, Mark Philip	Aalborg Univ.
Jensen, Morten	Aalborg Univ.
Møgelmose, Andreas	Aalborg Univ.

12:15-12:45	SuW6T6.7

*Looking-Outside: Vehicles and Trajectories (I)**

Kristoffersen, Miklas Strøm	Aalborg Univ.
Dueholm, Jacob Velling	Aalborg Univ.
Ohn-Bar, Eshed	Univ. of California San Diego
Satzoda, Ravi Kumar	Univ. of California San Diego

SuW8T7	Aktiviteten, Lindholmen 13

Workshop on Naturalistic Driving Data Analytics (Workshop)

Chair: Selpi, Selpi	Chalmers Univ. of Tech
Organizer: Selpi, Selpi	Chalmers Univ. of Tech
Organizer: Gellerman, Helena	SAFER
Organizer: Miyajima, Chiyomi	Nagoya Univ

09:05-09:40	SuW8T7.2

*Analysis of Non-Critical Left Turns at Intersections and LTAP/OD Crashes/near-Crashes Using Naturalistic Driving Data from EuroFOT and SHRP2 (I)**

Tiveste, Emma	Volvo Cars

09:40-10:05	SuW8T7.3

Brake Response Time under Near-Crash Cases with Cyclist (I), pp. 80-85

Chen, Mingyang	Tongji Univ
Zhu, Xichan	Tongji Univ
Ma, Zhixiong	Tongji Univ
Li, Lin	Tongji Univ
Wang, Dazhi	SAIC Motor Tech. Center(SMTC)
Liu, Junyong	SAIC Motor Tech. Center(SMTC)

In this paper, brake response time of 110 near-crash cases with cyclist is researched. Cyclists include bicyclist, electric bicyclist, motorcyclist and tricyclist. This paper refers to the time interval from the moment a collision threat appears to the moment the vehicle begins to decelerate to avoid the collision as brake response time (BRT). Values of BRT range from 0.47s to 2.13s with a mean of 1.016s and a standard deviation of 0.3875s. Influence of seven factors on BRT is analyzed using one-way Analysis of Variance and path analysis. Factors include occurrence time of near-crash, visibility, number of potential threat vehicles, intersection or not, road type, moving status and velocity of the vehicle. The results show that visibility, intersection or not and number of potential threat vehicles are significant factors. Better visibility in the darkness can significantly shorten BRT. BRT decreases with the increase of potential threat vehicles. However, when there are too many (more than three) potential threat vehicles ahead, drivers show significantly longer BRT. Drivers brake significantly more lately at intersection.

10:05-10:30	SuW8T7.4

*A Graph Database for Modelling and Analysis of Naturalistic Driving Data (I)**

Ciolac, Camelia Elena	Chalmers Univ.

11:00-11:30	SuW8T7.6

*Driving Characteristics from NDS Data - Challenges and Approaches to Manage, Extract Features, Analyze, and Predict Behaviors (I)**

Gunaratne, Pujitha — Toyota Motor Engineering and Manufacturing North America

11:30-11:55	SuW8T7.7

*Prediction of Individual Driving Behavior on Highway Curves (I)**

Naren, Bao — Nagoya Univ.

11:55-12:20	SuW8T7.8

*The Australian Naturalistic Driving Study (ANDS) (I)**

Williamson, Ann — Univ. of New South Wales

SuW9T6 — Kelvin

Cooperative Autonomous Intelligent Vehicles Are Advanced Robotic Systems of Systems: Current Trends and Challenges (Workshop)

Chair: Philips, Johan — KU Leuven

Organizer: Philips, Johan — KU Leuven

14:15-15:00	SuW9T6.2

*Cooperative Situation Awareness in Intelligent Transportation Systems (I)**

Nebot, Eduardo — ACFR Univ. of Sydney

Situation awareness involves the sensing of the local environment, understanding the situation and predicting the future state. For Intelligent Transportation Systems, situational awareness is essential for detecting unsafe behaviours and for allowing the introduction of autonomous systems into complex traffic scenarios. Cooperative situation awareness involves the sharing of information between local groups of vehicles to improve the understanding of the current scenario. By fusing the information received over communication networks it is possible for vehicles to have a better understanding of the risks, allowing safer operation and reducing accidents. Furthermore, existing fleet of vehicles will be able to share high level perception capabilities provided by smart autonomous vehicles operating in the proximity area. Multimodal perception and efficient communication of vital information between vehicles are required to successfully propagate information between vehicles (V2V) and the infrastructure (V2I, I2V).

15:00-15:50	SuW9T6.3

Analysis of Optimal Solutions to Robot Coordination Problems to Improve Autonomous Intersection Management Policies (I), pp. 86-91

Altché, Florent — MINES ParisTech

de La Fortelle, Arnaud — Mines ParisTech

The deployment of Cooperative Intelligent Transportation Systems (C-ITS) raises the question of future traffic management systems, which will be operating with an increasing amount of information and control over the infrastructure and the vehicles. This topic of research shares some similarities with robot coordination problems, inspiring our research on autonomous intersection management. In this article, we use a mixed-integer linear programming formulation for time-optimal robots coordination along specified paths and apply it to intersection management for autonomous vehicles. Our formulation allows to simultaneously solve a discrete optimal vehicle ordering problem, and a (discretized) continuous optimal velocity planning problem taking into account kinodynamics constraints. This allows faster pruning of the decision tree for the discrete problem, thus reducing computation time. A possible application for ITS is to evaluate the efficiency loss from a given vehicle ordering policy, or dynamically adapt policies to improve their efficiency. Moreover, any intermediary solution found by the solver can be used as a heuristically good policy, with proved bounds on sub-optimality.

15:50-16:35	SuW9T6.4

*A Collaborative Delegation-Based Framework for 3D Mapping Using Heterogeneous Unmanned Aircraft Systems (I)**

Doherty, Patrick — Linkoping Univ

In this talk, I will discuss a generic framework for collaboration among humans and multiple heterogeneous robotic systems based on the use of a formal characterization of delegation as a speech act. The fielded system consists of a complex set of integrated software modules that include a delegation manager, a task specification language, a task planner, multi-agent scan trajectory generation and region partitioning modules, and an infrastructure used to distributively instantiate any number of robotic systems and user interfaces in a collaborative team. The application to be demonstrated is focused on 3D reconstruction in alpine environments that provides situation awareness to alpine rescue teams. Two complex UAV systems, a fixed-wing and rotor-based system, have been used in the field experiments to be discussed. A fully autonomous collaborative mission demonstrated in the Italian Alps will be the basis for the talk.

SuW10T7 — Aktiviteten, Lindholmen 13

Workshop on Autonomous Vehicles in Off-Road Scenarios (Workshop)

Chair: Garcia, Fernando — Univ. Carlos III De Madrid

Organizer: Garcia, Fernando — Univ. Carlos III De Madrid

Organizer: Martin Gomez, David — Carlos III Univ. of Madrid

Organizer: Armingol Moreno, José María — Univ. Carlos III De Madrid

Organizer: de la Escalera, Arturo — Univ. Carlos III De Madrid

14:15-14:40	SuW10T7.2

Monocular Vision-Based Obstacle Detection/Avoidance for Unmanned Aerial Vehicles (I), pp. 92-97

Al-Kaff, Abdulla — Univ. Carlos III De Madrid

Meng, Qinggang — Department of Computer Science, Loughborough Univ

Martin Gomez, David — Carlos III Univ. of Madrid

de la Escalera, Arturo — Univ. Carlos III De Madrid

Armingol Moreno, José María — Univ. Carlos III De Madrid

Robust real-time obstacle detection/avoidance is a challenging problem especially for micro and small aerial vehicles due to the limited number of the on-board sensors due to the battery constraint and low payload. Usually lightweight sensors such as CMOS camera are the best choice comparing with laser or radar sensors. For real-time applications, most studies focus on using stereo cameras to reconstruct a 3D model of the obstacles or to estimate their depth. Instead, in this paper, a method that mimics the human behavior of detecting the state of the approaching obstacles using single camera is proposed. During the flight, this method is able to detect the changes of the size area of the obstacles. First, the method detects the feature points of the obstacles, and then extracts the obstacles that has probability of getting close. In addition, by comparing the changes in the area ratios of the obstacle in the image sequence, the method can decide if it is obstacle or not. Finally, by estimating the obstacle 2D position in the image and combining with the tracked waypoints, the UAV can take the action of avoidance.

14:40-15:00	SuW10T7.3

Autonomous Vehicle for Surveillance Missions in Off-Road Environment (I), pp. 98-103

Naranjo, Jose — Univ. Pol. De Madrid

Clavijo, Miguel | Univ. Pol. De Madrid
Jiménez, Felipe | Univ. Pol. De Madrid
Gómez Casado, Oscar | INSIA
Rivera, José Luis | Inst. Tecnológico La Marañosa - INTA
Anguita, Manuel | Inst. Tecnológico La Marañosa - INTA

The use of drones is nowadays an extended procedure in the surveillance and combat missions in the armies of the different NATO countries. The concept of drone is a generalization of the so called unmanned vehicles, whose more usual unit is the Unmanned Aerial Vehicle (UAV). However, in recent years the civil autonomous vehicles technology has been extended to military sector that demands autonomous technology to carry out missions in the ground with the so called Unmanned Ground Vehicles (UGV). These vehicles develop missions in unstructured environments, usually off-road, and must be able of combining autonomous behaviors plus tele-operation from a command station. In this paper we present the application of the civil autonomous vehicle technology to develop a demonstrator of UGV for the Spanish Army, including the background, architecture and first field tests.

15:00-15:55 SuW10T7.4

Autonomous Off-Road Navigation Using Stereo-Vision and Laser-Rangefinder Fusion for Outdoor Obstacle Detection (I), pp. 104-109

Hussein, Ahmed | Intelligent Systems Lab (LSI) - Univ. Carlos III De Madrid
Marin Plaza, Pablo | Univ. Carlos III De Madrid
Martin Gomez, David | Carlos III Univ. of Madrid
de la Escalera, Arturo | Univ. Carlos III De Madrid
Armingol Moreno, José María | Univ. Carlos III De Madrid

During the last decade, ground mobile robots that are able to drive autonomously in off-road environments have received a great deal of attention. Autonomous navigation in unstructured environments faces many new challenges compared to structured urban environments, these challenges increase the complexity of the localization, obstacle detection, path planning and navigation commands. Accordingly this paper presents a fusion system for stereo-vision and laser-rangefinder outdoor obstacle detection, which is implemented as an application for autonomous off-road navigation. The test platform is an electric golf-cart that is modified mechanically and electrically to operate in driver-less mode. This vehicle is equipped with binocular camera, laser-rangefinder, electronic compass and on-board embedded computer, which operates using Robotic Operating System (ROS) architecture. The proposed architecture gathers the data from all different sensors, in order to make navigation decisions from one point to another, avoiding obstacles in the path. Experimental results indicate the high performance of the proposed approaches, they show that the perception from the stereo-vision detection enhances the laser-rangefinder detection, which consequently makes a better decision in maneuvering the obstacle and returns back to the original path.

15:55-16:20 SuW10T7.5

*A Skyline Detection Algorithm for Use in Different Weather and Environmental Conditionse (I)**

Chiu, Chung-Cheng | National Defense Univ.
Liu, Yun Jiun | National Defense Univ.
Chiu, Sheng Yi | National Defense Univ.
Chang, Hsing-Chien | National Chung-Shan Inst. of Science & Tech. ROC
Hsu, Chia-Lun | National Chung-Shan Inst. of Science & Tech. ROC

Book of Abstracts: Monday June 20, 2016

Opening Conference Hall
Opening Session (Plenary Session)

08:30-08:45

Opening Speeches

Viberg, Mats — Chalmers Univ
Sjoberg, Jonas — Chalmers Univ
Morris, Brendan — Univ. of Nevada, Las Vegas

MoKeynoteP Conference Hall
Keynote: Volvo Group (Plenary Session)

Chair: Sjoberg, Jonas — Chalmers Univ
Co-Chair: Morris, Brendan — Univ. of Nevada, Las Vegas

08:45-09:15 MoKeynoteP.1

*Automation Will Completely Redefine Commercial Transport Solutions**

Kellstrom, Anders — Volvo AB
Grante, Christian — Volvo GTT, Advanced Tech. & Res

Volvo Group is redefining commercial transport solutions in daily life through automation and we strongly believe that automation is, and will be, part of new ways of working. As a company with global presence and many different product areas, the Volvo Group sees a great potential for automation in many types of transport scenarios and application areas, opening up for new business opportunities by providing added value services. The future is now within our reach. Our innovations are created to serve our customers, society and the environment in terms of: Productivity, Energy, Fuel Efficiency and Safety. First we showcased our innovations within platooning, now we are showcasing the autonomous tuck which will revolutionise productivity in future mining. Join us to hear Anders Kellström's (Senior Product Planner) insights about the platooning project and Christian Grante's (Volvo Group Technical Specialist – Preventive Safety and Automation) insights about the autonomous truck.

MoOralAT Conference Hall
Vision Sensing and Perception (Regular Session)

Chair: Sanchez-Medina, Javier J. — ULPGC
Co-Chair: Stiller, Christoph — Karlsruhe Inst. of Tech

09:15-09:32 MoOralAT.1

Semantic Stixels: Depth Is Not Enough, pp. 110-117

Schneider, Lukas — Daimler, ETH Zurich
Cordts, Marius — Daimler AG, TU Darmstadt
Rehfeld, Timo — MBRDNA
Pfeiffer, David — Daimler AG
Enzweiler, Markus — Daimler AG
Franke, Uwe — Daimler AG
Pollefeys, Marc — ETH Zurich
Roth, Stefan — TU Darmstadt

In this paper we present Semantic Stixels, a novel vision-based scene model geared towards automated driving. Our model jointly infers the geometric and semantic layout of a scene and provides a compact yet rich abstraction of both cues using Stixels as primitive elements. Geometric information is incorporated into our model in terms of pixel-level disparity maps derived from stereo vision. For semantics, we leverage a modern deep learning-based scene labeling approach that provides an object class label for each pixel.

Our experiments involve an in-depth analysis and a comprehensive assessment of the constituent parts of our approach using three public benchmark datasets. We evaluate the geometric and semantic accuracy of our model and analyze the underlying run-times and the complexity of the obtained representation. Our results indicate that the joint treatment of both cues on the Semantic Stixel level yields a highly compact environment representation while maintaining an accuracy comparable to the two individual pixel-level input data sources. Moreover, our framework compares favorably to related approaches in terms of computational costs and operates in real-time.

09:32-09:49 MoOralAT.2

Map-Supervised Road Detection, pp. 118-123

Laddha, Ankit — Carnegie Mellon Univ
Kocamaz, Mehmet — Carnegie Mellon Univ
Navarro-Serment, Luis — Carnegie Mellon Univ
Hebert, Martial — Carnegie Mellon Univ

We propose an approach to detect drivable road area in monocular images. It is a self-supervised approach which doesn't require any human road annotations on images to train the road detection algorithm. Our approach eliminates human labeling effort and makes training scalable. We combine the best of both supervised and unsupervised methods in our approach. First, we automatically generate training road annotations for images using OpenStreetMap, vehicle pose estimation sensors, and camera parameters. Next, we train a Convolutional Neural Network (CNN) for road detection using these annotations. We show that we are able to generate reasonably accurate training annotations in KITTI data-set. We achieve state-of-the-art performance among the methods which do not require human annotation effort.

09:49-10:06 MoOralAT.3

A Closer Look at Faster R-CNN for Vehicle Detection, pp. 124-129

Fan, Quanfu — IBM T. J. Watson Res. Center

Faster R-CNN achieves state-of-the-art performance on generic object detection. However, a simple application of this method to a large vehicle dataset performs moderately. In this paper, we take a closer look at this approach as it applies to vehicle detection. We conduct a wide range of experiments and provide a comprehensive analysis of the underlying structure of this model. We show that through suitable parameter tuning and algorithmic modification, we can significantly improve the performance of Faster R-CNN on vehicle detection and achieve competitive results on the KITTI car dataset.We believe our studies are instructive for other researchers investigating the application of Faster R-CNN to their problems and datasets.

10:06-10:23 MoOralAT.4

Hierarchical CNN for Traffic Sign Recognition, pp. 130-135

Mao, Xuehong — Cadence Design Systems
Hijazi, Samer — Cadence Design Systems
Casas, Rual — Cadence Design Systems
Kaul, Piyush — Cadence Design Systems
Kumar, Rishi — Cadence Design Systems
Rowen, Chris — Cadence Design Systems

The Convolutional Neural Network (CNN) is a breakthrough technique in object classification and pattern recognition. It has enabled computers to achieve performance superior to humans in specialized image recognition tasks. Prior art CNNs learn object features by stacking multiple convolutional/non-linear layers in sequence on top of a classifier. In this work, we propose a Hierarchical CNN (HCNN) which is inspired by a coarse-to-fine human learning methodology. For a given dataset, we introduce a CNN-oriented clustering algorithm to separate classes into K subsets, which are referred to as families. Then, the HCNN algorithm trains K+1 classification CNNs: one CNN for family classification and K dedicated CNNs corresponding to each family for member classification. We evaluate this HCNN approach on the German Traffic Sign Recognition Benchmark (GTSRB), and achieve 99.67% correct detection rate (CDR), which is superior to the best reported results (99.46%) achieved by a single network.

MoInvitedP	Conference Hall
Invited Talk: AIV (Plenary Session)	
Chair: Stiller, Christoph	Karlsruhe Inst. of Tech
Co-Chair: Sanchez-Medina, Javier J.	ULPGC

10:25-10:40 MoInvitedP.1

*Connected and Autonomous Vehicles: Challenges & Opportunities**

Tadjine, Hadj Hamma — IAV GmbH
Schonlau, Benedikt — IAV GmbH

All large vehicle manufacturers and many Tier1 suppliers are making substantial investments in connected and autonomous vehicle technology. An examination how these innovative vehicles will transform our vision, our industrial base, improving safety and congestion, driving up productivity and freeing up space usually devoted to vehicles in our urban areas will be discussed.

It is clear that new vehicles will be connected. To facilitate a variety of driving functions and other enhanced features, a powerful communications capabilities will be built in to automotive systems designed. Data will be exchanged via complex internal networks based on different internal control systems; other applications that interface with drivers through dashboard displays and devices could share information with other connected vehicles; they could also exchange data with connected roadside entities, such as streetlights, that are also linked-in to the Internet of Things.

As well as opportunities, the advent of the 'connected' vehicle brings several major challenges, and will affect the operating models of OEMs, distributors, dealers and mechanics, road infrastructure managers, law-makers, and of course drivers and their passengers. In the public domain verifiable information about automotive cyber security risk levels is scattered, and can tend toward the sensationalist. How far OEM'S have gone, and still have to go.

MoOralBT	Conference Hall
Self-Driving Vehicles (Regular Session)	
Chair: Mårtensson, Jonas	KTH Royal Inst. of Tech
Co-Chair: Olaverri Monreal, Cristina	UAS Tech. Wien

11:10-11:27 MoOralBT.1

Visual Autonomous Road Following by Symbiotic Online Learning, pp. 136-143

Öfjäll, Kristoffer — Linköping Univ
Felsberg, Michael — Linköping Univ
Robinson, Andreas — Linköping Univ

Recent years have shown great progress in driving assistance systems, approaching autonomous driving step by step. Many approaches rely on lane markers however, which limits the system to larger paved roads and poses problems during winter. In this work we explore an alternative approach to visual road following based on online learning. The system learns the current visual apperance of the road while the vehicle is operated by a human. When driving onto a new type of road, the human driver will drive for a minute while the system learns. After training, the human driver can let go of the controls. The present work proposes a novel approach to online perception-action learning for the specific problem of road following, which makes interchangeably use of supervised learning (by demonstration), instantaneous reinforcement learning, and unsupervised learning (self-reinforcement learning). The proposed method, symbiotic online learning of associations and regression (SOLAR), extends previous work on qHebb-learning in three ways: priors are introduced to enforce mode selection and to drive learning towards particular goals, the qHebb-learning methods is complemented with a reinforcement variant, and a self-assessment method based on predictive coding is proposed. The SOLAR algorithm is compared to qHebb-learning and deep learning for the task of road following, implemented on a model RC-car. The system demonstrates an ability to learn to follow paved and gravel roads outdoors. Further, the system is evaluated in a controlled indoor environment which provides quantifiable results. The experiments show that the SOLAR algorithm results in autonomous capabilities that go beyond those of existing methods with respect to speed, accuracy, and functionality.

11:27-11:44 MoOralBT.2

Testing and Validating High Level Components for Automated Driving: Simulation Framework for Traffic Scenarios, pp. 144-150

Zofka, Marc René — FZI Forschungszentrum Informatik
Klemm, Sebastian — FZI Forschungszentrum Informatik
Kuhnt, Florian — FZI Forschungszentrum Informatik
Schamm, Thomas — FZI Forschungszentrum Informatik
Zöllner, J. Marius — FZI Res. Center for Information Tech. KIT Karlsruhe In

Current advances in the research field of autonomous driving demand advanced simulation methods for testing and validation. By combining versatile foci of different simulations, we can provide an increased amount and diversity of realistic traffic scenarios, which are relevant to the development and verification of high level automated driving functions. The focus of the present paper is to propose a concept for realistic simulation scenarios, which is capable of running in different integration levels, from software- to vehicle-in-the-loop. Its application is demonstrated, exposing an experimental vehicle, which is used for autonomous driving development, to a traffic scenario with virtual vehicles on a real road network.

11:44-12:01 MoOralBT.3

A Dynamic Programming Approach for Nonholonomic Vehicle Maneuvering in Tight Environments, pp. 151-156

Schildbach, Georg — Univ. of California at Berkeley
Borrelli, Francesco — Univ. of California, Berkeley

State-of-the-art autonomous cars use various algorithms for path planning in different environments. The design of these algorithms is difficult when the nonlinear and the nonholonomic aspect of the vehicle dynamics are dominant. These aspects are small at high speeds and for simple maneuvers at low speeds, so effective algorithms exist. However, path planning for more complex maneuvers at low speeds, especially in tight and cluttered environments, remains a difficult challenge. This paper proposes a new approach to this problem. The presented algorithm performs a tree-search on a discretized state space using dynamic programming. It is shown in simulation and experiments that even complicated paths can be computed very efficiently. Since a path is composed of a sequence of simple arcs, it is easy to track by a linear controller.

12:01-12:18 MoOralBT.4

Automated Valet Parking and Charging for E-Mobility Results of the V-Charge Project, pp. 157-164

Schwesinger, Ulrich — ETH Zurich
Bürki, Mathias — Autnomous Systems Lab, ETH Zürich
Timpner, Julian — Tech. Univ. Braunschweig
Rottmann, Stephan — Tech. Univ. Braunschweig
Wolf, Lars — Tech. Univ. Braunschweig
Paz, Lina Maria — Univ. of Oxford
Grimmet, Hugo — Univ. of Oxford
Posner, Ingmar — Oxford Univ
Newman, Paul — Univ. of Oxford
Häne, Christian — ETHZ
Heng, Lionel — DSO National Lab
Lee, Gim Hee — National Univ. of Singapore

Sattler, Torsten	ETH Zurich
Pollefeys, Marc	ETH Zurich
Allodi, Marco	VisLab Srl
Valenti, Francesco	Univ. Degli Studi Di Parma
Mimura, Keiji	Robert Bosch GmbH
Göbelsmann, Bernd	Robert Bosch GmbH
Derendarz, Wojciech	Volkswagen AG
Muehlfellner, Peter	Volkswagen AG, Halmstad Univ
Wonneberger, Stefan	Volkswagen AG
Waldmann, Rene	Volkswagen AG
Last, Carsten	Volkswagen AG
Siegwart, Roland	ETH Zurich

Automated valet parking services provide great potential to increase the attractiveness of electric vehicles by mitigating their two main current deficiencies: reduced driving ranges and prolonged refueling times. The European research project V-Charge aims at providing this service on designated parking lots using close-to-market sensors only. For this purpose the project developed a prototype capable of performing fully automated navigation in mixed traffic on designated parking lots and GPS-denied parking garages with cameras and ultrasonic sensors only. This paper summarizes the work of the project, comprising advances in network communication and parking space scheduling, multi-camera calibration, semantic mapping concepts, visual localization and motion planning. The project pushed visual localization, environment perception and automated parking to centimetre precision. The developed infrastructure-based camera calibration and semi-supervised semantic mapping concepts greatly reduce maintenance efforts. Results are presented from extensive month-long field tests.

MoPosterAT1 Open Arena

Poster I: ADAS & Collision Avoidance (Poster Session)

Chair: Murgovski, Nikolce — Chalmers Univ. of Tech

13:20-14:45 MoPosterAT1.1

Predictive Safety Based on Track-Before-Detect for Teleoperated Driving through Communication Time Delay, pp. 165-172

Hosseini, Amin	Tech. Univ. of Munich
Lienkamp, Markus	Tech. Univ. München

Teleoperated driving is known as a transient technology toward full autonomous driving in urban areas. However, this mobility concept suffers mainly from the communication time delay, which may result in safety hazards as well as stop-and-go driving behavior in crowded inner-city areas. This paper presents a novel active safety concept to assist the human operator of the teleoperated vehicle considering the communication time delay. The proposed system reacts not only to the actual driving hazards, but also to the upcoming hazards the human operator is not aware of because of time delay. For this purpose, it predicts the future trajectories of dynamic objects in the vehicle surroundings using a stereo vision based track-before-detect approach and reacts autonomously to the predicted hazards through speed control. After each intervention, the human operator is informed about the autonomous intervention of the vehicle by a Human-Machine-Interface (HMI), having the ability to override this intervention. Results of the test drives show an overall increase of the safety by reduction of Time-To-Collision as well as an improvement of the acceptance of teleoperated driving through the reduction of the overall triggered deceleration during driving in urban areas.

13:20-14:45 MoPosterAT1.2

Fast Decision Making Using Ontology-Based Knowledge Base, pp. 173-178

Zhao, Lihua	National Inst. of Advanced Industrial Science and Tech
Ichise, Ryutaro	National Inst. of Informatics
Sasaki, Yutaka	Toyota Tech. Inst
Liu, Zheng	Univ. of British Columbia Okanagan
Yoshikawa, Tatsuya	AISIN SEIKI Co., Ltd

Making fast driving decisions at intersections is a challenging problem for improving safety of autonomous vehicles. Furthermore, representing sensor data in a machine understandable format is essential to enable vehicles to understand traffic situations. Ontologies are used to represent knowledge of sensor data for autonomous vehicles to aware traffic situations. In this paper, we introduce a fast decision making system, which utilizes only related part of the ontology-based knowledge base to make decisions at intersections. The decision making system performs real-time reasoning using traffic regulations and a part of the map information from the knowledge base.

13:20-14:45 MoPosterAT1.3

Monocular Parking Slots and Obstacles Detection and Tracking, pp. 179-185

Allodi, Marco	VisLab Srl
Castangia, Luca	Univ. of Parma
Cionini, Alessandro	VisLab Srl
Valenti, Francesco	Univ. Degli Studi Di Parma

This paper presents the main contributions of the University of Parma to the V-Charge Project, which focuses on the development of an automated valet parking and charging system. Different modules have been developed including a classifier of the regions of interest provided by an external stereo system, a detection and tracking algorithm covering the area around the vehicle, a feature tracking algorithm for obstacle detection in approaching crossroad, and a parking slots detection. All algorithms are based on images coming from fish-eye cameras installed on the four sides of the vehicle.

13:20-14:45 MoPosterAT1.4

Extensions for the Foresighted Driver Model: Tactical Lane Change, Overtaking and Continuous Lateral Control, pp. 186-193

Damerow, Florian	Tech. Univ. of Darmstadt
Flade, Benedict	Honda Res. Inst. (HRI)
Eggert, Julian	Honda Res. Inst. Europe GmbH

The Foresighted Driver Model (FDM) is a microscopic driver model which is based on the idea that a driver balances risk with utility. This paper deals with the modeling of advanced driving maneuvers for the FDM with a special focus on lateral positioning scenarios, such as lane changes in highway traffic. When driving at high speeds, tactical preparation for a safe lane change is of high importance. In this context, the paper presents maneuvers that allow for lane changes to be planned well in advance and carefully made without the restraint of requiring immediate action. Furthermore, the paper presents a continuous lateral control which allows driving on arbitrary paths other than the centerline, depending on the current traffic situation. Since more complex lateral maneuvers require more detailed considerations of the environment, an approach is presented to model the lane and the environmental influences. This paves the way for a modeling of variables such as lane markings, roadblocks, hard shoulders and more. Simulations illustrate how the introduced maneuvers allow successful preparation for upcoming lane changes and how traffic obstructions can be bypassed without performing a lane change but by using the continuous lateral control.

13:20-14:45 MoPosterAT1.5

Road Network Reconstruction Using Reversible Jump MCMC Simulated Annealing Based on Vehicle Trajectories from Fleet Measurements, pp. 194-201

Roeth, Oliver Bertin	Robert Bosch GmbH
Zaum, Daniel	Robert Bosch GmbH
Brenner, Claus	Inst. of Cartography and Geoinformatics, Leibniz Univ

Being regarded as essential for advanced driver assistance systems and autonomous driving, the research field of map generation from crowd-sourced vehicle information gained attention in the last decade. This paper introduces a novel approach for the derivation of street accurate road networks from such data. The method is applied to a real-world dataset of different accuracy gradation and is evaluated against a ground truth map. Furthermore, the results are compared to results of two state of the art algorithms.

13:20-14:45	MoPosterAT1.6

Trajectory Planning for Collision Avoidance in Urban Area, pp. 202-207

Ferdinand, Jens	Adam Opel AG
Yi, Boliang	Adam Opel AG

Automated evasive maneuvers require special methods of trajectory planning meeting the required demands. An optimal evasive trajectory requires drive-ability, guarantee of collision freeness, and optimal utilization of the available maneuver room. Meeting these demands, a combination of braking and steering is desirable which also comes with an increase of complexity. Further, from a functional safety stand point and the performance of close-to-production environmental sensor it is desirable to execute the maneuver as late as possible. In this publication we propose a trajectory planning procedure that combines braking and steering. We define an optimization problem that finds the last possible drivable trajectory. The potential of the proposed procedure is verified by a simulation followed by a further analysis and discussion.

13:20-14:45	MoPosterAT1.7

Estimation and Prediction of Vehicle Dynamics States Based on Fusion of OpenStreetMap and Vehicle Dynamics Models, pp. 208-213

Jiang, Kun	Univ. of Tech. of Compiegne
Correa Victorino, Alessandro	Univ. De Tech. De Compiègne (UTC)
Charara, Ali	Univ. De Tech. De Compiègne

This paper presents a novel approach for estimation and prediction of vehicle dynamics states by incorporating digital road map and vehicle dynamics models. Precise information about vehicle dynamics states is essential for the safety and stability of vehicle. In particular, the tire-road contact forces and vehicle side slip angle are the most important parameters for evaluating the safety of vehicle. Nevertheless,these dynamics states are immeasurable with low cost sensors. Therefore, different observers, or the so-called virtual sensors are developed to estimate vehicle dynamics states. However, the existing observers are only capable in estimating vehicle dynamics states at a current instant but not to predict the potential dangers in a future instant. In order to make time for correcting drive behaviors, especially when driving at high speed, it seems very appealing for us to predict an impending dangerous event and react before the danger occurs. In this paper, the estimation of vehicle dynamics states is based on the fusion of information from inertial sensors, GPS and OpenStreetMap. The geometry of the upcoming path ahead of vehicle is provided by the digital map and is employed to predict the future dynamics states.

13:20-14:45	MoPosterAT1.8

Vehicle Speed Tracking Using Chassis Vibrations, pp. 214-219

Lindfors, Martin	Linköping Univ
Hendeby, Gustaf	Linköping Univ
Gustafsson, Fredrik	Linköping Univ
Karlsson, Rickard	Linköping Univ

The speed of a wheeled vehicle is usually estimated using wheel speed sensors (WSS) or GPS. If these signals are unavailable, other methods must be used. We propose a novel approach exploiting the fact that vibrations from rotating axles, with fundamental frequency proportional to vehicle speed, are transmitted via the vehicle chassis. Using an accelerometer, these vibrations can be tracked to estimate vehicle speed while other sources of vibrations act as disturbances. A state-space model for the dynamics of the harmonics is presented and formulated such that there is a conditional linear-Gaussian substructure, enabling efficient Rao-Blackwellized methods. A variant of the Rao-Blackwellized point-mass filter is derived, significantly reducing computational complexity, and reducing the memory requirements from quadratic to linear in the number of grid points. It is applied to experimental data from the sensor cluster of a car and validated using the rotational frequency from WSS data. The proposed method shows improved performance and robustness in comparison to a Rao-Blackwellized particle filter implementation and a frequency spectrum maximization method.

13:20-14:45	MoPosterAT1.9

Analytical Derivation of Performance Bounds of Autonomous Emergency Brake Systems, pp. 220-226

Stellet, Jan Erik	Robert Bosch GmbH
Vogt, Patrick	Univ. of Darmstadt
Schumacher, Jan	Robert Bosch GmbH
Branz, Wolfgang	Robert Bosch GmbH
Zöllner, J. Marius	FZI Res. Center for Information Tech. KIT Karlsruhe In

Autonomous emergency brake (AEB) systems have to decide on brake interventions based on an uncertain and incomplete perception of the environment. This paper analyses theoretical limitations in AEB systems caused by noisy sensor measurements and uncertain prediction models. Such performance bounds can be used to derive sensor accuracy constraints, to identify challenging scenarios or to develop objective metrics.

In contrast to most previous studies, this work focusses on analytical derivations. To this end, the Cram'er-Rao bound of the best attainable state estimation covariance is derived from a model of sensor measurement errors. This state- and time-dependent covariance is then propagated to an AEB decision making logic that is based on a criticality measure. Additional inherent prediction uncertainty in this risk assessment is taken into account. The effectiveness of the AEB subject to uncertainties is compared to the deterministic baseline case in terms of the brake activation time and the collision energy reduction.

13:20-14:45	MoPosterAT1.10

Driver Lane Keeping Behavior in Normal Driving Using 100-Car Naturalistic Driving Study Data, pp. 227-232

Johnson, Taylor	Virginia Tech
Sherony, Rini	Toyota Motor Engineering and Manufacturing North America
Gabler, Hampton Clay	Virginia Tech

Lane departure warning (LDW) systems have great potential to reduce the number of road departures and resulting crashes, but only if drivers accept and react appropriately to the warnings. With a better understanding of normal lane keeping, there is the potential opportunity for improvement in the timing and driver acceptance of LDW warnings. The study investigates the distribution of lane keeping during normal driving based on the relationship of lateral velocity and lateral distance to lane boundary, and examines how this distribution changes with lane width and road radius of curvature. This study utilizes data from 6,109 trips driven by 40 unique primary drivers enrolled in the Virginia Tech Transportation Institute (VTTI) 100-Car naturalistic driving study.

13:20-14:45	MoPosterAT1.11

A Collision Avoidance System at Intersections Using Robust Model Predictive Control, pp. 233-238

Schildbach, Georg	Univ. of California at Berkeley
Soppert, Matthias	Hamburg Univ. of Tech
Borrelli, Francesco	Univ. of California, Berkeley

Collisions at intersections account for about 40% of all car accidents and for about 20% of all traffic fatalities in the United States. The main cause is human error in recognition and decision making. Active safety systems have thus a great potential for increasing vehicle safety at intersections. They may issue warnings to the driver or assume control of the vehicle in critical situations. Most approaches in current research rely on the assumption that all vehicles at the intersection are controllable,

and/or they can be coordinated by a central intersection manager. This paper considers the case of a single controllable ego vehicle surrounded by several uncontrollable target vehicles, without communication. Only a map with the current position and velocity of the target vehicles are assumed to be known, but no pre-defined crossing order is given. A Robust Model Predictive Control strategy is designed for finding safe gaps in the crossing traffic, and for planning optimal trajectories to maximize the ego vehicle's efficiency and driver comfort. It is shown that its performance can be enhanced by Affine Disturbance Feedback. The algorithm is tested in several simulation scenarios and implemented on a test vehicle for experimental validation.

13:20-14:45 MoPosterAT1.12

Driver Perception and Reaction in Collision Avoidance: Implications for ADAS Development and Testing, pp. 239-245

Sieber, Markus — Univ. Der Bundeswehr München
Färber, Berthold — Univ. Der Bundeswehr

The quality of an advanced driver assistance system (ADAS) is limited by the quality of its interaction with the driver. For an efficient human-machine-interaction design, it is necessary to possess a thorough understanding of driver behavior and perception in relevant driving situations. While several previous studies have addressed the topic of driver behavior in regard to collision avoidance, this paper examines how various situational parameters of a collision avoidance scenario relate to drivers' reactions and perceptions. A driving experiment with a cross traffic obstacle appearing at different speeds and different times-to-collision (TTC) was performed on a test track. While the TTC proved to be the most defining factor for the objective criticality of the situation, drivers' reactions and perceptions were impacted most severely by obstacle movement speed. The implications of these and other findings for ADAS research and development are discussed.

13:20-14:45 MoPosterAT1.13

3D Motion Planning of UAVs in GPS-Denied Unknown Forest Environment, pp. 246-251

Liao, Fang — National Univ. of Singapore
Lai, Shupeng — National Univ. of Singapore
Hu, Yuchao — National Univ. of Singapore
Cui, Jinqiang — National Univ. of Singapore
Wang, Jianliang — Nanyang Tech. Univ
Teo, Rodney — DSO National Lab
Lin, Feng — National Univ. of Singapore

In this paper, a decomposition hierarchic on-line motion planning approach consisting of path planning and trajectory generation is proposed for VTOL UAVs to fly in a GPS-denied unknown obstacle-rich environment such as forest and urban canyon. A closed-loop 3D path planning based on A* search algorithm is used to generate collision-free path and a 3D on-line trajectory generation based on maneuver automaton methods is used to generate a collision-free reference trajectory. The simulation and experiment on a VTOL UAV demonstrate the effectiveness of the proposed motion planning approach.

MoPosterAT2 Pascal

Poster I: Lidar & Fusion & Self-Driving Vehicles (Poster Session)

Chair: Wymeersch, Henk — Chalmers

13:20-14:45 MoPosterAT2.1

Multi-Sensor Tracking with SPRT in an Autonmous Vehicle, pp. 252-257

Stess, Marek — Volkswagen AG
Schildwächter, Christian — Tech. Univ. Braunschweig
Mersheeva, Vera — Otto-Von-Guericke Univ. Magdeburg
Ortmeier, Frank — Otto-Von-Guericke Univ. Magdeburg
Wagner, Bernardo — Leibniz Univ. Hannover,

Technologies for fully automated driving are currently a hot topic for both industry and academia. To achieve a full automation, self-driving cars need a precise localization module. Most of existing localization approaches consist of two main steps: map generation and actual localization that uses the map obtained at the first step. The localization quality of a system directly depends on the capabilities of its sensors, the quality of a map, as well as correctness and effectiveness with which a localization method uses new observations. Therefore, to provide the best results, such systems are equipped with ever-increasing number of sensors. However, extraction of relevant information from sensor data is still challenging.

This paper focuses on two localization components: landmark tracking and fusion. We consider landmarks corresponding to poles and road surface markings. They are extracted from the data provided by four fisheye cameras placed around a car and a front lidar. Detection of landmarks depends on characteristics of a sensor: its quality, delay (time), and output rate (frequency). Therefore, we have developed a tracking and fusion module based on the Sequential Probability Ratio Test which is used for both map generation and localization steps. This module was evaluated in a number of driving tests and the results showed high map quality and low localization error.

13:20-14:45 MoPosterAT2.2

Why the Association Log-Likelihood Distance Should Be Used for Measurement-To-Track Association, pp. 258-265

Altendorfer, Richard — Zf Trw
Wirkert, Sebastian — DKFZ (German Cancer Res. Center)

The Mahalanobis distance is commonly used in multi-object trackers for measurement-to-track association. Starting with the original definition of the Mahalanobis distance we review its use in association. Given that there is no principle in multi-object tracking that sets the Mahalanobis distance apart as a distinguished statistical distance we revisit the global association hypotheses of multiple hypothesis tracking as the most general association setting. Those association hypotheses induce a distance-like quantity for assignment which we refer to as association log-likelihood distance.

We compare the ability of the Mahalanobis distance to the association log-likelihood distance to yield correct association relations in Monte-Carlo simulations. Here, we use a novel method to generate multi-track scenarios that make the association evaluation independent of a specific track management scheme. We also explore the influence of the term proportional to the measurement dimension in the association log-likelihood distance on the assignment performance. It turns out that on average the distance based on association log-likelihood performs better than the Mahalanobis distance, confirming that the maximization of global association hypotheses is a more fundamental approach to association than the minimization of a certain statistical distance measure.

13:20-14:45 MoPosterAT2.3

Locally Adaptive Discounting in Multi Sensor Occupancy Grid Fusion, pp. 266-271

Seeger, Christoph — BMW Group
Manz, Michael — BMW Group
Matters, Patrick — BMW Group
Hornegger, Joachim — Friedrich-Alexander-Univ. Erlangen-Nürnberg

Obstacle fusion algorithms usually perform obstacle association and gating in order to improve the obstacle position if it was detected by multiple sensors. However, this strategy is not common in multi sensor occupancy grid fusion. Thus, the quality of the fused grid, in terms of obstacle position accuracy, largely depends on the sensor with the lowest accuracy. In this paper an efficient method to associate obstacles across sensor grids is proposed. Imprecise sensors are discounted locally in cells where a more accurate sensor, that detected the same obstacle, derived free space. Furthermore, fixed discount factors to optimize false

negative and false positive rates are used. Because of its generic formulation with the covariance of each sensor grid, the method is scalable to any sensor setup. The quantitative evaluation with a highly precise navigation map shows an increased obstacle position accuracy compared to standard evidential occupancy grid fusion.

13:20-14:45 MoPosterAT2.4

A New Geometric 3D LiDAR Feature for Model Creation and Classification of Moving Objects, pp. 272-278

Kusenbach, Michael Univ. of the Bundeswehr Munich
Himmelsbach, Michael Univ. of the Bundeswehr, Munich
Wuensche, Hans Joachim Joe Univ. Bw Munich

In this paper, we introduce a new geometric 3D feature combined with a clustering approach. Besides 3D data provided by a LiDAR point cloud, reflectivity information is used to further enhance the descriptivity of the feature. The proposed feature can be extracted and compared in real-time. Similar parts of an object, such as features belonging to an automobile headlight, are automatically clustered in an object model without explicit specification. Additionally, we provide a method for autonomous vehicles to automatically learn the shapes of observed moving objects and use them for real-time classification. The resulting object models consisting of the extracted feature clusters are interpretable by humans.

13:20-14:45 MoPosterAT2.5

Probabilistic Rectangular-Shape Estimation for Extended Object Tracking, pp. 279-285

Broßeit, Peter Daimler AG
Rapp, Matthias Ulm Univ
Appenrodt, Nils Daimler AG
Dickmann, Jürgen Mercedes-Benz AG

This paper presents new methods for the representation of a vehicle's contour by an oriented rectangle, also known as the bounding box. The parameters of this bounding box are originally modeled probabilistically by a single multivariate Gaussian distribution. This approach incorporates the sensor uncertainties, where the problem of estimating the parameters of this distribution from range measurements is addressed. Additionally, a transformation of the parameters into the measurement space is introduced. This representation is used to perform probabilistic updates by new measurements. The proposed method can handle strong parameter changes which might be affected by object occlusion. Experiments on real-world data demonstrate the robustness and accuracy of the probabilistic approach integrated in a tracking framework incorporating the Doppler measurements of automotive radars and laser measurements.

13:20-14:45 MoPosterAT2.6

Modeling and Simulation of Rain for the Test of Automotive Sensor Systems, pp. 286-291

Hasirlioglu, Sinan Tech. Hochschule Ingolstadt
Doric, Igor Tech. Hochschule Ingolstadt
Lauerer, Christian CARISSMA, Tech. Hochschule Ingolstadt
Brandmeier, Thomas Ingolstadt Univ. of Applied Sciences

This paper presents a new approach for the test of automotive sensor systems in rain. The approach is based on an indoor test method, which helps to save test kilometers and test effort. For the activation of safety systems detailed information about the vehicles environment is necessary. Laser scanners provide precise information about the environment and a high angular resolution in contrast to radar sensors. The performance of laser scanners depends on their local environment, because of the attenuation of the ambient atmosphere, precipitation and on the reflectivity of objects. False measurements in the field of vehicle safety can result in severe injury or death, so high reliability is essential. For this purpose a theoretical model is developed in order to determine the sensor behavior. Subsequently, a rain simulator is constructed to validate the theoretical model. Furthermore the developed rain simulator is validated by comparison with real rain. Based on determined rain disturbances benchmark tests of different sensor systems and algorithm approaches can be performed.

13:20-14:45 MoPosterAT2.7

Integration of a Dynamic Model in a Driving Simulator to Meet Requirements of Various Levels of Automatization, pp. 292-297

Gauerhof, Lydia Tech. Univ. München
Bilic, Anito Tech. Univ. München
Knies, Christian Tech. Univ. München
Diermeyer, Frank Tech. Univ. München

To enable the development of driver assistant systems in a driving simulator, a realistic modelling of the driving dynamics is required. A simple approach to the dynamics is using a single-track model or a double-track model. A more detailed and more realistic approach is a multi-body model. To this end, a multi-body model was integrated in the dynamic truck driving simulator and evaluated. The requirements are real-time capability, realistic driving behaviour and simulator compatibility. We increased the immersion into the simulation via realistic dynamic behaviour. Due to the multi-body model, the dynamics at starting, cornering and braking are accurately computed. Against the background of automated driving, we created opportunities for further functional extensions such as automated longitudinal and lateral control.

13:20-14:45 MoPosterAT2.8

A Direct Scattering Model for Tracking Vehicles with High-Resolution Radars, pp. 298-303

Knill, Christina Ulm Univ
Scheel, Alexander Univ. of Ulm
Dietmayer, Klaus Univ. of Ulm

In advanced driver assistance systems and autonomous driving, reliable environment perception and object tracking based on radar is fundamental. High-resolution radar sensors often provide multiple measurements per object. Since in this case traditional point tracking algorithms are not applicable any more, novel approaches for extended object tracking emerged in the last few years. However, they are primarily designed for lidar applications or omit the additional Doppler information of radars. Classical radar based tracking methods using the Doppler information are mostly designed for point tracking of parallel traffic. The measurement model presented in this paper is developed to track vehicles of approximately rectangular shape in arbitrary traffic scenarios including parallel and cross traffic. In addition to the kinematic state, it allows to determine and track the geometric state of the object. Using the Doppler information is an important component in the model. Furthermore, it neither requires measurement preprocessing, data clustering, nor explicit data association. For object tracking, a Rao-Blackwellized particle filter (RBPF) adapted to the measurement model is presented.

13:20-14:45 MoPosterAT2.9

Functional System Architectures towards Fully Automated Driving, pp. 304-309

Tas, Omer Sahin FZI Res. Center for Information Tech
Kuhnt, Florian FZI Forschungszentrum Informatik
Zöllner, J. Marius FZI Res. Center for Information Tech. KIT Karlsruhe In
Stiller, Christoph Karlsruhe Inst. of Tech

The functional system architecture of an automated vehicle plays a crucial role in the performance of the vehicle. When considered as a backbone, it does not only transmit information between distinct layers, but rather serves as a feedback mechanism coordinating the degradation between them and thereby regulates the behavior of the system against failures. Hence, the design of robust functional architectures is essential to cope with the uncertainties of the world.

This paper summarizes existing system architectures and investigates them regarding their robustness against measurement inaccuracies, failures, and unexpected evolution of traffic situations. After illustrating their strengths and deficiencies, we derive the requirements and propose a structure for future, robust system architectures.

MoPosterAT3	Conference Hall
Poster I: Vision Sensing and Perception (Poster Session)	
Chair: Charalambous, Themistoklis	Chalmers Univ

13:20-14:45 MoPosterAT3.1

Monocular 3D Shape Reconstruction Using Deep Neural Networks, pp. 310-315

Rao, Qing — Daimler AG
Krüger, Lars — Daimler AG
Dietmayer, Klaus — Univ. of Ulm

This paper presents a novel approach to reconstructing the 3D shape of an object from a single image. The approach combines deep neural networks with a silhouette-based 3D reconstruction process. The optimal 3D shape is sought efficiently inside an extremely low-dimensional latent shape space, and the viewpoint and the object shape are jointly optimized based on the result of image segmentation. Evaluation of this approach shows a nearly 20 percent performance gain in viewpoint estimation subsequent to the optimization.

13:20-14:45 MoPosterAT3.2

Additional Traffic Sign Detection Using Learned Corner Representations, pp. 316-321

Wenzel, Thomas — Robert Bosch Car Multimedia GmbH
Brueggert, Steffen — Robert Bosch GmbH
Denzler, Joachim — Friedrich-Schiller-Univ. Jena

The detection of traffic signs and recognizing their meanings is crucial for applications such as online detection in automated driving or automated map data updates. Despite all progress in this field detecting and recognizing additional traffic signs, which may invalidate main traffic signs, has been widely disregarded in the scientific community. As a continuation of our earlier work we present a novel high-performing additional sign detector here, which outperforms our recently published state-of-the-art results significantly. Our approach relies on learning corner area representations using Aggregated Channel Features (ACF). Subsequently, a quadrangle generation and filtering strategy is applied, thus effectively dealing with the large aspect ratio variations of additional signs. It yields very high detection rates on a challenging dataset of high-resolution images captured with a windshield-mounted smartphone, and offers very precise localization while maintaining real-time capability. More than 95% of the additional traffic signs are detected successfully with full content detection at a false positive rate well below 0.1 per main sign, thus contributing a small step towards enabling automated driving.

13:20-14:45 MoPosterAT3.3

Robust Pedestrian Attribute Recognition for an Unbalanced Dataset Using Mini-Batch Training with Rarity Rate, pp. 322-327

Fukui, Hiroshi — Chubu Univ
Yamashita, Takayoshi — Chubu Univ
Yamauchi, Yuji — Chubu Univ
Fujiyoshi, Hironobu — Chubu Univ
Murase, Hiroshi — Nagoya Univ

Pedestrian attributes are significant information for Advanced Driver Assistance System(ADAS). Pedestrian attributes such as body poses, face orientations and open umbrella are meant action or state of pedestrian. In general, this information is recognized using independent classifiers for each task. Performing all of these separate tasks is too time-consuming at the testing stage. In addition, the processing time increases with the number of tasks. To address this problem, multi-task learning, or heterogeneous learning, is able to train a single classifier to perform multiple tasks. In particular, heterogeneous learning is able to simultaneously train regression and recognition tasks, thereby reducing both training and testing time. However, heterogeneous learning tends to result in a lower accuracy rate for classes with few training samples. In this paper, we propose a method to improve the performance of heterogeneous learning for such classes. We introduce a rarity rate based on the importance and class probability of each task. The appropriate rarity rate is assigned to each training sample. Thus, the samples in a mini-batch for training a deep convolutional neural network are augmented by this rarity rate to focus on the class with few samples. Our heterogeneous learning approach with the rarity rate attains better performance on pedestrian attribute recognition, especially for classes representing open umbrellas.

13:20-14:45 MoPosterAT3.4

Fast Traffic Scene Segmentation Using Multi-Range Features from Multi-Resolution Filtered and Spatial Context Channels, pp. 328-334

Costea, Arthur Daniel — Tech. Univ. of Cluj-Napoca
Nedevschi, Sergiu — Tech. Univ. of Cluj-Napoca

In this paper we describe a fast solution for the semantic segmentation of traffic scenarios. We propose a multiresolution filtering scheme over LUV + HOG image channels using high pass and low pass filtered channels at multiple scales. To add spatial context, we extend the filtered channels with horizontal and vertical position channels. We introduce multi-range classification features that capture local structure and context for achieving fast semantic segmentation of traffic scenarios. Binary boosting based pixel classifiers are trained for each semantic class. Finally, we use these classifiers to provide the unary potential term in a dense Conditional Random Field. We evaluate the proposed solution on the CamVid traffic scene segmentation benchmark and achieve state of art results at 25 FPS, being the fastest top performing approach.

13:20-14:45 MoPosterAT3.5

Improving Stereo Reconstruction by Sub-Pixel Correction Using Histogram Matching, pp. 335-341

Vancea, Cristian Cosmin — Tech. Univ. of Cluj-Napoca
Miclea, Vlad — Tech. Univ. of Cluj-Napoca
Nedevschi, Sergiu — Tech. Univ. of Cluj-Napoca

The accuracy of stereo matching algorithms is one of the key aspects in autonomous driving nowadays. In case of large distances, sub-pixel accurate solutions are required, especially for algorithms in discrete settings. It has been previously shown that a strong correlation between the matching algorithm and the sub-pixel interpolation method exists, and there are ways to determine it. Unfortunately all methodologies presented so far are laborious and time-consuming.

We present here a novel sub-pixel disparity correction technique based on applying histogram matching through the use of generated Look-up Tables (LUTs). Our method is flexible, fast and produces more accurate results than previous solutions in the discrete domain. Although we show the improvements over the Semi-Global matching algorithm, it can be adapted to other matching algorithms that preserve constant misalignment for any kind of 3D scenarios. The proposed method was tested on multiple systems and datasets (Synthetic images, Traffic scenes, Middlebury images, KITTI images) and we show that we can find LUTs that outperform the accuracy of previous solutions on all these sets. The histogram matching procedure lacks in complexity and results indicate a strict dependency of a particular LUT to the underlying stereo matching and the stereo vision system, but not on the image composition.

13:20-14:45 MoPosterAT3.6

DeepTLR: A Single Deep Convolutional Network for Detection and Classification of Traffic Lights, pp. 342-348

Weber, Michael — FZI Res. Center for Information Tech

Wolf, Peter FZI Res. Center for Information Tech

Zöllner, J. Marius FZI Res. Center for Information Tech. KIT Karlsruhe In

Reliable real-time detection of traffic lights is a major concern for the task of autonomous driving. As deep convolutional networks have proven to be a powerful tool in visual object detection, we propose DeepTLR, a camera-based system for real-time detection and classification of traffic lights. Detection and state classification are realized using a single deep convolutional network. DeepTLR does not use any prior knowledge about traffic light locations. Also the detection is executed frame by frame without using temporal information. It is able to detect traffic lights on the whole camera image without any presegmentation. This is achieved by classifying each fine-grained pixel region of the input image and performing a bounding box regression on regions of each class. We show that our algorithm is able to run on frame-rates required for real-time applications while reaching notable results.

13:20-14:45 MoPosterAT3.7

Directional-DBSCAN: Parking-Slot Detection Using a Clustering Method in Around-View Monitoring System, pp. 349-354

Lee, Soomok Seoul National Univ

Hyeon, Daejin Seoul National Univ

Park, Gikwang Seoul National Univ

Baek, Il-joo LG Electronics

Kim, Seong-Woo Seoul National Univ

Seo, Seungwoo Seoul National Univ

Parking slot detection algorithms using visual sensors have been required for various automated parking assistant systems. In most previous studies, popular feature detectors, such as the Harris corner or the Hough line detector, have been employed for detecting parking slots. However, these algorithms were originally designed to find distinct features and are inadequate for the short, curvy, faint, and distorted parking lines of long-range surround-view images, especially in around-view monitoring systems. In this paper, we propose a robust parking slot detection algorithm based on the line-segment-level clustering method. The proposed algorithm consists of line-segment detection with the proposed Directional-DBSCAN line-level feature-clustering algorithm and slot detection with slot-pattern recognition. In comparison to other feature detectors, we show that the Directional-DBSCAN algorithm robustly extracts lines even when they are short and faint. Moreover, we verify that the parking-slot detection algorithm with pattern recognition can be applicable to diverse slot types and environments with experiments on abundant dataset.

13:20-14:45 MoPosterAT3.8

Combined 2d/3d Traffic Signs Recognition and Distance Estimation, pp. 355-360

Ben Romdhane, Nadra MIRACL Lab

Mliki, Hazar MIRACL Lab

Elbeji, Rabii National Engineering School of Gabes

Hammami, Mohamed MIRACL Lab

Accidents caused by reduced concentration of drivers on traffic signs indications continue to represent an important part of accident-prone situations. Face to this threat, our work aims to develop a vision-based traffic sign recognition method based on a two-step recognition and 3D distance computing module. Firstly, a monocular color based segmentation method is applied to generate traffic sign candidates. Then, HoG features are applied to encode the detected traffic signs and compute the feature vector. This vector is used as an input to a SVM classifier to identify the traffic sign class. Secondly, a dense disparity map between the left and right images is created for the recognized traffic sign region to compute its distance to the vehicle carrying the stereovision. Our method affords high precision rates under different weather conditions. Moreover, it operates with a timing that is reasonable for real-time applications. The obtained results, compared to leading methods from the literature, prove the efficiency of our proposed method.

MoOralCT Conference Hall

Cooperative Systems (V2X) (Regular Session)

Chair: Gavrila, Dariu M. Daimler AG

Co-Chair: Fidan, Baris Univ. Ofg Waterloo

14:45-15:02 MoOralCT.1

Cooperative Adaptive Cruise Control: An Artificial Potential Field Approach, pp. 361-367

Semsar-Kazerooni, Elham TNO

Verhaegh, Jan TNO

Ploeg, Jeroen TNO

Alirezaei, Mohsen TNO

In this paper, in addition to the main functionality of vehicle following, cooperative adaptive cruise control (CACC) is enabled with additional features of gap closing and collision avoidance. Due to its nonlinear nature, a control objective such as collision avoidance, cannot be addressed using a linear controller such as a PD controller. However, the artificial potential functions can be adopted to design controllers which accommodate multiple (nonlinear) control objectives in a single design. By defining an appropriate control law, the system state is always driven to the minima of the designed potential function which guarantees the required performance of the system.

15:02-15:19 MoOralCT.2

V2V Communication for Analysis of Lane Level Dynamics for Better EV Traversal, pp. 368-375

Agarwal, Akash International Inst. of Information Tech. Hyderabad

Paruchuri, Praveen International Inst. of Information Tech. Hyderabad

Slow moving traffic in heavily populated cities, can many times result in loss of lives due to emergency vehicles not being able to reach their destination hospitals on time. Recent advances in the field of Intelligent Transportation Systems (ITS) makes it increasingly likely that vehicles in the near future will be equipped with advanced systems that allow inter vehicular communication. In this paper, we assume the usage of such a system to optimize the lane level dynamics for an emergency vehicle (EV), traversing a multi lane stretch of road under a variety of traffic settings. In particular, we present the Fixed Lane Strategy (FLS) and the Best Lane Strategy (BLS) for EV traversal and perform an extensive agent based analysis to study their strengths and weaknesses. Through a series of experiments performed using the well-known traffic simulator SUMO, we could show that: (a) BLS performs better than SUMO strategy on all traffic settings we tested. (b) BLS performs better than FLS in settings that capture real-world traffic conditions involving congestion and uncertainties while FLS performs better in well-behaved conditions and (c) BLS was found to be the best strategy for the setting calibrated using real world data (obtained from NYCDOT).

15:19-15:36 MoOralCT.3

A Hierarchical Model Predictive Control Framework for On-Road Formation Control of Autonomous Vehicles, pp. 376-381

Qian, Xiangjun MINES ParisTech

de La Fortelle, Arnaud Mines ParisTech

Moutarde, Fabien Mines ParisTech

This paper presents an approach for the formation control of autonomous vehicles traversing along a multi-lane road with obstacles and traffic. A major challenge in this problem is a requirement for integrating individual vehicle behaviors such as lane-keeping and collision avoidance with a global formation maintenance behavior. We propose a hierarchical Model Predictive Control (MPC) approach. The desired formation is modeled as a virtual structure evolving curvilinearly along a centerline, and vehicle configurations are expressed as curvilinear relative longitudinal and lateral offsets from the virtual center. At high-level, the trajectory generation of the virtual center is achieved through an MPC framework, which allows various on-road driving constraints to be considered in the optimization. At low-level, a local MPC controller computes the vehicle inputs in order to track the desired trajectory, taking into account more personalized driving constraints. High-fidelity simulations show that the proposed approach drives vehicles to the desired formation while retains some freedom for individual vehicle behaviors.

15:36-15:53	MoOralCT.4

Vehicular Platooning: Multi-Layer Consensus Seeking, pp. 382-387

Fusco, Mauro	TNO
Semsar-Kazerooni, Elham	TNO
Ploeg, Jeroen	TNO
van de Wouw, Nathan	Eindhoven Univ. of Tech

In this paper, a novel Multi-Layer Consensus Seeking (MLCS) framework is proposed, focusing on the vehicular platooning problem. The vehicles are described by linear heterogeneous dynamics. For example, we consider third-order systems, however the algorithms discussed are suitable for any higher-order. A velocity dependent intervehicle spacing policy is rigorously addressed. The approach used is both multi-layered and consensus-based. The multi-layer approach allows to separate the problem of estimating the desired trajectories from the problem of controlling the vehicles towards those trajectories while keeping a safety distance. Consensus algorithms will be employed on each layer to solve these two problems.

MoPosterBT1 Open Arena

Poster II: Driver State/Intention & Situation Analysis/Planning (Poster Session)

Chair: Williamson, Ann	Univ. of New South Wales
Co-Chair: Murgovski, Nikolce	Chalmers Univ. of Tech

16:25-17:50	MoPosterBT1.1

Study on Estimating Driver Awareness of Pedestrians While Turning Right at Intersection Based on Vehicle Behavior Utilizing Driving Simulator, pp. 388-393

Tateiwa, Kei	Meijo Univ
Nakamura, Akinori	Meijo Univ
Yamada, Keiichi	Meijo Univ

To support safe driving and prevent pedestrian accidents, it is important to recognize whether a driver is aware of pedestrians. This paper deals with a method of estimating, from the vehicle behavior, whether a driver is aware of pedestrians who cross or are about to cross a crosswalk when the driver is about to turn right at an intersection. The method was validated using right-turn data at an intersection at night collected on a driving simulator. The correct detection rate of driver unaware of pedestrians was 92% and the false detection rate was 18% when the vehicle was 10 m from the crosswalk. When an alarm was issued based on the estimation of the driver's unawareness of pedestrians, the positive effect of the assistance would be expected in 89% of the cases.

16:25-17:50	MoPosterBT1.2

Detection of Driver Cognitive Distraction: An SVM Based Real-Time Algorithm and Its Comparison Study in Typical Driving Scenarios, pp. 394-399

Liao, Yuan	State Key Lab of Automotive Safety and Energy, Department of Aut
Li, Shengbo	Dept of Automotive Eng., Tsinghua Univ
Li, Guofa	Tsinghua Univ
Wang, Wenjun	Tsinghua Univ
Cheng, Bo	State Key Lab. of Automotive Safety and Energy, Tsinghua U
Chen, Fang	Chalmers Univ. of Tech

Detection of driver cognitive distraction is critical for active safety systems of road vehicles. Compared with visual distraction, cognitive distraction is more challenging for detection due to the lack of apparent exterior features. This paper presents a novel real-time detection algorithm for driver cognitive distraction by using support vector machine (SVM). Data are collected from 26 subjects, driving in typical urban and highway scenarios in a simulator. The chosen urban scenario is the stop-controlled intersection and the highway scenario is the speed-limited highway. Driver cognitive distraction while driving is induced by clock tasks which compete with the main driving tasks for visuospatial short working memory. For each subject, distracted driving instances and the equal number of non-distracted driving instances were collected (24 for urban scenario and 20 for highway scenario in total). Features concerning both driving performance and eye movement are used for training and validation. The proposed algorithm have correct rate of 93.0% and 98.5% for highway and urban scenarios respectively. Results also show that driver distraction can be recognized 6.5 s to 9.0 s after its happening, indicating good performance of the detection algorithm.

16:25-17:50	MoPosterBT1.3

Driver Drowsiness and Behavior Detection in Prolonged Conditionally Automated Drives, pp. 400-405

Schmidt, Jürgen	Daimler AG
Braunagel, Christian	Daimler AG
Stolzmann, Wolfgang	Daimler AG
Karrer-Gauss, Katja	Tech. Univ. Berlin

This paper reports a study that investigated driver behavior between manual and conditionally automated driving and behavioral progress in a long conditionally automated phase. The goal was to evaluate a novel framework of an assistant system for driver state monitoring during conditionally automated driving. The framework was based on the analysis of the drivers' eye closure and head movements provided by a driver observation camera. Furthermore, individual alertness requests to verify the take-over and reaction ability of the driver during the automated phase were included in the framework. The basis of the evaluation was a realistic driving simulator study with 18 participants and long monotonous drives (Mean: 2:51 +/- 0:18 h) with the majority of the drive being conditionally automated. The data showed a significant difference in the behavioral indicators (eye closure and head movement) between drivers driving manually or conditionally automated, independently of their current drowsiness state. These findings suggest that many of the common features used for drowsiness detection in manual driving phases are not applicable to the automated driving context without an adaption as presented within the framework provided.

16:25-17:50	MoPosterBT1.4

Developing a Model of Driver's Uncertainty in Lane Change Situations for Trustworthy Lane Change Decision Aid Systems, pp. 406-411

Yan, Fei	Univ. of Oldenburg
Eilers, Mark	OFFIS E.v
Luedtke, Andreas	OFFIS-Inst. for Information Tech
Baumann, Martin	Ulm Univ

Inspired by the „emancipation" theory of trust, this paper proposes to develop driver's trust in assistance systems based on the assumption that driver's appropriate trust in these systems can be built, when the support of assistance systems is adapted to the drivers' uncertainty state and helps reducing their uncertainty. For example, a trustworthy lane change assistance system is supposed to provide support to the driver during a lane change maneuver by adapting to the state of the driver's uncertainty about distance gaps and closing speeds in respect to the surrounding traffic. The precondition for such a system is a model of driver's uncertainty, which can be used to recognize driver's uncertainty states in lane change situations. This paper mainly presents the development of a probabilistic model for classifying driver's uncertainty in lane change situations. Using experimental data obtained in a simulator experiment, we considered three Bayesian networks: a naive Bayesian classifier, a Tree-Augmented-Naive

Bayesian classifier, and a fully connected Bayesian Network. Based on the Bayesian Information Criterion and Accuracy metrics, the Tree-Augmented Naive Bayesian classifier was chosen to predict driver's uncertainty in lane change situations.

16:25-17:50	MoPosterBT1.5

Predicting Lane Keeping Behaviour of Visually Distracted Drivers Using Inverse Suboptimal Control, pp. 412-418

Schmitt, Felix	Robert Bosch GmbH
Bieg, Hans-Joachim	Robert Bosch GmbH
Manstetten, Dietrich	Robert Bosch GmbH
Herman, Michael	Robert Bosch GmbH
Stiefelhagen, Rainer	Karlsruhe Inst. of Tech

Driver distraction strongly contributes to crashrisk. Therefore, assistance systems that warn drivers if their distraction poses a hazard to road safety, promise a great safety benefit. Current approaches either seek to detect critical situations using environmental sensors or estimate a driver's attention state solely from his/her behavior. However, this neglects that driving situation, driver deficiencies and compensation strategies altogether determine the risk of an accident. This work proposes to use inverse suboptimal control to predict these aspects in visually distracted lane keeping. In contrast to other approaches, this allows a situation-dependent assessment of the risk posed by distraction. Real traffic data of seven drivers are used for evaluation of the predictive power of our approach. For comparison, a baseline was built using established behavior models. In the evaluation our method achieves a consistently lower prediction error over speed and track-topology variations. Additionally, our approach generalizes better to driving speeds unseen in training phase.

16:25-17:50	MoPosterBT1.6

Monitoring Driver Cognitive Load Using Functional Near Infrared Spectroscopy in Partially Autonomous Cars, pp. 419-425

Sibi, Srinath	Stanford Univ
Ayaz, Hasan	Drexel Univ
Kuhns, David	Intel Corp
Sirkin, David	Stanford Univ
Ju, Wendy	Stanford Univ

In partially automated cars, it is vital to understand the driver state, especially the driver's cognitive load. This might indicate whether the driver is alert or distracted, and if the car can safely transfer control of driving. In order to better understand the relationship between cognitive load and the driver performance in a partially autonomous vehicle, functional near infrared spectroscopy (fNIRS) measures were employed to study the activation of the prefrontal cortex of drivers in a simulated environment. We studied a total of 14 participants while they drove a partially autonomous car and performed common secondary tasks. We observed that when participants were asked to monitor the driving of an autonomous car they had low cognitive load compared to when the same participants were asked to perform a secondary reading or video watching task on a brought in device. This observation was inline with the increased drowsy behavior observed during intervals of autonomous system monitoring in previous studies. Results demonstrate that fNIRS signals from prefrontal cortex indicate additional cognitive load during manual driving compared to autonomous. Such brain function metrics could be used with minimally intrusive and low cost sensors to enable real-time assessment of driver state in future autonomous vehicles to improve safety and efficacy of transfer of control.

16:25-17:50	MoPosterBT1.7

Predicting Pedestrian Crossing Using Quantile Regression Forests, pp. 426-432

Voelz, Benjamin	Robert Bosch GmbH
Mielenz, Holger	Robert Bosch Group
Siegwart, Roland	ETH Zurich
Nieto, Juan Ignacio	ETH Zurich

Future automated driving systems will require a comprehensive scene understanding. Considering these systems in an urban environment it becomes immediately clear that reasoning about the future behavior and trajectories of pedestrians represents one major challenge. In this paper we focus on predicting the pedestrians' time-to-cross when approaching a crosswalk. Due to the complexity of the underlying model, we propose a data-driven approach that by means of regression models learns the target variable. Instead of utilizing a standard mean regression, we propose the use of Quantile Regression. We show that this special type of regression is more suited to describe the variability of real world pedestrian trajectories. We examine and compare two approaches: Linear Quantile Regression and Quantile Regression Forest, which is an extended version of Random Forests. We present evaluations with real data and a detailed analysis emphasizing strengths and weaknesses of quantile regression for the target application.

16:25-17:50	MoPosterBT1.8

Adaptive Learning Based on Guided Exploration for Decision Making at Roundabouts, pp. 433-440

Gritschneder, Franz	Univ. of Ulm
Hatzelmann, Patrick	Inst. of Measurement, Control and Microtechnology
Thom, Markus	Univ. of Ulm
Kunz, Felix	Univ. Ulm
Dietmayer, Klaus	Univ. of Ulm

This paper proposes a learning-based behavior generation approach for automated vehicles which is adapted sequentially. Instead of engineering behavioral policies for a variety of individual traffic situations by hand, our approach concentrates on a general problem description which is adjusted using a learning algorithm that successively derives safe actions as an outcome. Recent approaches apply Reinforcement Learning techniques for this problem using Markov Decision Processes (MDP). Our approach benefits from a trajectory planning module that uses an optimal control approach and generates realistic trajectories. Further, the trajectory planning module is exploited for the exploration in solving the adaption of the action selection problem. The task of action selection for merging into a roundabout as an exemplary traffic situation is examined. The contributions of this paper are the usage of an underlying optimization-based trajectory generation module and the evaluation of convergence of the adapted behavior, also for real-world data.

16:25-17:50	MoPosterBT1.9

Optimizing a Driving Strategy by Its Sensor Coverage of Relevant Environment Information, pp. 441-446

Heinrich, Steffen	Freie Univ. Berlin
Stubbemann, Jannes	Univ. of Paderborn
Rojas, Raúl	Berlin Univ

We propose a novel approach for automated vehicle motion planning systems that introduces the likelihood of an information gain at future positions to trajectory optimization. In the same way as human drivers, computer controlled vehicles have to be fully aware of their surroundings and the current driving situation. Even though automated cars have a full 360 degrees field of view through sensor data fusion, objects can be hidden behind other obstacles. We optimize the vehicle's future pose (position and orientation) on the road and within the traffic stream, so that it can perceive as much as possible while fulfilling other constraints related to the overall safety or driving comfort. Our results show that perception benefits from maximizing the entropy in areas of interest (EAI) over field of view (FOV). The computation of an EAI is expensive and achieved by using an optimized algorithm for modern GPGPUs.

16:25-17:50	MoPosterBT1.10

Tactical Cooperative Planning for Autonomous Highway Driving Using Monte-Carlo Tree Search, pp. 447-453

Lenz, David	Fortiss GmbH
Kessler, Tobias	Fortiss GmbH
Knoll, Alois	Tech. Univ. München

Human drivers use nonverbal communication and anticipation of other drivers' actions to master conflicts occurring in everyday driving situations. Without a high penetration of vehicle-to-vehicle communication an autonomous vehicle has to have the possibility to understand intentions of others and share own intentions with the surrounding traffic participants. This paper proposes a cooperative combinatorial motion planning algorithm without the need for inter vehicle communication based on Monte Carlo Tree Search (MCTS). We motivate why MCTS is particularly suited for the autonomous driving domain. Furthermore, adoptions to the MCTS algorithm are presented as for example simultaneous decisions, the usage of the Intelligent Driver Model as microscopic traffic simulation, and a cooperative cost function. We further show simulation results of merging scenarios in highway-like situations to underline the cooperative nature of the approach.

16:25-17:50	MoPosterBT1.11

Driver and Pedestrian Awareness-Based Collision Risk Analysis, pp. 454-459

Roth, Markus	Daimler R&D
Flohr, Fabian	Daimler AG
Gavrila, Dariu M.	Daimler AG

We present a novel approach for vehicle-pedestrian collision risk analysis that incorporates mutual situational awareness, a degree of potential motion coupling and the spatial layout of the environment. The approach uses a Dynamic Bayesian Network (DBN) for modeling the individual object paths; collision risk is subsequently computed by an intersection operation.

More specifically, the proposed DBN consists of two subgraphs for modeling pedestrian and vehicle path, respectively. They consist of latent states on top of Switching Linear Dynamical Systems (SLDSs) to anticipate changes in object Dynamics. The pedestrian- and vehicle-related sub-graphs contain latent states to model whether the pedestrian has seen the oncoming vehicle, and conversely, whether the driver seen the pedestrian (associated measurements involve the respective head orientations). The pedestrian-related sub-graph furthermore contains a latent state modeling whether the pedestrian is at the curbside or not. Finally, a latent state is shared by the two sub-graphs, which models the potential motion coupling (i.e. at full awareness of the other traffic participant).

We consider the scenario of a crossing pedestrian, who might stop or continue walking at the curb, in combination with an approaching vehicle, that might stop or continue driving. In experiments we illustrate that with the proposed approach, a more anticipatory driver warning and/or vehicle control strategy can be implemented.

MoPosterBT2	Pascal
Poster II: Energy Efficiency & Mapping (Poster Session)	
Chair: Garcia, Fernando	Univ. Carlos III De Madrid
Co-Chair: Wymeersch, Henk	Chalmers

16:25-17:50	MoPosterBT2.1

*New High-Efficiency Architecture for Regenerative Braking Systems**

Saci, Samir	Tsinghua Univ
Zhang, Junzhi	Tsinghua Univ
Li, Yutong	Tsinghua Univ. Department of Automotive Engineering - Beij

16:25-17:50	MoPosterBT2.2

An Adaptive Equivalent Consumption Minimization Strategy for Parallel Hybrid Electric Vehicle Based on Fuzzy PI, pp. 460-465

Zhang, Fengqi	Beijing Inst. of Tech
Xi, JunQiang	Beijing Inst. of Tech
Langari, Reza	Texas A&M Univ

This paper proposes a new energy management based on equivalent consumption minimization strategy (ECMS) for hybrid electric vehicles. The aim is to impose SoC charge-sustainability and enhance the fuel economy. First, the equivalent factor (EF) of ECMS is derived from Pontryagin's Minimum Principle. Second, a new adaptation law using Fuzzy Proportional plus Integral (PI) controller is developed to adjust EF in real-time. Finally, simulations for two driving cycles using ECMS are compared with rule-based (RB) control strategy, indicating that the proposed adaptation law can provide a promising blend in terms of fuel economy and charge-sustainability. The results show that ECMS with Fuzzy PI adaptation of EF achieves significant improvement compared with RB in terms of fuel economy and is more robust than ECMS with constant EF.

16:25-17:50	MoPosterBT2.3

Online MPC Based PHEV Energy Management Using Conic Interior-Point Methods, pp. 466-471

Sangili Vadamalu, Raja	TU Darmstadt
Beidl, Christian	TU Darmstadt

Energy Management (EM) strategy relying on online optimization is proposed for Plug-in Hybrid Electric Vehicle (PHEV). The implementation is based on Model Predictive Control (MPC) and can account for varying driving conditions. EM problem is solved online by iterative optimization of an objective function over the constrainted feasible region, formulated as a Second Order Cone Problem (SOCP). The optimization relies on predictive information about future driving conditions within a limited time horizon. The EM strategy adapts its functionality based on situation-aware prediction and offers a possibility to tune online the optimization process by heuristics on constraint limits.

16:25-17:50	MoPosterBT2.4

Performance of Current Eco-Routing Methods, pp. 472-477

Kubicka, Matej	Lab. of Signals and Systems, CNRS, Supélec and Paris-Sud U
Klusáček, Jan	Brno Univ. of Tech
Sciarretta, Antonio	IFP
Cela, Arben	ESIEE Paris
Mounier, Hugues	LSS
Laurent, Thibault	IFPEN
Niculescu, Silviu-Iulian	Lab. De Signaux Et Systemes (L2S, UMR CNRS 8506)

Eco-routing is a vehicle navigation method that aims to minimize fuel or energy consumption for a given trip. It is based on a hypothesis that we can trade extra travel time for lower consumption. While the hypothesis was experimentally verified the design of a method that would fully exploit its potential proves challenging. Current solutions hinge on assumption that energy spent on any given road does not change in time. We challenge validity of this assumption by studying performance of such methods in detailed second-by-second simulation that pronounces the time-dependencies. This allows us to quantify the real savings attainable with current eco-routing.

16:25-17:50	MoPosterBT2.5

How to Distinguish Inliers from Outliers in Visual Odometry for High-Speed Automotive Applications, pp. 478-483

Buczko, Martin	Tech. Univ. of Darmstadt
Willert, Volker	TU Darmstadt

In this paper, we present an outlier removal scheme for stereo-based visual odometry which is especially suited for improving high-speed pose change estimations in large-scale depth environments. First we investigate the variance of the reprojection error on the 3D position of a feature given a fixed error in pose change to conclude that a detection of outliers based on a fixed threshold on the reprojection error is inappropriate. Then we propose an optical flow dependent feature-adaptive scaling of the reprojection error to reach almost invariance to the 3D position of each feature. This feature-adaptive scaling is derived from an approximation showing the relation between longitudinal pose change of the camera, absolute value of the optical flow, and distance of the feature. Using this scaling, we develop an iterative alternating scheme to guide the separation of inliers from outliers. It optimizes the tradeoff between finding a good criterion to remove outliers based on a given pose change and improving the pose change hypothesis based on the current set of inliers. Including the new outlier removal scheme into a pure two-frame stereo-based visual odometry pipeline without applying bundle adjustment or SLAM-filtering we are currently ranked amongst the top camera-based algorithms and furthermore outperform camera and laser scanner methods in Kitti benchmark's highspeed scenarios.

16:25-17:50 MoPosterBT2.6

*Monocular Self Localization in an Urban Environment Using a Prior-Based Soft Optimization Robust Estimation Method**

Dekel, Shay — General Motors Advanced Tech. Center Israel
Levi, Dan — General Motors, Advanced Tech. Center, Israel
Slutsky, Michael — General Motors Advanced Tech. Center Israel
Shimshoni, Ilan — Univ. of Haifa

Autonomous vehicle driving in urban environments is a challenging task that requires localization accuracy exceeding that available from GPS-based inertial guidance systems. For map-based driving, a 3D laser scanner can be utilized to localize the vehicle within a previously recorded 3D map. Such scanners are however not feasible for mass production due to cost considerations. In this paper we present a localization algorithm that creates off-line a predefined map and then localizes with respect to this map. First, the map is constructed by a service vehicle equipped with a calibrated stereo camera rig and a high precision navigation system. Then, the global localization ego-pose can be obtained in any vehicle equipped with a standard GPS and a single forward looking camera for extracting and matching features to relevant map candidates. We use a recently proposed estimation method called SOREPP (Soft Optimization method for Robust Estimation based on Pose Priors) that utilizes relevant priors for achieving high performance, fast and reliable estimation, even with a small fraction of inliers. During the estimation it uses all the matched correspondences without need for random sampling to find the inliers. This method eventually obtains an outlier-free set of landmarks, used to estimate the ego-pose with high accuracy. We evaluate our algorithm on real world data comprised of a challenging 4.5km drive. Our algorithm achieves accurate localization results: a mean lateral absolute error of 14.35cm and a mean longitudinal absolute error of 18.63cm.

16:25-17:50 MoPosterBT2.7

FastSLAM Filter Implementation for Indoor Autonomous Robot, pp. 484-489

Buonocore, Luciano — Federal Univ. of Maranhão
Barros dos Santos, Sergio Ronaldo — Federal Univ. of Maranhão
de Almeida Neto, Areolino — Federal Univ. of Maranhão
Nascimento Junior, Cairo Lucio — Inst. Tecnologico De Aeronautica

In this paper, we present a FastSLAM particle filter algorithm used to efficiently map large indoor environments features. The proposed filter uses an unknown data association to match the extracted environment characteristics, such as walls and doors. Data association (DA) is chosen due to two reasons: 1) permit to rearrange the filter particles in the prediction phase of the filter, and 2) enable to incorporate the extracted features in the map of each particle. Indoor SLAM experiments were conducted in a long corridor composed by several wooden walls. These provisional walls were used to create a more challenging environment. From the map obtained by the mapping process, the robot is capable of navigating through the environment using the set of 22 predefined poses. The SLAM filter measurements are compared with their actual measured values.

16:25-17:50 MoPosterBT2.8

Reliable Scale Estimation and Correction for Monocular Visual Odometry, pp. 490-495

Zhou, Dingfu — Australian National Univ
Dai, Yuchao — The Australian National Univ
Li, Hongdong — Australian National Univ

Recovering absolute scale (i.e. metric information) from monocular vision system is a very challenging problem yet is highly desirable for vision-based autonomous driving. This paper proposes a new method for scale recovery, based on the idea of knowing camera height (relative to ground-plane). While this idea of using known camera height is not new in this context, existing implementations of this idea suffer significantly from severe numerical instability arisen in the ground plane homography decomposition stage. Our novel contribution of this work is to alleviate this issue by a divide and conquer approach, i.e. decomposing the motion parameters in the homography from the structure parameters of the ground plane. We also describe a robust procedure to correct scale drift in the monocular visual odometry system. Experimental results on KITTI standard benchmark dataset and our self-collected driving dataset both show significant improvements.

MoPosterBT3	Conference Hall
Poster II: V2X and Control (Poster Session)	

Co-Chair: Charalambous, Themistoklis — Chalmers Univ

16:25-17:50 MoPosterBT3.1

*A Freeway Speed Harmonization Experiment Using I2V Communication with Connected, Automated Vehicles**

Dailey, Daniel J. — Univ. of Washington
Jagannathan, Ramesh — Regional Municipality of Durham
Lochrane, Taylor — U.S. Department of Transportation - Federal Highway Administrati

In this paper we present an experiment that uses connected/automated vehicles to implement speed harmonization on an active and congested segment of the I-66 freeway inside I-495 (the Beltway) near Washington DC, USA. Speed harmonization on the freeway is accomplished using vehicles that are specially equipped with automated longitudinal control such that speed recommendations, based on real-time macroscopic traffic measurements, are sent from the laboratory directly into the Original Equipment Manufacturer (OEM) speed controller equipment in the vehicles. The experiment is conducted using a small number of control vehicles, and a small set of probe vehicles to measure the localized effects on the traffic stream. Results are developed based on the measurements made of the speed trajectories for control and probe vehicles.

16:25-17:50 MoPosterBT3.2

Cooperative Localization of Vehicles Sharing GNSS Pseudoranges Corrections with No Base Station Using Set Inversion, pp. 496-501

Lassoued, Khaoula — Univ. of Tech. of Compiegne
Bonnifait, Philippe — Univ. of Tech. of Compiegne
Fantoni, Isabelle — Univ. of Tech. of Compiègne, CNRS

Fully distributed localization methods with no central server are relevant for autonomous vehicles that need real-time cooperation. In this paper, mobile vehicles share pseudo-ranges GNSS common errors also known as biases. The biases that affect the pseudo-ranges are due mainly to signal propagation and inaccurate ephemeris data. By describing the measurements as geometric constraints, the cooperative localization problem turns into a distributed set inversion problem. The solution of this problem is guaranteed to contain the true vehicles positions. We consider two vehicles, which cooperate and exchange information in order to improve the absolute and relative position by fusing common biases corrections shared in a moving way. Results using real measurements are presented to illustrate the performance of the proposed approach in comparison with a standalone method.

16:25-17:50	MoPosterBT3.3

Towards a Safety Mechanism for Platooning, pp. 502-507

Van Nunen, Ellen — TNO
Tzempetzis, Dimitrios — Eindhoven Univ. of Tech
Koudijs, Gerald — TNO
Nijmeijer, Henk — Eindhoven Univ. of Tech
van den Brand, Mark — Eindhoven Univ. of Tech

Platooning has shown to be technically feasible, but safety aspects are still challenging. Wireless communication between vehicles allows to maintain reduced intervehicle distances, thereby improving traffic throughput and decreasing fuel consumption. As the driver can no longer be a backup at short inter-vehicle distances, the system needs to be fail-safe for both hazardous traffic situations as well as failures. In this paper, a scenario is defined which combines a hazardous traffic situation with a communication failure. First, the methodology for developing safety related functionality in automated driving is presented. This methodology combines aspects of the ISO26262 standard with the Harmony profile. Second, the safety mechanism to avoid a collision by braking is described. This ensures that a safe state can be reached for a set of use cases which are derived from the defined scenario. Finally, the proposed solution is tested in a simulation environment and is also implemented on test vehicles. The result of the simulations and experiments demonstrate the practical validity and show increased safety related functionality.

16:25-17:50	MoPosterBT3.4

Visible Light Inter-Vehicle Communication for Platooning of Autonomous Vehicles, pp. 508-513

Abualhoul, Mohammad — INRIA Paris-Rocquencourt
Shagdar, Oyunchimeg — INRIA, Paris-Rocquencourt
Nashashibi, Fawzi — INRIA

In this paper, we study a use of Visible Light Communication (VLC) technology for a platoon of autonomous vehicles. We present a low-cost, low-latency and simple outdoor VLC prototype, which can be installed as vehicular tail-lighting system. The architecture of our VLC system is introduced, followed by performance evaluation with an especial attention on the VLC link resilience to ambient noise and communication range. Through the experiments, we observe that a use of proper optical filter stage at the receiver side, together with narrowing the transmitter Field-of-view (FOV), result in an extended communication range and make the VLC system more resilient to the ambient noises. Experimental results show that the system can provide 30 meter of inter-vehicle communication with 36 ms of latency even on sunny days. The benefit of using the VLC system for platooning control is showed using a Simulink system that integrates our VLC platform for inter-communications and simulates the performance of autonomous vehicles platoon.

16:25-17:50	MoPosterBT3.5

Design and Validation of an MPC-Based Torque Blending and Wheel Slip Control Strategy, pp. 514-520

Satzger, Clemens Wolfgang — DLR
de Castro, Ricardo — Faculdade De Engenharia Da Univ. Do Porto
Knoblach, Andreas — German Aerospace Center (DLR)
Brembeck, Jonathan — German Aerospace Center (DLR)

This article presents a braking control algorithm for electric vehicles endowed with redundant actuators, i.e. friction brakes and wheel-individual electric motors. This algorithm relies on a model predictive control framework and is able to optimally split the wheel braking torque among the redundant actuators, while providing anti-lock braking features (i.e. wheel slip regulation). It will be shown that, the integration of these two control functions together with energy metrics, actuator constraints and dynamics improves the control performance compared to state-of-art control structures. Additionally, experimental measurements recorded with our prototype vehicle demonstrate a precise wheel slip regulation and high energy efficiency of the proposed braking control methodology.

16:25-17:50	MoPosterBT3.6

Parameter Identification for a Multi-Body Vehicle Model, pp. 521-526

Traub, Lukas — Tech. Univ. München
Butakov, Vadim — Univ. of Southern California
Simpson, Robin — Volkswagen Group of America

Driving dynamics simulations are used in early stage autonomous vehicle algorithm development. For the utility of the simulation it is essential the vehicle model performs very similarly to the real-world car. A novel approach is introduced in this paper to identify parameters for a multi-body vehicle model from measurements of real world driving maneuvers. The approach does not need any prior knowledge of the model and is more time and cost-effective compared to the conventional method. Simulation results show the validity of the obtained model parameters.

16:25-17:50	MoPosterBT3.7

Combined Lateral and Longitudinal CACC for a Unicycle-Type Platoon, pp. 527-532

Bayuwindra, Anggera — Eindhoven Univ. of Tech
Aakre, Øyvind Løberg — Norwegian Univ. of Science and Tech
Ploeg, Jeroen — TNO
Nijmeijer, Henk — Eindhoven Univ. of Tech

This paper presents the controller design for combined lateral and longitudinal Cooperative Adaptive Cruise Control (CACC) for a unicycle-type platoon with emphasis on the cornering maneuvers. A decentralized controller for lateral and longitudinal behavior is designed using input-output linearization by static feedback. A preceding vehicle look-ahead approach is adapted in the controller to maintain desired inter-vehicle distance. However, due to the position control of the look-ahead point, the follower vehicle may cut corners on turns. In this paper, the extension of a look-ahead point that is able to compensate the cutting-corner behavior is then proposed. To validate the theoretical analysis, the full nonlinear system together with the developed controller is simulated for two scenarios, a circular path and a particular path scenario, and a comparison is made between the system with the preceding vehicle look-ahead and the extended look-ahead. The simulation shows that the proposed lateral and longitudinal controller using the extended look-ahead eliminates the cutting corner behavior.

16:25-17:50	MoPosterBT3.8

Road Friction Estimation Using Recursive Total Least Squares, pp. 533-538

Shao, Liang — Graz Univ. of Tech
Lex, Cornelia — Graz Univ. of Tech
Hackl, Andreas — Graz Univ. of Tech
Eichberger, Arno — TU Graz

Automated vehicles require information on the current road condition, namely the tire road friction coefficient, for trajectory planning and braking or steering interventions. Recursive Total Least Squares is used to estimated the tire road friction coefficient only utilizing the information from Electric Power Steering System and other sensors installed in production vehicles. A new state, the front wheel slip angle divided by the tire road friction coefficient, is introduced which is observed by a proposed nonlinear observer. This state serves as a measurement for friction estimation and judge when the estimation result is reliable. The proposed method is verified in IPG CarMaker.

16:25-17:50	MoPosterBT3.9

Experimental Validation of Geometric Path Following Control with Demand Supervision on an Overactuated Robotic Vehicle, pp. 539-545

Ritzer, Peter — German Aerospace Center
Winter, Christoph — German Aerospace Center

Brembeck, Jonathan German Aerospace Center (DLR)

This work describes the development and experimental validation of a geometric path following control strategy with demand supervision applied to an over-actuated robotic vehicle, the ROboMObil. The proposed method enables the ROboMObil to automatically follow paths while the driver is free to control the velocity along the path. Beside the longitudinal degree of freedom, two lateral degrees of freedom can be controlled relative to the path. If this demand interface were provided without supervision, the driver may potentially overwrite the path following control in a manner such that the vehicle limits are violated and the vehicle becomes unstable. To avoid such critical situations a demand supervisor is introduced into the path following framework. The work concludes by a simulative demonstration of the supervised control system and an experimental validation of the presented approach implemented in the ROboMObil.

16:25-17:50 MoPosterBT3.10

Vehicle Stability Enhancement by an Energy Optimal Control Approach, pp. 546-551

Arslan, M. Selçuk Yildiz Tech. Univ

Vehicle stability enhancement based on an energy optimal control method is presented. The direct yaw moment control of a road vehicle is aimed by the intervention of individual braking forces. The optimal controller has been designed to minimize the given criteria function. This function has two essential elements: the control performance measure and the input power. The employment of yaw moment and yaw rate in the control performance measure enables the incorporation of the most important dynamics into the control law. By designing the input power based on the braking forces, the yaw moment input is automatically calculated by the controller. The effectiveness of the control approach has been shown by the application of the controller in the case of rapid lane change for two different initial velocity conditions.

16:25-17:50 MoPosterBT3.11

Lane Keeping System Based on Kinematic Model with Road Friction Coefficient Adaptation, pp. 552-557

Kang, Chang Mook Hanyang Univ
Lee, Seung-Hi Hanyang Univ
Chung, Chung Choo Hanyang Univ

It is known that the kinematic model based motion control is robust against unknown vehicle parameters variation. Recently we reported that lane keeping system (LKS) with look-ahead distance using the kinematic vehicle lateral motion model is feasible and its performance is compatible with a dynamic vehicle lateral motion model using look-ahead distance under a limited condition in highway driving. In this paper, we developed a kinematic vehicle motion model with road friction coefficient estimation. The adaptive kinematic vehicle motion based lateral controller requires no complex tuning process. The proposed method provides improved LKS performance over the previous method. Control performance of model was validated via computational simulation results with CarSim and MATLAB/Simulink.

TuKeynoteP Conference Hall

Keynote: Highway Loss Data Institute (Plenary Session)

Chair: Nilsson-Ehle, Anna — SAFER

Co-Chair: Takeda, Kazuya — Nagoya Univ

08:30-09:15 TuKeynoteP.1

*Conclusions on Autonomous Emergency Braking Systems and Other Advanced Driver Assistance Technologies**

Moore, Matt — Highway Loss Data Inst

On March 17, 2016 the Insurance Institute for Highway Safety and the U.S. Department of Transportation's National Highway Traffic Safety Administration announced a historic commitment by 20 automakers representing more than 99 percent of the U.S. auto market to make automatic emergency braking a standard feature on virtually all new cars no later than NHTSA's 2022 reporting year. This presentation will review research, real world results and on track testing from the Insurance Institute for Highway Safety and the Highway Loss Data Institute that served as a catalyst for the agreement. In addition to covering autonomous emergency braking systems the presentation will include results for other advanced driver assistance technologies and projected timelines for the fitment of these technologies in the U.S. fleet.

TuOralAT Conference Hall

Sensor and Data Fusion (Regular Session)

Chair: Cherfaoui, Véronique — Univ. DE Tech. DE COMPIEGNE

Co-Chair: Fredriksson, Jonas — Chalmers Univ. of Tech

09:15-09:32 TuOralAT.1

Multi-Sensor Multi-Object Tracking of Vehicles Using High-Resolution Radars, pp. 558-565

Scheel, Alexander — Univ. of Ulm
Knill, Christina — Ulm Univ
Reuter, Stephan — Univ. of Ulm
Dietmayer, Klaus — Univ. of Ulm

Recent advances in automotive radar technology have led to increasing sensor resolution and hence a more detailed image of the environment with multiple measurements per object. This poses several challenges for tracking systems: new algorithms are necessary to fully exploit the additional information and algorithms need to resolve measurement-to-object association ambiguities in cluttered multi-object scenarios. Also, the information has to be fused if multi-sensor setups are used to obtain redundancy and increased fields of view. In this paper, a Labeled Multi-Bernoulli filter for tracking multiple vehicles using multiple high-resolution radars is presented. This finite-set-statistics-based filter tackles all three challenges in a fully probabilistic fashion and is the first Monte Carlo implementation of its kind. The filter performance is evaluated using radar data from an experimental vehicle.

09:32-09:49 TuOralAT.2

Robust Estimation of Vehicle Longitudinal Dynamics Parameters, pp. 566-571

Altmannshofer, Simon — Tech. Hochschule Ingolstadt
Endisch, Christian — Tech. Hochschule Ingolstadt
Martin, Jan — Tech. Hochschule Ingolstadt
Gerngroß, Martin — Tech. Univ. München
Limbacher, Reimund — Audi Ag

Vehicle longitudinal control can be improved by knowledge of vehicle parameters. A robust estimation algorithm is presented to estimate unknown or uncertain vehicle parameters. These parameters are mass, rolling coefficient, air drag coefficient and brake disc friction coefficient. The proposed estimator considers non-Gaussian measurement errors, insufficient excitation and a prior knowledge of parameter bounds. The robust estimator shows good performance on real-world data with difficult characteristics compared to existing algorithms

09:49-10:06 TuOralAT.3

Manoeuvre Segmentation Using Smartphone Sensors, pp. 572-577

Woo, Christopher — Univ. of Waterloo
Kulic, Dana — Univ. of Waterloo

In this paper, we propose a classifier-based approach for driving manoeuvre recognition from mobile phone data. We introduce a driving manoeuvre classifier using Support Vector Machines (SVM). We investigate the performance of a sliding window of velocity and angular velocity signals obtained using a smartphone as features for our classifier. Principal Component Analysis (PCA) is used for dimensionality reduction. The classifiers use a vehicle simulation for training data and experimental data for validation. A novel technique to extract the rotation matrix using PCA is presented to calibrate the smartphone's orientation. A classifier performance of 0.8158 average precision and 0.8279 average recall was achieved resulting in an average F1 score of 0.8194. Balanced accuracy was calculated to be 0.8874.

10:06-10:23 TuOralAT.4

Energy Harvesting System for Intelligent Tyre Sensors, pp. 578-583

Jousimaa, Otso Jeremias — Aalto Univ
Xiong, Yi — Aalto Univ
Niskanen, Arto Juhani — Aalto Univ. School of Engineering
Tuononen, Ari Juhani — Aalto Univ

An intelligent tyre system enables the active chas- sis control system to directly access the information about tyre-road interactions. However, supplying power to the system is still a bottleneck which limits the applicability of the intelligent tyre system. This paper proposes a piezoelectric energy harvesting system with energy storage to address this issue. The system was installed to the inside of a car tyre and measured with a chassis dynamometer. The harvester was found to produce approximately 88 μW of power at a driving speed of 60 km/h, which is enough to supply energy for a low-power in-tyre sensor system with radio link connectivity such as a tyre pressure monitoring system.

TuInvitedP Conference Hall

Invited Talk: Volvo Cars (Plenary Session)

Chair: Fredriksson, Jonas — Chalmers Univ. of Tech

10:25-10:40 TuInvitedP.1

*Self-Driving Cars in the Hands of Real Customers on Normal Roads – Safety and Comfort**

Coelingh, Erik — Volvo Car Corp

Autonomous – or self-driving – vehicles have long been part of an utopian vision of the future, because they will free people from the boring aspects of driving and open up exciting new ways to travel. They also have the potential to make the road transportation system more sustainable in terms of safety, energy efficiency and transport efficiency. This presentation will provide a quick review of the challenges in the Drive Me program in which we try to bring the benefits of self-driving to real customers on the public road.

For more information look at: www.volvocars.com/autopilot

TuOralBT Conference Hall

Vehicle Control (Regular Session)

Chair: Borrelli, Francesco — Univ. of California, Berkeley

Co-Chair: Axehill, Daniel — Linköping Univ

11:10-11:27 TuOralBT.1

Real Time Integrated Vehicle Dynamics Control and Trajectory Planning with MPC for Critical Maneuvers, pp. 584-589

Yi, Boliang | Adam Opel AG
Gottschling, Stefan | Adam Opel AG
Ferdinand, Jens | Adam Opel AG
Simm, Norbert | Adam Opel AG
Bonarens, Frank | Adam Opel AG
Stiller, Christoph | Karlsruhe Inst. of Tech

Collision avoidance maneuvers using braking and steering provide opportunities to avoid a collision at higher velocities compared to braking or steering only. This work investigates control concepts with integrated trajectory planning for combined braking and steering maneuvers using model predictive control (MPC) approaches. A major challenge here is the computational efficiency of the optimization process accounting for nonlinear constraints or nonlinear dynamic models. The main contribution of this work is the introduction of several simplifications which reduces the nonlinear optimization problem to a quadratic program and thus enables application in a vehicle demonstrator. Comparison of the quadratic MPC with the nonlinear MPC shows not only similar performance in a simulation environment, but demonstrates strongly reduced computation time by a factor of approximately 400.

11:27-11:44 TuOralBT.2

Coordination of Motion Actuators in Heavy Vehicles Using Model Predictive Control Allocation, pp. 590-596

Sinigaglia, Andrea | Chalmers Univ. of Tech
Tagesson, Kristoffer | Volvo GTT & Chalmers Uni. of Tech
Falcone, Paolo | Chalmers Univ. of Tech
Jacobson, Bengt J H | Chalmers Univ. of Tech

The paper presents a Model Predictive Control Allocation (MPCA) method in order to coordinate the motion actuators of a heavy vehicle. The presented method merges the strong points of two different control theories: Model Predictive Control (MPC) and Control Allocation (CA); MPC explicitly considers the motion actuators dynamics before deciding on a suitable input for the actuators while CA dynamically decides how to use the motion actuators in order to modify the vehicle behaviour. The designed MPCA formulation belongs to the class of Quadratic Programming (QP) problems so that the solution is optimization based, i.e. at every step a quadratic cost function has to be minimized while fulfilling a set of linear constraints. Three scenarios were set up to evaluate the effectiveness of the controller: split-μ braking, split-friction acceleration and brake blending. Split-friction means that the wheels on one side of the vehicle are in contact with a slippery surface (e.g. ice) while the wheels of the other side lay on a normal surface (e.g. dry asphalt). The split-friction scenarios aim to combine three different types of motion actuators, disc brakes, powertrain and rear active steering (RAS), in order to brake/accelerate the vehicle while keeping it on course. The third scenario is a mild braking event on a normal road and its purpose is to combine the use of the engine brake with the disc brakes. Simulation results of the scenarios have shown promising vehicle performance when using MPCA to coordinate the motion actuators. Tests on a real vehicle have then confirmed the expected vehicle behaviour in a slit-friction braking scenario. MPCA has also been compared to a simpler CA formulation, in all scenarios. The performance of the two is comparable in steady state, but MP

11:44-12:01 TuOralBT.3

Simultaneous Stabilization and Tracking of Basic Automobile Drifting Trajectories, pp. 597-602

Goh, Jonathan Y. | Stanford Univ
Gerdes, J Christian | Stanford Univ

Professional drivers in 'drifting' competitions are able to precisely negotiate a specified course at high sideslip angles while operating in an unstable region of state-space. Studying this practice could provide insight into autonomous car control during emergency maneuvers that excurse outside stable handling limits. This paper presents a simple and physically insightful controller for autonomous drifting with simultaneous tracking of a reference path. A feasible reference trajectory is treated as a sequence of unstable drifting equilibrium points, and a basic example is generated from vehicle parameters using a four-wheel model with steady-state weight transfer. Lookahead error and sideslip are chosen as reference states, and a controller for tracking both objectives around an equilibrium point is derived using a simpler single-track model. Experiments on the rear-wheel drive MARTY test vehicle demonstrate good tracking performance of both objectives even at values of sideslip as high as 45 degrees.

12:01-12:18 TuOralBT.4

Nonlinear Lateral Vehicle Control in Combined Emergency Steering and Braking Maneuvers, pp. 603-610

Kranz, Tobias | Univ. of Applied Sciences Aschaffenburg
Hahn, Stefan | Univ. of Applied Sciences Aschaffenburg
Zindler, Klaus | Univ. of Applied Sciences Hochschule Aschaffenburg

This paper presents a new nonlinear control scheme for lateral vehicle guidance in combined emergency steering and braking maneuvers. It is based on a vehicle model which considers the nonlinear coupling between the lateral and longitudinal tire forces by means of a friction ellipse. The derived model belongs to the class of nonlinear systems with time-varying model parameters. A follow-up controller is designed by adapting the well-known method of input-output linearization to the present class of a time-varying plant model. Using the example of a pedestrian collision avoidance maneuver the advantages of the proposed nonlinear control scheme compared to standard linear lateral vehicle control are demonstrated.

TuPosterAT1 Open Arena

Poster III: Lidar & Sensor Fusion (Poster Session)

Chair: Falcone, Paolo | Chalmers Univ. of Tech

13:20-14:45 TuPosterAT1.1

Understanding the Data-Processing Challenges in Intelligent Vehicular Systems, pp. 611-618

Costache, Stefania | IBM
Gulisano, Vincenzo | Chalmers Univ. of Tech
Papatriantafilou, Marina | Chalmers Univ. of Tech

Vehicular sensors able to perceive and measure the environment, ranging from in-vehicle sensors to speed cameras, are revolutionizing how technology can interact with our daily lives, enabling Intelligent Vehicular Systems (IVSs). These sensors generate large volumes of data which can reveal useful information for enhancing the sustainable development (through improved utilization of resources), as well as the safety and functionality of the system.

In this context, a key challenge is to reduce the large data streams into manageable sets of valuable information in a real-time, reliable and cost-affordable fashion. Due to the data volume size and velocity, relying exclusively on traditional data processing systems, such as databases and batch processing, is no longer a suitable option, since it is not feasible to store the data to later process it. Moreover, careful decisions should be made to leverage the existing computing capacity, from embedded devices found in the IVSs to cloud infrastructures.

In this paper we study trade-offs of possible options for data-stream processing models and computing infrastructures. Through building an experimental platform that emulates realistic components of a future deployable IVS and validating two different data-stream processing systems with a well-known benchmark for IVSs, we study options and trade-offs in real-time data stream processing in IVS infrastructures. Our evaluation shows that existing data-stream processing models can be leveraged in different ways, based on the processing requirements.

13:20-14:45 TuPosterAT1.2

Wireless Energy Autonomous Light Sensor for Automotive Applications, pp. 619-624

Haider, Majumder City Univ. Bremen
Kanning, Bastian Hella Fahrzeugkomponenten GmbH Bremen
Peik, Soeren F. City Univ. Bremen

The primary goal of this research work is to develop a new kind of light sensor for automotive applications to switch the headlights of a car automatically. In contrast to the commonly used wired light sensors, this new concept implements solar energy harvesting as power supply and a low power wireless communication interface to the Electronic Control Unit (ECU) of the vehicle. With the new features the proposed light sensor can act as a completely self-supporting device without any wired connection. The sensor can be retrofitted by customers without professional maintenance support. This work focuses on the detailed analysis of energy harvesting solutions for safe and reliable wireless connections. Furthermore, a prototype hardware has been created to demonstrate the reliable wireless operation.

13:20-14:45 TuPosterAT1.3

Towards the Friction Potential Estimation: A Model-Based Approach to Utilizing In-Tyre Accelerometer Measurements, pp. 625-629

Niskanen, Arto Juhani Aalto Univ. School of Engineering
Xiong, Yi Aalto Univ
Tuononen, Ari Juhani Aalto Univ

Tyre-road contact condition information would benefit many vehicle safety and control systems. However, direct information is still not available in production vehicles. Tyre sensing could provide this necessary information but many aspects must still be studied. In this paper, a physical ring tyre model is used to estimate and remove the acceleration profile caused by the contact deformation from the measured in-tyre acceleration data. This residual acceleration can then be used to study the tyre-road contact conditions. A simple analysis with standard deviation is used to show the effects of different road surfaces on the measured in-tyre acceleration.

13:20-14:45 TuPosterAT1.4

Multisensor Simultaneous Vehicle Tracking and Shape Estimation, pp. 630-635

Elfring, Jos TNO
Appeldoorn, Rein TNO
Kwakkernaat, Maurice TNO

This work focuses on vehicle automation applications that require both the estimation of kinematic and geometric information of surrounding vehicles, e.g., automated overtaking or merging. Rather then using one sensor that is able to estimate a vehicle's geometry from each sensor frame, e.g., a lidar, a multisensor simultaneous vehicle tracking and shape estimation approach is proposed. Advanced measurement models and adequate Bayesian filters enable the shape estimation that is impossible with any of the sensors individually. The use of multiple sensors increases robustness, lowers the complexity of the sensors involved and leads to a gradual loss of performance in case a sensor fails. A series of real world experiments is performed to analyze the performance of the proposed method.

13:20-14:45 TuPosterAT1.5

Accuracy and Robustness of Road Observers with Uncertainties for Reconstruction of the Road Elevation Profile, pp. 636-641

Noll, Andreas Audi AG and (Univ. of Augsburg)

For intelligent or autonomous vehicles the knowledge of the street course and the road condition are indispensable in order to react as early as possible in case of danger. We want to investigate new possibilities for the observation of the road elevation profile in order to warn the driver or road user e.g. of upcoming large potholes or bad roads. This work is a contribution to develop so-called road observers to determine the road profile directly by the vehicle. The derived road observers considering model uncertainties are compared in order to analyze the potential for the road profile reconstruction in simulation and on a measured reference road. It will be shown that the different road observers can be used to estimate the road elevation profile. One of them (in this work is called as "Kalman-4dof"), which is based on the simplified vehicle model, is less sensitive to parameter variations, so that this observer is going to prefer in further applications.

13:20-14:45 TuPosterAT1.6

Integrating Driving Behavior and Traffic Context through Signal Symbolization, pp. 642-647

Yamazaki, Suguru Nagoya Univ
Miyajima, Chiyomi Nagoya Univ
Yurtsever, Ekim Nagoya Univ
Takeda, Kazuya Nagoya Univ
Mori, Masataka DENSO Corp
Hitomi, Kentarou DENSO Corp
Egawa, Masumi DENSO Corp

This paper presents a novel method for integrating driving behavior and traffic context through signal symbolization in order to summarize driving semantics from sensor outputs. The method has been applied to risky lane change detection. Language models (nested Pitman-Yor language model) and speech recognition algorithms (hidden Markov Model) have been utilized for converting continuous sensor signals into a sequence of non-uniform segments (chunks). After symbolization, Latent Dirichlet Allocation (LDA) is used to integrate the symbolized driving behavior and the surrounding vehicle information for establishing the semantics of the driving scene. 988 lane changes of real-world highway driving are used for the evaluation. Risk level of each lane change rated by 10 subjects are used as ground truth. Best results have been obtained when driving behavior and surrounding vehicle information are integrated through co-occurrence chunking after independent symbolization of behavior and context signals.

13:20-14:45 TuPosterAT1.7

Machine Learning in Tracking Associations with Stereo Vision and Lidar Observations for an Autonomous Vehicle, pp. 648-653

Allodi, Marco VisLab Srl
Broggi, Alberto Univ. of Parma
Giaquinto, Domenico Univ. Di Parma
Patander, Marco VisLab - Parma Univ
Prioletti, Antonio Univ. of Parma

Obstacles detection is used nowdays for a number of road safety applications, increasing the drivers awareness in potential dangerous situations. A reliable and robust obstacles detection continues to be largely investigated and still remains an open challenge, especially for difficult scenarios and in general cases, with loosened constraints and multiple simultaneous use-cases. This work presents an obstacles detection, tracking and fusion algorithm which allows to reconstruct the environment surrounding the vehicle. While the techniques used for the detection are well-known in literature, the improvements introduced by this paper regard the data association and tracking approach of heterogeneous sensors observations. An innovative multi-dimensional structure based on association costs originating from a classifier provides an optimal solution to the association problem with respect to the total association cost. An Unscented Kalman Filter (UKF) managing a variable number of observations, arbitrarily composable, allows to correctly address the combined tracking and fusion challenge. The results, obtained on a public benchmark, show improvements with respect to state of the art systems.

13:20-14:45 TuPosterAT1.8

Model-Based Rail Detection in Mobile Laser Scanning Data, pp. 654-661

Stein, Denis FZI Res. Center for Information Tech
Spindler, Max Karlsruhe Inst. of Tech. (KIT)
Lauer, Martin Karlsruher Inst. Für Tech

Similar to autonomous vehicles, future train applications require an

accurate on-board self-localization for railway vehicles. Therefore, a reliable and real-time capable environment perception is required. In particular, the knowledge of the track taken at a turnout overcomes ambiguities in self-localization. As the most important groundwork for this, the paper introduces a new approach for the detection of rails and tracks solely from 2d lidar measurements. The technique is based on a new feature point method for lidar data, a template matching approach, and a spatial clustering technique to extract rails and tracks from the detected rail elements. The new approach is evaluated on six different datasets taken outdoors at a demanding test ground. It provides reliable and accurate detection results with centimeter accuracy, a recall of about 90 %, and a precision of about 95 %. The approach is able to detect rails even in complex real-world topologies such as at turnouts and even on tracks with more than two rails.

13:20-14:45 TuPosterAT1.9

Automatic Detection of Vehicles at Road Intersections Using a Compact 3D Velodyne Sensor Mounted on Traffic Signals, pp. 662-667

Aijazi, Ahmad Kamal	Pascal Inst. Univ. Blaise Pascal
Checchin, Paul	Univ. Blaise Pascal - Clermont-Ferrand - FRANCE
Malaterre, Laurent	Inst. Pascal
Trassoudaine, Laurent	Univ. of Clermont-Ferrand

Real-time traffic monitoring can play an important role in efficient traffic management and increasing road capacity. In this paper, we present a new method for automatic detection of vehicles using a compact 3D Velodyne sensor mounted on traffic signals in the urban environment. Different aspects of the new Velodyne sensor are first studied and its data are characterized for its effective utilization for our application. The sensor is then mounted on top of a traffic signal to detect vehicles at road intersections. The 3D point cloud obtained from the sensor is first over-segmented into super-voxels and then objects are extracted using a Link-Chain method. The segmented objects are then detected/classified as vehicles or non-vehicles using geometrical models and local descriptors. The results evaluated on real data not only demonstrate the efficacy but also the suitability of the proposed solution for such traffic monitoring applications.

13:20-14:45 TuPosterAT1.10

Efficient Automotive Grid Maps Using a Sensor Ray Based Refinement Process, pp. 668-675

Jungnickel, Ruben	Ibeo Automotive Systems GmbH
Köhler, Michael	Ibeo Automotive Systems GmbH
Korf, Franz	Hamburg Univ. of Applied Sciences

The occupancy grid mapping technique is widely used for environmental mapping of moving vehicles. Occupancy grid maps with fixed cell size have been extended using the quadtree implementation with adaptive cell size. Adaptive grid maps have proven to be more resource efficient than fixed cell size grid maps. Dynamic cell sizes introduce the necessity of a split and merge process to trigger the refinement of grid cells. This paper presents a novel ray-based refinement process in order to choose the appropriate resolution for the sensor observation. Based on measurement conflicts some approaches use an iterative refinement process until all conflicts are solved. In contrast this paper presents an non-iterative approach based on the sensor resolution. Using the measurement data efficiently we propose an algorithm, which solves the problem of partially free cells in an adaptive grid map. The proposed algorithm is compared against other widely used algorithms and methodologies.

13:20-14:45 TuPosterAT1.11

Track-Before-Detect Approach on LIDAR Signal Processing for Low SNR Target Detection, pp. 676-682

Ogawa, Takashi	DENSO Corp
Wanielik, Gerd	Chemnitz Univ. of Tech

In recent years, LIDAR sensor has been getting higher interests as one of the prospective sensors for the future intelligent vehicles. In order to enable advanced applications on variety of road environment, it becomes more important to detect various types of objects from further distance. In order to increase detection sensitivity with maintaining low false alarm rate, signal processing plays important role to derive the potential information contained in the raw sensor data. Therefore, in this research, we focus on LIDAR signal processing and propose an algorithm to detect low SNR target. The approach is based on Track-Before-Detect technique, where target existence or non-existence with its state is estimated on Bayesian probabilistic framework, and it has capability of multi-target detection. It utilizes not only the amplitude but also the profile of the intensity to calculate the likelihood of the state and therefore it enables to discriminate the actual target from the background noise, even if target has low SNR. Fundamental experiment using automotive LIDAR has been done to evaluate the detection performance, in comparison to primitive intensity-based constant thresholding approach on only one single frame observation. The results have shown significant improvement on both static and dynamic scenario. The detector has been also evaluated on point measurement and it is confirmed that additional measurements on low SNR target become available from further distance.

13:20-14:45 TuPosterAT1.12

Robust Virtual Scan for Obstacle Detection in Urban Environments, pp. 683-690

Mengwen, He	Nagoya Univ
Takeuchi, Eijiro	Nagoya Univ
Ninomiya, Yoshiki	Nagoya Univ
Kato, Shinpei	Nagoya Univ

Obstacle detection is an essential technique for intelligent vehicles. Environmental sensing especially plays a vital role to achieve accurate obstacle detection. Unlike classical 2D scan, emerging 3D Light Detection and Ranging (LiDAR) sensors can scan dense point cloud at one time, which represents detailed information of urban environments. The downside of obstacle detection using 3D LiDAR, on the other hand, is its computational cost posed by a large amount of 3D data. The virtual scan (VScan), first introduced by Petrovskaya et al. for efficient vehicle detection and tracking, is a 2D compression of 3D point cloud to represent free space, obstacles and unknown areas. To overcome the computational problem of obstacle detection using 3D LiDAR, therefore, VScan is suitable. In addition, it can bridge across new-born 3D LiDAR sensors and many matured applications based on 2D scan, including occupancy grid map, SLAM, planning, detection, and tracking, due to its 2D representation of 3D point cloud. A key challenge to VScan for intelligent vehicles is that we must improve robustness of VScan in complex urban environments. For example, steep ramps with large slope, low curbs along the road, and overhung barrier gates at the entrance often make VScan mis-behave. In this paper, we present a robust VScan generation method for intelligent vehicles driving in complex urban environments. Our method uses a new data structure, called basic VScan matrix (BVSM), to represent 3D point cloud around the own vehicle. We also develop (i) a simultaneous road filtering and obstacle detection method that works on top of BVSM to generate robust VScan generation, and (ii) a sorted array based acceleration method to perform the VScan generation in real-time.

TuPosterAT2 Pascal

Poster III: Self-Driving Vehicles (Poster Session)

Chair: Lidberg, Mathias — Chalmers Univ. of Tech

13:20-14:45 TuPosterAT2.1

Identification of Potential Hazardous Events for an Unmanned Protective Vehicle, pp. 691-697

Bagschik, Gerrit	Tech. Univ. Braunschweig
Reschka, Andreas	Tech. Univ. Braunschweig
Stolte, Torben	Inst. of Control Engineering, Tech. Univ. Braunsc
Maurer, Markus	TU Braunschweig

The project Automated Unmanned Protective Vehicle for Highway

Hard Shoulder Road Works (aFAS) aims to develop an unmanned protective vehicle to reduce the risk of injuries due to crashes for road workers. To ensure functional safety during operation in public traffic the system shall be developed following the ISO 26262 standard. After defining the functional range in the item definition, a hazard analysis and risk assessment has to be done. The ISO 26262 standard gives hints how to process this step and demands a systematic way to identify system hazards. Best practice standards provide systematic ways for hazard identification, but lack applicability for automated vehicles due to the high variety and number of different driving situations even with a reduced functional range. This contribution proposes a new method to identify hazardous events for a system with a given functional description. The method utilizes a skill graph as a functional model of the system and an overall definition of a scene for automated vehicles to identify potential hazardous events. An adapted Hazard and Operability Analysis approach is used to identify system malfunctions. A combination of all methods results in operating scenes with potential hazardous events. These can be assessed afterwards towards their criticality. A use case example is taken from the current development phase of the project aFAS.

13:20-14:45 TuPosterAT2.2

Dynamic Carbon Emissions Minimization for Autonomous Vehicles in the Context of On-Demand Transportation Systems, pp. 698-703

Fatnassi, Ezzeddine	Higher Inst. of Management of Tunis
Chaouachi, Jouhaina	Inst. of Advanced Business Studies of Carthage

Road transportation tools are a major contributor to carbon emissions. Reducing the impact of these emissions on the environment requires an understanding of the environmental dimension in route planning and fleet management strategies of transportation tools. On the other hand, on-demand transportation systems are an advanced form of public transportation tools. They use a set of autonomous intelligent vehicles. They are user oriented and characterized by a very flexible schedule. This paper proposes to study the behavior of a specific class of on-demand transportation systems under carbon emissions constraints. Two strategies are proposed and verified via simulation. It was found that under the low-carbon constraints, both total traveled distance and carbon emissions could be reduced and they represent rather two different objectives.

13:20-14:45 TuPosterAT2.3

Using Plug&Play Control for Stable ACC-CACC System Transitions, pp. 704-709

Navas, Francisco	INRIA
Milanés, Vicente	INRIA
Nashashibi, Fawzi	INRIA

This paper examines the transition between the already commercially available Adaptive Cruise Control (ACC) system, and its evolution by adding vehicle-to-vehicle communications: the cooperative ACC (CACC) version. The transition between ACC and CACC controllers will be done through the new control technique called Plug&Play. This technique is able to deal with living systems and the changes in its sensors and actuators to preserve the system stable. The aim is to ensure the system stability during transitions between controllers when the vehicle-to-vehicle communication link is changing from unavailable to available or vice versa.

13:20-14:45 TuPosterAT2.4

Experimental Evaluation of Economic Model Predictive Control for an Autonomous Truck, pp. 710-715

Russo de Almeida Lima, Pedro Filipe	KTH Royal Inst. of Tech
Trincavelli, Marco	Scania CV AB
Nilsson, Mattias	Scania CV AB
Mårtensson, Jonas	KTH Royal Inst. of Tech
Wahlberg, Bo	KTH Royal Inst. of Tech

In this paper, we propose a controller for smooth autonomous path following. The controller is formulated as an economic model predictive controller. The economic cost introduced in the objective function leads to a smooth driving, since we minimize the first and second derivatives of the curvature function (i.e., we encourage linear curvature profiles). Since the curvature in clothoids varies linearly with the path arc-length, we use the smoothness and comfort characteristics of clothoid-driving to obtain a compact and intuitive controller formulation. We enforce convergence of the controller to the reference path with soft constraints that avoid deviations from the reference path. Finally, we present real life experiments where the controller is deployed on a Scania construction truck that show that the proposed controller outperforms a pure-pursuit controller. Moreover, we detail how the few tuning parameters can affect the obtained solution in practice.

13:20-14:45 TuPosterAT2.5

Human-Like Planning of Swerve Maneuvers for Autonomous Vehicles, pp. 716-721

Gu, Tianyu	Carnegie Mellon Univ
Dolan, John	Carnegie Mellon Univ
Lee, Jin-Woo	General Motors Res. and Development

In this paper, we develop a motion planner for on-road autonomous swerve maneuvers that is capable of learning passengers' individual driving styles. It uses a hybrid planning approach that combines sampling-based graph search and vehicle model-based evaluation to obtain a smooth trajectory plan. To automate the parameter tuning process, as well as to reflect individual driving styles, we further adapt inverse reinforcement learning techniques to distill human driving patterns from maneuver demonstrations collected from different individuals. We found that the proposed swerve planner and its learning routine can approximate a good variety of maneuver demonstrations. However, due to the underlying stochastic nature of human driving, more data are needed in order to obtain a more generative swerve model.

13:20-14:45 TuPosterAT2.6

Realization of Different Driving Characteristics for Autonomous Drive by Using Model Predictive Control, pp. 722-728

Koga, Ayame	Nagoya Univ
Okuda, Hiroyuki	Nagoya Univ
Tazaki, Yuichi	Nagoya Univ
Suzuki, Tatsuya	Nagoya Univ
Haraguchi, Kentaro	TOYOTA Tech. DEVELOPMENT Corp
Kang, Zibo	TOYOTA Tech. DEVELOPMENT Corp

This paper presents a control system for autonomous driving based on MPC in which driving style can be easily modified by changing control parameters. Each of the motion controls for the longitudinal and the lateral direction are formulated as the model predictive control problem. Finally the experimental verification by using driving simulator and a real electric vehicle is performed by implementing MPC on each platform, and it is confirmed that the proposed system can produce a large variety of driving characteristics. The implemented MPC package will also be beneficial to the developers and researchers in various fields other than control engineering field.

13:20-14:45 TuPosterAT2.7

The Worst-Time-To-Collision Metric for Situation Identification, pp. 729-734

Wachenfeld, Walther	Tech. Univ. Darmstadt, Mechanical Engineering
Junietz, Philipp	TU Darmstadt
Wenzel, Raphael	TU Darmstadt, Inst. of Automotive Engineering
Winner, Hermann	Tech. Univ. Darmstadt

Currently, the introduction of highly automated vehicles is one of

the major targets of the whole automotive industry. However, it is still unclear how to cope with the testing effort necessary to approve an automated vehicle. One possibility to reduce the testing effort is to focus the assessment on critical situations. To describe the criticality of these situations, metrics are required. Firstly, this paper states requirements on assessment metrics. Secondly, this paper introduces a simple but comprehensive metric to select objects and situations out of a typical test drive to reduce the amount of data saved for further analysis. As it must not be assumed that the same situations are critical for human drivers and for automation, the metric only relies on driving dynamics and the physical possibilities of the vehicle. The special feature of this metric is the worst case assumption for vehicle behavior. If a situation is uncritical, even with the worst possible maneuvers, it is allowed to be neglected in the assessment process.

13:20-14:45 TuPosterAT2.8

Cross Datasets Vegetation Detection with Spatial Prior and Local Context, pp. 735-740

Fan, Heng — Temple Univ
Mei, Xue — Toyota Res. Inst. North America
Prokhorov, Danil — Toyota Res. Inst. NA
Ling, Haibin — Temple Univ

In this paper, we propose a vision-based approach for roadside vegetation detection by superpixel matching with local context. Unlike previous detection methods which seek help from additional sensors such as lidar, our algorithm only requires an off-the-shelf camera. The proposed method contains two stages. In the first stage, a superpixel database is constructed by segmenting training images into superpixels, and each superpixel patch is represented with multiple features. After that, the appearance information of vegetation or non-vegetation is encoded in the superpixel database. In the second stage, vegetation detection in each testing image is achieved by superpixel matching. The test image is segmented into superpixels and the (vegetation) label cost of each superpixel is derived by comparing with the k-nearest neighbors in the superpixel database. Furthermore, we incorporate the local context information through the feedback to refine superpixel matching. Taking this context information into account, Markov Random Field (MRF) is utilized to further improve the classification accuracy. Besides, considering the stable layout of road scene images, we utilize spatial priors of road scene to guide vegetation classification. Experiments on real-world datasets demonstrate the promise of our method.

13:20-14:45 TuPosterAT2.9

Decoupled Cooperative Trajectory Optimization for Connected Highly Automated Vehicles at Urban Intersections, pp. 741-746

Krajewski, Robert — Inst. Für Kraftfahrzeuge, RWTH Aachen Univ
Themann, Philipp — Inst. Für Kraftfahrzeuge, RWTH Aachen Univ
Eckstein, Lutz — RWTH Aachen Univ

The increasing market penetration of connected vehicles supports the development of highly automated vehicles for various traffic situations. Especially intersections form a bottleneck for the traffic flow and thus offer a high potential not only to increase the efficiency, but also to ensure safety. This paper presents a decoupled and decentralized approach using graph-based methods to optimize longitudinal trajectories for multiple vehicles at urban intersections. The approach enables the vehicles to cooperate, while avoiding collisions, considering dynamic influences like traffic lights, and minimizing a cost function. Furthermore, several heuristics are introduced, reducing the computational effort to solve these complex tasks. Simulations of an intersection scenario using the Monte Carlo method show a reduction of summarized costs, which represent travel time, efficiency and driving comfort, by ~28% compared to a driver model and by ~2.6% compared to a non-cooperative system.

13:20-14:45 TuPosterAT2.10

Reactive Trajectory Planning and Tracking for Pedestrian-Aware Autonomous Driving in Urban Environments, pp. 747-754

Cofield, Robert — Auburn Univ
Gupta, Rakesh — Honda Res. Inst. USA Inc

In this paper, we address the problem of trajectory planning while simultaneously reacting to the presence of pedestrians for an autonomous car on urban roads. Past work limits jerk, velocities and acceleration for smooth trajectories, without considering reactive behaviors such as responding to pedestrians. Other systems based on collision avoidance, plan paths around obstacles and pedestrians in unstructured environments. In this paper, we present an integrated trajectory generation and tracking system. Our system simultaneously considers both parameter and reactive constraints for smooth trajectory and updates it in real-time.

We present a novel online method for planning trajectories to follow a given urban path while honoring traffic regulations such as stop signs at intersections. We update the trajectory to safely avoid pedestrians on the road by slowing down or stopping. Our method has closed form solutions, runs at 20 Hz, and is efficient and reliable for use in online planning. We have confirmed this with a test vehicle and pedestrians with over 100 hours of testing under driverless operation.

13:20-14:45 TuPosterAT2.11

Human-Driver Speed Profile Modeling for Autonomous Vehicle's Velocity Strategy on Curvy Paths, pp. 755-760

Geng, Xinli — Univ. of Science and Tech. of China
Liang, Huawei — Inst. of Applied Tech. Hefei Inst. of Physical Sc
Xu, Hao — Univ. of Nevada, Reno
Yu, Biao — Inst. of Advanced Manufacturing Tech
Zhu, Maofei — The Inst. of Advanced Manufacturing Tech. Chinese Acad

As autonomous-vehicle-related technologies tend to be mature, improving passengers' experience by learning driving styles from human drivers becomes a promising research topic. This study aims at learning human drivers' velocity planning strategies for driving at curvy paths (e.g. negotiating sharp curves, turning at intersections, etc.) on structural road. First, we identified and extracted training trips from the latest naturalistic driving study database. Vehicle trajectories and the disturbances caused by other vehicles were estimated based on sensor data. Road characteristics, environmental parameters were identified from road information database and video clips. Then, neural network based models were developed to fit drivers' speed profiles under different driving situations. Five models with different prediction steps were trained by up to 600 driving trips. Three error criteria were used to evaluate the performance of proposed models. This study verified the possibility of using human drivers' experience to generate velocity recommendations for different driving conditions. The limitations of the models are also documented.

TuPosterAT3 Conference Hall

Poster III: Vehicle Control & Collision Avoidance (Poster Session)

Chair: Sjoberg, Jonas — Chalmers Univ

13:20-14:45 TuPosterAT3.1

String Stability of Heterogeneous Leader-Following Vehicle Platoons Based on Constant Spacing Policy, pp. 761-766

Guo, Xianggui — Nanyang Tech. Univ
Wang, Jianliang — Nanyang Tech. Univ
Liao, Fang — National Univ. of Singapore
Teo, Rodney — DSO National Lab

This paper is concerned with a leader-follower problem for a heterogeneous vehicle platoon subject to external bounded unknown acceleration disturbances. Distributed controller based on sliding mode control (SMC) approach are designed for the

second-order follower-vehicles under the common assumption that the initial spacing and velocity errors are zero. The constant spacing policy known to have high traffic density and thus have high traffic flow is applied to design distributed controller. In addition, adaptive compensation technique is applied to compensate the time-varying effect of external disturbances. It is worth mentioning that the upper and lower bounds of the disturbances are not required to be known in advance. Furthermore, with the help of an explicitly constructed Lyapunov function, it is proved that the string stability of the vehicle platoon can be guaranteed. At the same time, the reduction of the chattering in sliding mode is achieved by introducing continuous function in control. Finally, a numerical example is given for illustration.

13:20-14:45	TuPosterAT3.2

High-Precision Motion Control Method and Practice for Autonomous Driving in Complex Off-Road Environments, pp. 767-773

Sun, Zhenping	National Univ. of Defense Tech
Huang, Zhenhua	National Univ. of Defense Tech
Zhu, Qi	Coll. of Mechatronics and Automation, National Univ. of D
Li, Xiaohui	National Univ. of Defense Tech
Liu, Daxue	National Univ. of Defense Tech

In the last decade, autonomous driving technology has become an important research topic due to its potential economic and social benefits. There has been considerable research activities contributed to make the autonomous driving system adapt to complex environments. Motion control is vital to the overall autonomous driving system, especially when the autonomous vehicle is driving in complex off-road environments. The aim of our work in this paper is to develop a high-precision motion controller for autonomous driving system running on rugged mountain roads and sand roads. Different from most existing methods in which the motion control problem is decoupled into lateral control and longitudinal control. In this work, a coupling controller is designed for solving the motion control problem of autonomous driving system. Experiments in the real-world rugged mountain road and sand road environment have been conducted to demonstrate the high-precision performance and efficiency of the proposed motion controller.

13:20-14:45	TuPosterAT3.3

Hail-A-Drone: Enabling Teleoperated Taxi Fleets, pp. 774-781

d'Orey, Pedro M.	Inst. De Telecomunicações, Univ. of Porto
Hosseini, Amin	Tech. Univ. of Munich
Azevedo, José	Inst. De Telecomunicações, Univ. Do Porto
Diermeyer, Frank	Tech. Univ. München
Ferreira, Michel	Inst. De Telecomunicações (VAT Nr: PT 502 854 200)
Lienkamp, Markus	Tech. Univ. München

Despite impressive developments in automated driving technology, several technical, economic and social challenges hinder the large-scale deployment of highly or full automated vehicles. We present teleoperated driving - where in-car drivers are replaced by tele-drivers located at a control center- as a transient technology to enable a driverless, door-to-door taxi service. In this novel service, the transmission of video and audio streams of the vehicle surroundings via wireless networks to the taxi dispatch center allows a human operator to remotely sense the environment through a virtual windshield and to remotely operate the vehicle controls through an emulated cockpit. This safe and cost-effective transport service merges together aspects of taxi transport with car sharing services if the passenger drives part of the route. A large-scale empirical evaluation study proves the feasibility of this novel taxi operation mode and shows that the implementation of the system can reduce, on average, the number of drivers to between 15% and 27% when considering teleoperation during pickup/dropoff and service, respectively. A premium service where passengers are remotely also driven from their origin to the destination also presents considerable gains for taxi operators. Teleoperation of taxi fleets could revolutionize urban mobility by offering a cost-effective and safe door-to door transportation service

13:20-14:45	TuPosterAT3.4

Direct Homography Control for Vision-Based Platooning, pp. 782-789

Schaub, Alexander	German Aerospace Center (DLR) - Robotics Mechatronics Center
de Castro, Ricardo	Faculdade De Engenharia Da Univ. Do Porto
Burschka, Darius	Tech. Univ. Munich

This paper introduces a vision-based controller for automatic vehicle following, also known as 2-vehicle platooning. A direct homography controller is applied to calculate the motion demand for an autonomous vehicle from only the data of a monocular camera. The direct control without an intermediate step to a Cartesian representation increases the robustness of the scheme. A robustness analysis of the closed loop controller is provided using the parameter space approach. Furthermore, the direct homography controller is extended by an estimation of the absolute angular difference to the goal position, which then enables the estimation of the position error. The proposed homography-based position estimation is tested on rendered camera images for better evaluation of the underlying error and the platooning controller is verified in simulation. Finally, the results of both are presented.

13:20-14:45	TuPosterAT3.5

Model-Based Design and Control of Long Heavy Vehicle Combinations, pp. 790-795

Sundström, Peter	Modelon AB
Andreasson, Johan	Modelon Ab

Predicting and understanding the behavior of vehicle combinations is important both for the design of active and passive safety, as well as operability. This paper presents a modular structure to define articulated vehicle combinations that can handle arbitrary number of units and axles. It is illustrated how this modular approach can be used to design and control long heavy vehicle combinations.

13:20-14:45	TuPosterAT3.6

Active Trailer Braking System Design with Linear Matrix Inequalities Based Multi-Objective Robust LQR Controller for Vehicle-Trailer Systems, pp. 796-801

Sever, Mert	Yildiz Tech. Univ
Kaya, Ece Ebru	Yildiz Tech. Univ
Arslan, M. Selçuk	Yildiz Tech. Univ
Yazici, Hakan	Yildiz Tech. Univ

An Active Trailer Braking system is designed for the mitigation of trailer sway. Motion of the vehicle-trailer system on the horizontal plane with three degrees of freedom is modeled. Variations on the dynamic behaviors are studied due to the changes in longitudinal velocity. Then, performance objectives of controller are specified in terms of robust stability and lower bound of damping ratio for a prescribed longitudinal velocity range. Linear Matrix Inequalities based robust multi-objective LQR controller is designed with constraints on closed-loop pole locations and guarantee of robust stability. Finally, superiority of the designed controller is shown by using some numerical comparison with a classical Algebraic Riccati Equation based LQR design reported in the literature.

13:20-14:45	TuPosterAT3.7

Scenario Model Predictive Control for Robust Adaptive Cruise Control in Multi-Vehicle Traffic Situations, pp. 802-807

Schmied, Roman	Johannes Kepler Univ. Linz
Moser, Dominik	Johannes Kepler Univ. Linz
Waschl, Harald	Johannes Kepler Univ. Linz
del Re, Luigi	Johannes Kepler Univ. Linz

Considering multi-lane and multi-vehicle scenarios common adaptive cruise control (ACC) systems often face the problem of sudden and uncomfortable control actions when surrounding vehicles change the lane leading to a switch in the target vehicle of the ACC. Probabilistic modeling of the lane change behavior of surrounding traffic participants allows to predict such lane changes. This enables anticipatory control actions to avoid hard braking maneuvers and hence increases driving comfort and economy. This paper presents a scenario model predictive control (SCMPC) which estimates the lane change tendency of surrounding drivers by drawing a number of scenarios from a stochastic lane change prediction model. The model itself is identified based on real driving data. Simulation results show the advantages of the proposed control strategy by means of comparison to a common PI controlled ACC system.

13:20-14:45 TuPosterAT3.8

The Modeling of Transfer of Steering between Automated Vehicle and Human Driver Using Hybrid Control Framework, pp. 808-814

Kaustubh, Mani AVL LIST GmbH
Willemsen, Dehlia TNO
Mazo Jr, Manuel Tech. Univ. of Delft

Proponents of autonomous driving pursue driverless technologies, whereas others foresee a gradual transition where there will be automated driving systems that share the control of the vehicle with the driver. With such advances it becomes pertinent that the developed automated systems need to be safe. One crucial aspect of safety is to prove that the switching between the human driver and the automated system results in stable system behavior. This paper presents the hybrid control framework used for modeling switching of control authority between manual and automated driving. Also, first results of evaluating stable switching and the inclusion of parameters to address effects of driver comfort and safety are presented. The system developed in this paper consists of an automated driving system that is a combination of a cruise control system and an automated lane keeping system. The manual driving component is modeled as a preview steering controller with a neuromuscular dynamics component. A novel feature of our approach is using the concept of hybrid automata to model the different modes of driving, using the concept of average dwell time to evaluate stability, and using metric interval temporal logic to incorporate verification of different parameters that may affect the switching. We present initial, simulation based results to validate the correctness and usability of the developed framework for future developments.

13:20-14:45 TuPosterAT3.9

Appearance-Based Brake-Lights Recognition Using Deep Learning and Vehicle Detection, pp. 815-820

Wang, Jian-Gang Inst. for Infocomm Res
Zhou, Lubing Inst. for Infocomm Res. A*STAR, Singapore
Pan, Yu Inst. for Infocomm Res. A*STAR
Lee, Serin Inst. for Infocomm Res. A*STAR
Song, Zhiwei Inst. for Infocomm Res. (I2R), Agency for Science, Tech
Han, Boon Siew Inst. for Infocomm Res. (I2R), Agency for Science, Tech
Saputra, Vincensius Billy Inst. for Infocomm Res

Vehicle following is one of the fundamental functions of an autonomous driving system. Detection and recognition of tail light signal is important to prevent an autonomous vehicle from rear-end collisions or accidents. Although sensors like acoustic sonar or commercialized Advanced Driving Assistance System (ADAS) products such as mobileye could be used for rear-end collision warning, a cost-effective approach is expected. In this paper, we have developed a novel two-stage approach to detect vehicles and recognize brake lights from a single image in real-time. Unlike previous approaches where pair taillight has to be extracted explicitly, we use vehicle rear appearance image instead. On a large database, “Brake Lights Patterns” (BLP) are learned by a multi-layer perception neural network. Given an image, the vehicles can be classified as “brake” or “normal” using the deep classifier. The vehicle can be detected quickly and robustly by combining multi-layer lidar (IBEO Lux fusion system) and a camera. Road segmentation and a novel vanishing point region of interest (ROI) determination method are explored to further speed up the detection and improve the robustness. The experimental results conducted on some real on-road videos have shown the robustness and efficiency of the proposed approach.

13:20-14:45 TuPosterAT3.10

Data Veracity in Intelligent Transportation Systems: The Slippery Road Warning Scenario, pp. 821-826

Staron, Miroslaw Univ. of Gothenburg
Scandariato, Riccardo Univ. of Gothenburg

Intelligent transportation systems rely on the availability of high quality data in order to allow the multiple actors to make correct decisions in multiple traffic situations. Traditionally the high quality is associated with the correctness of the data, its timeliness or integrity. In this paper we explore the challenges of assessing and calculating the veracity of the data -- the data being "true". We use literature studies to identify relevant scenarios where data veracity is important. We use the conceptual mapping techniques to derive a map of veracity and the related concepts and we use design research to construct the case scenarios to illustrate the applicability of the data veracity assessment algorithms in practice. Our results show that the concept of veracity is related to such concepts as believability and correctness of the data. However, it is also different from these concepts as it requires more advanced assessment methods and has more complex impact on the traffic scenarios. Our conclusions are that in the increasing use of large quantities of data in decision-making in traffic situations, data veracity needs to be automatically assessed and non-veracious data (and its source) need to be flagged in order to avoid accidents.

13:20-14:45 TuPosterAT3.11

Longitudinal and Lateral Motion Planning Method for Avoidance of Multi-Obstacles in Urban Environments Based on Inverse Collision Probability, pp. 827-832

Akagi, Yasuhiro Tokyo Univ. of Agriculture and Tech
Raksincharoensak, Pongsathorn Tokyo Univ. of Agriculture and Tech

This paper presents a longitudinal and lateral motion planning method for driver assistance systems in urban scenarios. We proposed a Bayesian network based motion planner to generate the trajectory, including the positions and velocities to path through multiple traffic participants. To design the probabilistic models which represent a lane keeping maneuver and an obstacle avoidance maneuver, we collect and analyze natural driving data. Then, it is difficult to collect collision data in the real world. Therefore, we analyze the inverse collision probability from safety driving trajectories of expert drivers. The proposed method generates the optimal trajectory plan by using the global optimization algorithm named Belief Propagation. Finally, we show the evaluation experiment that compares the difference between the trajectories generated by the proposed method and natural driving data.

13:20-14:45 TuPosterAT3.12

*Anticipation Based on a Bi-Level Bi-Objective Modeling for the Decision-Making in the Car-Following Behavior**

Bennajeh, Anouer Stratégies d'optimisation et informatique intelligente
Kebair, Fahem Higher Inst. of Computer Science of Tunis
Ben Said, Lamjed Higher Inst. of Computer Science of Tunis
Akinine, Samir Univ. Claude Bernard Lyon 1

13:20-14:45 TuPosterAT3.13

Trajectory Prediction of Cyclists Using a Physical Model and an Artificial Neural Network, pp. 833-838

Zernetsch, Stefan — Univ. of Applied Sciences Aschaffenburg
Kohnen, Sascha-Marcel — Aschaffenburg Univ. of Applied Sciences
Goldhammer, Michael — Univ. of Applied Sciences Aschaffenburg
Doll, Konrad — Univ. of Applied Sciences Aschaffenburg
Sick, Bernhard — Univ. of Kassel

This article presents two methods for predicting the trajectories of cyclists at an intersection and compares them to a Kalman Filter (KF) approach. The first method uses a physical model of cyclists to predict their future position. The second method is based on a polynomial least-squares approximation in combination with a multilayer perceptron artificial neural network and is able to predict the future position of cyclists independent of their motion type such as ”Starting”, ”Stopping”, ”Waiting” or ”Passing”. To evaluate the performance of the methods, 566 tracks (394 for training, 172 for testing) of uninstructed cyclists were recorded at a public intersection using a wide angle stereo camera system and laser scanners. Using the tracks as input data, the future trajectory was predicted for a time horizon of 2.5 s. For starting motions the prediction using the physical model leads to 27% more accurate positions than the KF approach for a forecast horizon of 2.5 s. The neural network shows a 34% more accurate result for starting and stopping motions and a similar result for waiting and passing motions.

TuOralCT — Conference Hall
Mapping and Localization (Regular Session)

Chair: Nedevschi, Sergiu — Tech. Univ. of Cluj-Napoca
Co-Chair: Sörstedt, Joakim — Volvo Car Group

14:45-15:02 — TuOralCT.1

Robust Localization Based on Radar Signal Clustering, pp. 839-844

Schuster, Frank — Daimler AG
Wörner, Marcus — Daimler AG
Keller, Christoph Gustav — Daimler AG
Haueis, Martin — Daimler AG
Curio, Cristobal — Reutlingen Univ. & Max Planck Inst. for Biological Cybe

Significant advances have been achieved in mobile robot localization and mapping in dynamic environments, however these are mostly incapable of dealing with the physical properties of automotive radar sensors. In this paper we present an accurate and robust solution to this problem, by introducing a memory efficient cluster map representation. Our approach is validated by experiments that took place on a public parking space with pedestrians, moving cars, as well as different parking configurations to provide a challenging dynamic environment. The results prove its ability to reproducibly localize our test vehicle within an error margin of below 1% with respect to ground truth using only point based radar targets. A decay process enables our map representation to support local updates.

15:02-15:19 — TuOralCT.2

Towards Online Mobile Mapping Using Inhomogeneous Lidar Data, pp. 845-850

Vlaminck, Michiel — IPI - Ghent Univ. - Iminds
Luong, Hiep — IPI - Ghent Univ. - Iminds
Goeman, Werner — Grontmij
Philips, Wilfried — Ghent Univ. IMinds
Veelaert, Peter — Ghent Univ

In this paper we present a novel approach to quickly obtain detailed 3D reconstructions of large scale environments. The method is based on the consecutive registration of 3D point clouds generated by modern lidar scanners such as the Velodyne HDL-32e or HDL-64e. The main contribution of this work is that the proposed system specifically deals with the problem of sparsity and inhomogeneity of the point clouds typically produced by these scanners. More specifically, we combine the simplicity of the traditional iterative closest point (ICP) algorithm with the analysis of the underlying surface of each point in a local neighbourhood. The algorithm was evaluated on our own collected dataset captured with accurate ground truth. The experiments demonstrate that the system is producing highly detailed 3D maps at the speed of 10 sensor frames per second.

15:19-15:36 — TuOralCT.3

A Compact Representation of the Environment and Its Frontiers for Autonomous Vehicle Navigation, pp. 851-857

Lopez, Eduardo — Univ. of Alicante
Martinez-Marin, Tomas — Univ. De Alicante

In this paper we propose a new map representation based on contours. A contour is a polyline defined by an ordered set of points with attributes that represents the perimeter of some physical obstacle of the environment. This representation provides several advantages over occupancy grid maps, point or line landmarks maps and conventional polylines. In particular, the contours are adaptable to any surface and represent its uncertainty with very low memory storage. The method has been tested with the current benchmark procedure for SLAM algorithms assessment, showing high quality maps in relation to contemporary methods requiring several orders of magnitude less memory storage. Moreover, the method is suitable for autonomous vehicle navigation since it is highly scalable and the new concept of frontier as a virtual contour closing the explored area allows a more efficient path planning. Simulation and experimental results over the Intel Research Lab and ACES datasets and a conventional golf cart are reported to show the satisfactory performance of the method.

15:36-15:53 — TuOralCT.4

Vehicle Localization with Tightly Coupled GNSS and Visual Odometry, pp. 858-863

Schreiber, Markus — FZI Res. Center for Information Tech
Königshof, Hendrik — FZI Res. Center for Information Tech
Hellmund, André-Marcel — FZI Res. Center for Information Tech
Stiller, Christoph — Karlsruhe Inst. of Tech

Accurate localization is a key task in map based autonomous driving. While in many cases high precision differential GPS is used, more and more vision based methods gain popularity to improve positioning in GNSS denied environments and to avoid high costs in high quality GNSS receivers. However, to generate a globally referenced map, satellite based methods are still important, even in vision based mapping algorithms. In this paper we present a method for integrating locally accurate visual odometry obtained from an onboard stereo camera system with satellite observations of a low cost GNSS receiver. To account for a low number of visible satellites we directly incorporate pseudorange measurements for sensor data fusion. Hence, we present a low cost satellite and camera based positioning system and evaluate it for the usage as part of an inner city mapping system.

TuPosterBT1 — Open Arena
Poster IV: Mapping and Localization (Poster Session)

Chair: Nedevschi, Sergiu — Tech. Univ. of Cluj-Napoca
Co-Chair: Falcone, Paolo — Chalmers Univ. of Tech

16:25-17:50 — TuPosterBT1.1

Vehicle Localization with Low Cost Radar Sensors, pp. 864-870

Ward, Erik — KTH Royal Inst. of Tech
Folkesson, John — KTH -Royal Inst. of Tech

Autonomous vehicles rely on GPS aided by motion sensors to localize globally within the road network. However, not all driving surfaces have satellite visibility. Therefore, it is important to augment these systems with localization based on environmental sensing such as cameras, lidar and radar in order to increase reliability and robustness. In this work we look at using radar for localization. Radar sensors are available in compact format devices well suited to automotive applications. Past work on localization using radar in automotive applications has been based on careful sensor modeling and Sequential Monte Carlo, (Particle) filtering. In this work we investigate the use of the Iterative Closest Point, ICP, algorithm together with an Extended Kalman filter, EKF, for localizing a vehicle equipped with automotive grade radars. Experiments using data acquired on public roads shows that this computationally simpler approach yields sufficiently accurate results on par with more complex methods.

16:25-17:50	TuPosterBT1.2

Vehicle Localization Using an AVM Camera for an Automated Urban Driving, pp. 871-876

Park, Sungyoul	Seoul National Univ
Kim, Dongwook	Seoul National Univ
Yi, Kyongsu	Seoul National Univ

This paper presents a map-matching-based vehicle localization algorithm for application to automated driving on urban road. Vehicle position estimation of centimeter-level with low-priced commercial sensor setup is one of the key issue in urban automated driving. The information fusion method of localization algorithm utilizes vehicle chassis sensor and Around View Monitoring (AVM) module with four fish-eyed cameras. The proposed localization algorithm consists of three sections: a lane detection, a position correction, and a localization filter. A lane information is extracted from AVM image around the vehicle. This lane information is possible to correct vehicle position by the iterative closest point (ICP) algorithm which estimates the rigid transformation between the lane map and lanes obtained by AVM in real-time. The corrected vehicle position by this transformation is fused with the information of vehicle sensors based on an extended Kalman filter (EKF). In order to achieve higher accuracy, the covariance of the ICP algorithm is estimated by using Haralick's method. The performance of proposed localization is verified through vehicle experiments on proving ground and actual urban road.

16:25-17:50	TuPosterBT1.3

Track-Constrained GNSS/Odometer-Based Train Localization Using a Particle Filter, pp. 877-882

Liu, Jiang	Beijing Jiaotong Univ
Cai, Baigen	Beijing Jiaotong Univ
Wang, Jian	Beijing Jiaotong Univ

The accurate and reliable localization of the trains is one decisive factor for a lot of specific location-based railway applications. Considering the cost-efficiency of construction and maintenance, the Global Navigation Satellite System (GNSS) is an effective approach for train localization systems which aim to replace the track-side Balises with on-board sensors. Thus, the accumulative error of the odometer is calibrated by the GNSS receivers and the autonomy of the on-board equipment is surely improved. In order to cope with the uncertainties in raw sensor measurements, the Bayesian filtering frame is adopted to obtain an accurate estimation of the train's state. Based on that, an enhanced particle filter solution is presented to realize iterative estimation. In this method, the cubature Kalman filter (CKF) is involved to generate the proposal distribution by using the track constraint, which indicates a modified kinematical model and an extended measurement model. The coupling of track constraint is designed to generate the importance proposal distribution for the update stage of the sequential importance sampling. Results from simulation with field data demonstrate the capability of the track-constrained particle filter for train localization using GNSS and odometer, which is with great potential for enabling the next generation GNSS-based railway systems.

16:25-17:50	TuPosterBT1.4

Road DNA Based Localization for Autonomous Vehicles, pp. 883-888

Li, Liang	Shanghai Jiao Tong Univ
Yang, Ming	Shanghai Jiao Tong Univ
Wang, Chunxiang	Shanghai Jiao Tong Univ
Wang, Bing	Shanghai Jiao Tong Univ. SEIEE

High-precision and reliable localization is current research focus in the area of autonomous vehicles. Previous studies rely on either high-cost sensors or some specific characteristics, which means that the methods are limited to only a bit given situations. In this paper, a road DNA based localization method is proposed. It could afford high-precision result and does not have the shortcomings of previous methods at the same time. The scenery on both sides of the roads are used to generate the prior-map. The map is presented as grid map by the joint probability of occupation and reflectivity. With this type of map, different environments show different properties, which means that this method is not limited to specific environments and is effective in most cases. It costs much less memory than the previous maps. The map and live road scene flatting are both generated by data collected by low-cost LIDAR. Normalized Information Distance is utilized to align the live road scene flatting with the road DNA. Experiments show the validation and precision of this method.

16:25-17:50	TuPosterBT1.5

Lane-Level Positioning with Sparse Visual Cues, pp. 889-895

Kogan, Victoria	Univ. of Haifa
Shimshoni, Ilan	Univ. of Haifa
Levi, Dan	General Motors, Advanced Tech. Center, Israel

Vehicle localization and autonomous navigation consist of accurately positioning a vehicle in a lane. This paper presents topological localization methods by matching the visual cues from the on-board monocular camera images and the preprocessed database. We propose two methods for vehicle localization. The first exploits the 3D information of the sparse visual cues from the database. The relative vehicle rotation and translation are extracted using SOREPP method which is able to handle challenging scenarios with extremely low inlier fractions. The translation length is selected among multiple triangulation candidates. In order to select the best candidate, we suggest a robust soft-threshold estimation method which is not prone to local maxima even when the inliers' fragment is very small. The other method seeks for a refined test vehicle position estimation using a soft-threshold on Sampson distances and Cross-ratio measurements given a current noisy vehicle pose and several near-by database images. This method does not require any 3D knowledge for operation. The main challenge our optimization algorithm addresses is due to the camera and scene configurations. The database images and the test image are all taken from positions which are approximately co-linear. In addition, the scene points visible in all these images are almost co-linear with the camera positions. In this configuration, standard localization algorithms will exhibit difficulties in obtaining accurate results. The novel algorithm we present here is able to overcome this problem. The suggested localization methods are initialized by a rough position estimation thus require a regular vehicle GPS on-board. We evaluate the proposed methods on real data from the KITTI database with the RTK-GPS output.

16:25-17:50	TuPosterBT1.6

Ego-Lane Estimation for Lane-Level Navigation in Urban Scenarios, pp. 896-901

Rabe, Johannes	Daimler AG
Necker, Marc	Daimler AG
Stiller, Christoph	Karlsruhe Inst. of Tech

Future lane-precise navigation systems will recommend lane changes to drivers if needed. To achieve this, robust lane-level localization on a navigable map is essential. We propose an ego-lane estimation algorithm to robustly determine the ego-lane in urban scenarios based on a particle filter approach. The method only requires sensors available in a current production car, i.e. visual lane-marking detection, radar, and GPS, and a digital map describing road geometry and topology. Extensive experimental validation has shown an error rate of less than 0.75% with an availability of 95% of the total time and below 0.4% at 96%

availability in situations most relevant for navigation. The influence of the used sensors has been evaluated.

16:25-17:50	TuPosterBT1.7

3D Occupancy Grid Mapping Using Statistical Radar Models, pp. 902-908

Degerman, Johan	SafeRadar Res. Sweden
Thomas, Pernstål	SafeRadar Res. Sweden
Alenljung, Klas	DENSO International Europe

We have developed a numerically efficient occupancy grid mapping method in three dimensions for automotive radar, where we take into account the radar measurement signal-to-noise ratio. The mapping performance, i.e. to estimate length, height, and in-between spacing of parked cars, is demonstrated as we use acquired data from a radar prototype developed in collaboration with Qamcom Research and Technology. The radar has a unique antenna providing unambiguous azimuth and elevation for a wide field of view radar, covering 50 in both dimensions, making mapping in three dimensions feasible. Employing self-developed off-line radar signal processing on raw data, we extract SNR which is used together with a Swerling 1 model to compute the probability of detection for grid map update. Moreover, we present a novel very simplistic way of updating the grid as we use fast trilinear interpolation in the measurement domain, in which the grid spacing is uniform. Having mounted the radar in forward direction the EGO-vehicle drive parallel to four parked cars with different inter-spacing, and we manage to measure the distances within the error of the grid spacing, 0.2 m.

16:25-17:50	TuPosterBT1.8

Ego Lane Estimation Using Vehicle Observations and Map Information, pp. 909-914

Svensson, Daniel	Volvo Car Corp
Sörstedt, Joakim	Volvo Car Group

An ego vehicle localization algorithm must be able to estimate where the vehicle is on the road. This is typically performed with a positioning filter that operates in global coordinates. Herein, we take a different approach, by splitting the localization problem into two parts: in-lane localization and ego lane estimation. The paper addresses the latter problem. For this, we have developed theory and algorithms which, based on information about the positions of surrounding vehicles, give the probability of being in each of the current number of lanes. The object positions are provided by one or several low-cost on-board perception sensors. The derived Bayesian filter is evaluated on real data from a prototype self-driving car. Preliminary results show that when other vehicles are present, the proposed method is able to estimate the lane of travel with high probability.

16:25-17:50	TuPosterBT1.9

A Robust Terrain-Based Road Vehicle Localization Algorithm, pp. 915-920

Li, Tianyi	Shanghai Jiao Tong Univ
Yang, Ming	Shanghai Jiao Tong Univ
Zhou, Xujin	Shanghai Jiao Tong Univ
Wang, Chunxiang	Shanghai Jiao Tong Univ

Terrain-based localization is an alternate to the global positioning system (GPS) in signal blocked areas. However, terrain-based localization technique may suffer from low accuracy or even fail when brake vibration occurs. This paper presents a real-time algorithm for vehicle localization which is robust against brake vibration. The input includes a reference map of pitch difference and measurements from rear wheel encoders and inertial measurement units (IMU). This method consists of two steps. In the first step, terrain map is generated using pitch difference at equidistant intervals. After that, the Bayesian inference and particle filters are adopted in the second step to identify the vehicle location during travel. To enhance system stability, we propose dynamic distributions of filter variances according to acceleration input. Experimental results demonstrate that the localization method with dynamic distributions can localize the vehicle quickly with high accuracy even when a quite severe shuddering happens.

16:25-17:50	TuPosterBT1.10

Using a Single Band GNSS Receiver to Improve Relative Positioning in Autonomous Cars, pp. 921-926

Stenborg, Erik	Chalmers Univ. of Tech. Volvo Car Corp
Hammarstrand, Lars	Chalmers Univ. of Tech

We show how the combination of a single band global navigation satellite systems (GNSS) receiver, standard automotive level inertial measurement unit (IMU), and wheel speed sensors, can be used for relative positioning with accuracy on a decimeter scale. It is realized without the need for expensive dual band receivers, base stations or long initialization times. This is implemented and evaluated in a natural driving environment against a reference systems and against two simple base line systems; one using only IMU and wheel speed sensors, the other also adding basic GNSS. The proposed solution provides substantially slower error growth than either of the two base line systems.

16:25-17:50	TuPosterBT1.11

Vehicle Self-Localization Using 3D Building Map and Stereo Camera, pp. 927-932

Bao, Jiali	The Univ. of Tokyo
Gu, Yanlei	The Univ. of Tokyo
Hsu, Li-Ta	The Univ. of Tokyo
Kamijo, Shunsuke	The Univ. of Tokyo

Abstract— Self-localization is one of the most important part in autonomous driving system. In urban canyon, the multipath and non-line-of-sight effects to GPS receiver decrease the precision of self-localization of the vehicle. More specifically, the lateral error is more serious because of the blockage of the satellites. However, the building on roadside could be the stable reference object for localization. Therefore, this paper proposes to use stereo camera and 3D building map to reduce the lateral error of positioning result. In our proposal, stereo camera is used to detect and reconstruct the building side view. Lateral distance between building and vehicle estimated by stereo camera is compared with 3D building map to rectify the lateral position of vehicle. In addition, this paper employs the inertial sensor and GPS receiver to decide the longitudinal position of vehicle. The particle filter is used for the sensor fusion. The experiment is conducted in the center of Tokyo, Japan, which is a typical urban city scene with high density of tall buildings. It demonstrates that the proposed method could achieve sub-meter level accuracy in GPS difficult environments.

16:25-17:50	TuPosterBT1.12

Keypoint Trajectory Estimation Using Propagation Based Tracking, pp. 933-939

Fanani, Nolang	Goethe Univ. Frankfurt
Ochs, Matthias	Goethe Univ. Frankfurt Am Main
Bradler, Henry	Goethe Univ. Frankfurt Am Main
Mester, Rudolf	Univ. Frankfurt

One of the major steps in visual environment perception for automotive applications is to track keypoints and to subsequently estimate egomotion and environment structure from the trajectories of these keypoints. This paper presents a propagation based tracking method to obtain the 2D trajectories of keypoints from a sequence of images in a monocular camera setup. Instead of relying on the classical RANSAC to obtain accurate keypoint correspondences, we steer the search for keypoint matches by means of propagating the estimated 3D position of the keypoint into the next frame and verifying the photometric consistency. In this process, we continuously predict, estimate and refine the frame-to-frame relative pose which induces the epipolar relation. Experiments on the KITTI dataset as well as on the synthetic COnGRATS dataset show promising results on the estimated courses and accurate keypoint trajectories.

16:25-17:50	TuPosterBT1.13

Landmark Based Localization : LBA Refinement Using MCMC-Optimized Projections of RJMCMC-Extracted Road Marks, pp. 940-947

Soheilian, Bahman — Univ. Paris-Est, IGN/SR, MATIS
Qu, Xiaozhi — Univ. Paris-Est
Brédif, Mathieu — IGN

Precise localization in dense urban areas is a challenging task for both mobile mapping and driver assistance systems. This paper proposes a strategy to use road markings as localization landmarks for vision based systems. First step consists in reconstructing a map of road marks. A mobile mapping system equipped with precise georeferencing devices is applied to scan the scene in 3D and to generate an ortho-image of the road surface. A RJMCMC sampler that is coupled with a simulated annealing method is applied to detect occurrences of road marking templates instanced from an extensible database of road mark patterns. The detected objects are reconstructed in 3D using the height information obtained from 3D points. A calibrated camera and a low cost GPS receiver are embedded on a vehicle and used as localization devices. Local bundle adjustment (LBA) is applied to estimate the trajectory of the vehicle. In order to reduce the drift of the trajectory, images are matched with the reconstructed road marks frequently. The matching is initialized by the initial poses that are estimated by LBA and optimized by a MCMC algorithm. The matching provides ground control points that are integrated in the LBA in order to refine the pose parameters. The method is evaluated on a set of images acquired in a real urban area and is compared with a precise ground-truth.

TuPosterBT2	Pascal
Poster IV: Vision Sensing and Perception (Poster Session)	
Chair: Bergasa, Luis M.	Univ. of Alcala
Co-Chair: Lidberg, Mathias	Chalmers Univ. of Tech

16:25-17:50 — TuPosterBT2.1

Geodesic Distance Transform-Based Salient Region Segmentation for Automatic Traffic Sign Recognition, pp. 948-953

Fu, Keren — Chalmers Univ. of Tech
Gu, Irene Y.H. — Chalmers Univ. of Tech
Odblom, Anders — Active Safety CAE, Volvo Cars Corp. Dept. Volvo Cars AB, S
Liu, Feng — Active Safety CAE, Volvo Cars Corp. Department, Volvo Car

Visual-based traffic sign recognition (TSR) requires first detecting and then classifying signs from captured images. In such a cascade system, classification accuracy is often affected by the detection results. This paper proposes a method for extracting a salient region of traffic sign within a detection window for more accurate sign representation and feature extraction, hence enhancing the performance of classification. In the proposed method, a superpixel-based distance map is firstly generated by applying a signed geodesic distance transform from a set of selected foreground and background seeds. An effective method for obtaining a final segmentation from the distance map is then proposed by incorporating the shape constraints of signs. Using these two steps, our method is able to automatically extract salient sign regions of different shapes. The proposed method is tested and validated in a complete TSR system. Test results show that the proposed method has led to a high classification accuracy (97.11%) on a large dataset containing street images. Comparing to the same TSR system without using saliency-segmented regions, the proposed method has yielded a marked performance improvement (about 12.84%). Future work will be on extending to more traffic sign categories and comparing with other benchmark methods.

16:25-17:50 — TuPosterBT2.2

Online Vehicle Detection Using Deep Neural Networks and Lidar Based Preselected Image Patches, pp. 954-959

Lange, Stefan, Stefan — Freie Univ. Berlin
Ulbrich, Fritz — Freie Univ. Berlin
Goehring, Daniel — Freie Univ. Berlin

In this paper we present a vehicle detection system using convolutional neural networks on 2d image data. Since realtime capabilities are crucial for object detection systems running in real-traffic situations, we will show how the calculation time of our algorithm can be significantly reduced by taking advantage of depth information from lidar sensors. One part of this work focusses on useful network topologies and network parameters to increase the classification precision. We will test the presented algorithm on an autonomous car in different real-traffic scenarios with regards to detection accuracy and calculation time and show experimental results.

16:25-17:50 — TuPosterBT2.3

A Ground Truth Building Approach for Evaluation of Grid Based Discretization Techniques in Automotive Scenarios, pp. 960-965

Valenti, Francesco — Univ. Degli Studi Di Parma
Ghidini, Francesca — Vislab Srl
Patander, Marco — VisLab - Parma Univ
Broggi, Alberto — Univ. of Parma

Three-dimensional environment perception is one of the most important tasks for an autonomous vehicle. Map-based approaches play a fundamental role in the representation of vehicle surroundings, allowing several perception features, such as obstacle detection or road classification. However, benchmarks available in literature do not allow to evaluate the accuracy of these discrete representations, focusing only on the results downstream the maps. The proposed system uses a stochastic approach to evaluate a generic discrete representation of a three-dimensional world. The evaluation process consists in comparing a local perceived representation with the corresponding previously computed ground truth. The ground truth is automatically generated exploiting either accurate depth sensing and precise localization information. A test case is proposed, using stereo vision data and Digital Elevation Maps.

16:25-17:50 — TuPosterBT2.4

Continuous Extrinsic Online Calibration for Stereo Cameras, pp. 966-971

Mueller, Georg Rupert — Univ. of the Bundeswehr Munich
Wuensche, Hans Joachim Joe — Univ. Bw Munich

Accurate stereo camera calibration is crucial for 3D reconstruction from stereo images. In this paper, we propose an algorithm for continuous online recalibration of all extrinsic parameters of a stereo camera, which is rigidly mounted on an autonomous vehicle. The algorithm estimates the six degrees-of-freedom (6-DoF) of the transformation from the vehicle coordinate system to the coordinate system of the stereo camera and at the same time the relative 6-DoF transformation between the two camera sensors. Salient points in the environment that are observed by both cameras are tracked over time in 3D space. An Unscented Kalman Filter (UKF) is applied to recursively estimate the extrinsic stereo camera calibration and the 3D position of all observed points. The projections of the points and the measured vehicle motion, which is estimated using an inertial measurement unit (IMU), are given as input. The observability of the stereo camera calibration states is analyzed to identify critical vehicle motion sequences. Results with real world data show that the algorithm is capable of continuously estimating the stereo camera calibrations in spite of large initial errors and varying extrinsic parameters.

16:25-17:50 — TuPosterBT2.5

Parts Selective DPM for Detection of Pedestrians Possessing an Umbrella, pp. 972-977

Shimbo, Yuto — Nagoya Univ
Kawanishi, Yasutomo — Nagoya Univ
Deguchi, Daisuke — Nagoya Univ
Ide, Ichiro — Nagoya Univ
Murase, Hiroshi — Nagoya Univ

In recent years, pedestrian detection from an in-vehicle camera has been attracting attention. However, in the case of a raining situation, the detection accuracy decreases because the head of a pedestrian tends to be occluded by an umbrella. In oder to handle such cases, in this paper, as a variation of the Deformable Part

Model (DPM) which is widely used in the field of object recognition, we propose ``Parts Selective DPM (PS-DPM)'' which selectively chooses the original part filters and additional part filters trained independently. In the detection of pedestrians possessing an umbrella, the selection of head and umbrella parts will make pedestrian detection more robust to the occlusion. We conducted experiments to evaluate the performance of the proposed method. As a result, pedestrian detection with the proposed PS-DPM achieved high detection accuracy in rainy weather, compared with the detection by the conventional DPM. Moreover, we confirmed that it did not decrease the pedestrian detection accuracy in fine weather.

16:25-17:50 TuPosterBT2.6

Thermal-Infrared Based Drivable Region Detection, pp. 978-985

Yoon, Jae Shin — KOREA ADVANCED Inst. OF SCIENCE AND Tech. (KAIST)
Park, Kibaek — KAIST
Hwang, Soonmin — KAIST
Kim, Namil — KAIST
Choi, Yukyung — KAIST
Rameau, Francois — KAIST, RCV Lab
Kweon, In So — KAIST

Drivable region detection is challenging since various types of road, occlusion or poor illumination condition have to be considered in a outdoor environment, particularly at night. In the past decade, Many efforts have been made to solve these problems, however, most of the already existing methods are designed for visible light cameras, which are inherently inefficient under low light conditions. In this paper, we present a drivable region detection algorithm designed for thermal-infrared cameras in order to overcome the aforementioned problems. The novelty of the proposed method lies in the utilization of on-line road initialization with a highly scene-adaptive sampling mask. Furthermore, our prior road information extraction is tailored to enforce temporal consistency among a series of images. In this paper, we also propose a large number of experiments in various scenarios (on-road, off-road and cluttered road). A total of about 6000 manually annotated images are made available in our website for the research community. Using this dataset, we compared our method against multiple state-of-the-art approaches including convolutional neural network (CNN) based methods to emphasize the robustness of our approach under challenging situations.

16:25-17:50 TuPosterBT2.7

Evaluating Visual ADAS Components on the COnGRATS Dataset, pp. 986-991

Biedermann, Daniel — Goethe Univ. Frankfurt Am Main
Ochs, Matthias — Goethe Univ. Frankfurt Am Main
Mester, Rudolf — Univ. Frankfurt

We present a framework that supports the development and evaluation of vision algorithms in the context of driver assistance applications and traffic surveillance. This framework allows the creation of highly realistic image sequences featuring traffic scenarios. The sequences are created with a realistic state of the art vehicle physics model; different kinds of environments are featured, thus providing a wide range of testing scenarios. Due to the physically-based rendering technique and variable camera models employed for the image rendering process, we can simulate different sensor setups and provide appropriate and fully accurate ground truth data.

16:25-17:50 TuPosterBT2.8

Robust Localization Via Turning Point Filtering with Road Map, pp. 992-997

Jin, Yidong — Zhejiang Univ
Xiang, Zhiyu — Zhejiang Univ

To deal with the frequent failure of GPS in urban areas, vision-based localization methods such as visual odometry (VO) have been popular in recent years. However, VO still suffers from the problem of drift. In this paper, a novel Turning Point Filtering (TPF) algorithm is proposed to restrain the VO's drift by inducing the constraint from a concise road map. Different from the traditional road map based methods, we believe the simple “edge-node” road map is not enough to well model the true trajectory of the vehicle. Therefore our method does not enforce the corrected trajectory exactly on the edges of the map. A flexible turning point filtering mechanism is designed under a particle filter framework to well balance the information from the VO and the road map. The method features making reliable corrections only on the turning points of the trajectory, which adds little additional computation burden to VO. Experiments on various datasets including KITTI and the data acquired in our campus demonstrate the outperformance of our method.

16:25-17:50 TuPosterBT2.9

Real-Time Stereo Vision System at Nighttime with Noise Reduction Using Simplified Non-Local Matching Cost, pp. 998-1003

Xu, Yuquan — Toyota Tech. Inst
Long, Qian — Toyota Tech. Inst
Mita, Seiichi — Toyota Tech. Inst
Tehrani Nik Nejad, Hossein — DENSO Corp
Ishimaru, Kazuhisa — Nippon Soken Inc
Shirai, Noriaki — DENSO Corp

Reconstructing the depth information from the 3D scene using stereo vision is a key element in the development of advanced driver assistance systems. We previously proposed a novel real-time stereo matching method based on the Multi-paths Viterbi that outperforms the well-known SGBM (Semi-Global Block-Matching Algorithm) algorithm in both disparity accuracy and density. In this paper, we extend the previous framework to estimate the depth information for challenging environments such as nighttime. Estimating the depth at nighttime is generally challenging as the night images are dark and noisy and the estimated depth information is not accurate. In our proposed work, we modify the non-local means filter and propose a new non-local cost function to combine the noise reduction and stereo vision within a single framework. We evaluate our proposed algorithm on both natural and synthetic datasets and show that the proposed algorithm can significantly improve the quality of the stereo results in the low light condition. Moreover, our proposed method can be implemented in real-time for autonomous driver applications.

16:25-17:50 TuPosterBT2.10

Robust Road Marking Detection Using Convex Grouping Method in Around-View Monitoring System, pp. 1004-1009

Hyeon, Daejin — Seoul National Univ
Lee, Soomok — Seoul National Univ
Jung, Soonhong — LG Electronics
Kim, Seong-Woo — Seoul National Univ
Seo, Seungwoo — Seoul National Univ

As the around-view monitoring (AVM) system becomes one of the essential components for advanced driver assistance systems (ADAS), many applications using AVM such as parking guidance system are actively being developed. As a key step for such applications, detecting road markings robustly is a very important issue to be solved. However, compared to the lane marking detection methods, detection of non-lane markings, such as text marks painted on the road, has been less studied so far. While some of methods for detecting non-lane markings exist, many of them are restricted to roadways only, or work poorly on AVM images. In this paper, we propose an algorithm which can robustly detect non-lane road markings on AVM images. We first propose a difference-of-Gaussian based method for extracting a connected component set, followed by a novel grouping method for grouping connected components based on convexity condition. For a classification task, we exploit the Random Forest classifier. We demonstrate the robustness and detection accuracy of our methods through various experiments by using the dataset collected from various environments.

16:25-17:50 TuPosterBT2.11

Vision for Intelligent Vehicles & Applications (VIVA): Face

Detection and Head Pose Challenge, pp. 1010-1014

Martin, Sujitha — Univ. of California, San Diego
Yuen, Kevan — Univ. of California, San Diego
Trivedi, Mohan M. — Univ. of California at San Diego

Intelligent vehicles of the future are that which, having a holistic (i.e. inside and outside the vehicle) perception and understanding of the driving environment, make it possible for passengers to go from point A to point B safely and in a timely manner. This may happen by way of providing active assistance for drivers, giving full control to automated cars or some combination of the two. No matter how, a holistic perception and understanding of inside and outside the vehicle is absolutely necessary, and vision based techniques are expected to play an increasing role in this holistic view.

The question is, how well do these vision techniques work in order to be used in time and safety critical driving situations? We introduce one part of the Vision for Intelligent Vehicles and Applications (VIVA), the face challenge. VIVA is a platform designed to share naturalistic driving data with the community in order to: present issues and challenges in vision from real-world driving conditions, benchmark existing vision approaches using proper metrics and progress the development of future vision algorithms. With a special focus on challenges from looking inside at the driver's face, this articles provides information on how the data is acquired and annotated, and how methods are compared.

16:25-17:50 TuPosterBT2.12

Safe Maneuverability Zones & Metrics for Data Reduction in Naturalistic Driving Studies, pp. 1015-1021

Satzoda, Ravi Kumar — Univ. of California San Diego
Trivedi, Mohan M. — Univ. of California at San Diego

Naturalistic driving studies (NDSs) capture drive data from multiple sensor modalities over long periods of time and under varying road conditions. NDS data reduction dictionaries list a range of events that are directly related to the conflicts and threat posed by the dynamics of the surrounding vehicles on the ego-vehicle. Manual reduction of such large scale data for events/conflicts related to dynamics of multiple vehicles is inefficient and prone to errors. In this paper, we present drive analysis techniques for automated NDS data reduction that can be deployed to identify, quantify and visualize threats posed to the ego-vehicle. In this regard, we propose safe maneuver zones (SMZs) that are derived based on the dynamics of surrounding vehicles with respect to the ego-vehicle. A set of metrics are formulated using the SMZs to quantify the threat posed by surrounding vehicles on the ego-vehicle. A detailed drive analysis of naturalistic driving data comprising more than 500,000 frames of data from over 5 hours of highway driving is presented. The resulting drive analysis reports characterize 7 different drives using the different metrics from the SMZs.

16:25-17:50 TuPosterBT2.13

Vision-Based Pedestrian Monitoring at Intersections Including Behavior & Crossing Count, pp. 1022-1027

Shokrolah Shirazi, Mohammad — Univ. of Nevada, Las Vegas
Morris, Brendan — Univ. of Nevada, Las Vegas

This work presents a tracking system which delivers count and behavior analysis of pedestrians by leveraging existing traffic camera infrastructure. The proposed system is able to detect either stationary or moving pedestrians through contextual fusion of appearance and motion cues. Pedestrian recognition performance is improved through cooperating tracking algorithms. Greedy bipartite graph matching is used to initialize newly detected pedestrians and optical flow is then utilized to handle tracking through partial occlusions. Experimental results including system evaluation and behavior analyses of pedestrians show the efficiency of the system to count and assess pedestrians' waiting time and crossing speeds. Additionally, heat-maps which indicate the waiting and moving locations of pedestrians at the intersection are provided to better understand usage patterns.

16:25-17:50 TuPosterBT2.14

A New Benchmark for Vision-Based Cyclist Detection, pp. 1028-1033

Li, Xiaofei — Tsinghua Univ. Beijing
Flohr, Fabian — Daimler AG
Yang, Yue — Driver Assistance and Chassis Systems, Daimler Greater China Ltd
Xiong, Hui — Beihang Univ. China
Braun, Markus — Daimler AG
Pan, Shuyue — Tech. Univ. of Braunschweig
Li, Keqiang — Tsinghua Univ
Gavrila, Dariu M. — Daimler AG

Significant progress has been achieved over the past decade on vision-based pedestrian detection; this has led to active pedestrian safety systems being deployed in most mid- to high-range cars on the market. Comparatively little effort has been spent on vision-based cyclist detection, especially when it concerns quantitative performance analysis on large datasets. We present a large-scale experimental study on cyclist detection where we examine the currently most promising object detection methods; we consider Aggregated Channel Features, Deformable Part Models and Region-based Convolutional Networks. We also introduce a new method called SP-FRCN to detect cyclists based on the stereo proposals and FRCN framework. Experiments are performed on a dataset containing 22161 annotated cyclist instances in over 30000 images, recorded from a moving vehicle in the urban traffic of Beijing. Results indicate that all the three solution families can reach top performance around 0.9 average precision on the easy case, but the performance drops gradually with the difficulty increasing. The dataset including rich annotations, stereo images and evaluation scripts (termed “Tsinghua-Daimler Cyclist Benchmark”) is made public to the scientific community, to serve as a common point of reference for future research.

16:25-17:50 TuPosterBT2.15

Development and Comparison of Homography Based Estimation Techniques for Camera to Road Surface Orientation, pp. 1034-1040

Westerhoff, Jens — Bergische Univ. Wuppertal
Lessmann, Stephanie — Delphi
Meuter, Mirko — Delphi Electronics & Safety
Jan, Siegemund — Delphi
Kummert, Anton — Univ. of Wuppertal

This paper focuses on dynamic orientation estimation of a vehicle-mounted mono camera. In particular, the pitch and roll angles of the camera relative to the road surface. Information about the orientation angles is included in the homography (projective transformation) between two images of a planar road surface. The extraction of angles from a homography matrix is possible but not recommended due to parameter ambiguities. For this reason we do not estimate a full homography matrix but reduce the parameter space to two parameters. In this area of parameter estimation there are mainly two different approaches: The optical flow based approach and the image registration based approach. In order to decide which of these approaches is more favorable for the angle estimation problem, we develop one optical flow based and one image registration based angle estimation algorithm. We are the first directly evaluating and comparing both approaches with each other with the help of an artificial image sequence as well as real-world driving scenarios. In addition, this paper lifts the common limitation of roll angle of zero degree for dynamic camera orientation estimation. Our research finds that there is only a small difference between the parameter estimation results of the optical flow and image registration based approach.

16:25-17:50 TuPosterBT2.16

Accurate and Robust Lane Detection Based on Dual-View Convolutional Neutral Network, pp. 1041-1046

He, Bei — Baidu Map

Ai, Rui	Baidu Map
Yan, Yang	Baidu Map
Lang, Xianpeng	Baidu Map

In this paper, we propose a Dual-View Convolutional Neutral Network (DVCNN) framework for lane detection. First, to improve the low precision ratios of literature works, a novel DVCNN strategy is designed where the front-view image and the top-view one are optimized simultaneously. In the front-view image, we exclude false detections including moving vehicles, barriers and curbs, while in the top-view image non-club-shaped structures are removed such as ground arrows and words. Second, we present a weighted hat-like filter which not only recalls potential lane line candidates, but also alleviates the disturbance of the gradual textures and reduces most false detections. Third, different from other methods, a global optimization function is designed where the lane line probabilities, lengths, widths, orientations and the amount are all taken into account. After the optimization, the optimal combination composed of true lane lines can be explored. Experiments demonstrate that our algorithm is more accurate and robust than the state-of-the-art.

TuPosterBT3 Conference Hall

Poster IV: V2X & Eco-Driving & Traffic Flow (Poster Session)

Chair: Fredriksson, Jonas	Chalmers Univ. of Tech
Co-Chair: Cherfaoui, Véronique	Univ. DE Tech. DE COMPIEGNE

16:25-17:50 TuPosterBT3.1

Platooning at Traffic Lights - a Microscopic Simulation Study, pp. 1047-1053

Günther, Hendrik-Jörn	Volkswagen Group Res. and Tech. Univ. Braunschwei
Kleinau, Sandra	Volkswagen AG Group Res
Trauer, Oliver	C4c Engineering GmbH Braunschweig
Wolf, Lars	Tech. Univ. Braunschweig

Congested roads not only lead to inattentive and inpatient drivers, but also have a significant negative economic impact. Especially during rush hour traffic at traffic light regulated intersections, inefficient cycle plans and the increased demand raise the need for mechanisms that increase the traffic efficiency. This paper presents a rule based algorithm for realizing platooning at traffic lights, in order to increase the throughput and to reduce the shock wave effect commonly observed at intersections. The algorithm makes use of V2X communication technologies, by actively exchanging messages between the vehicles in order to set up the platoon. As a distinction to related work, the algorithm focuses on mixed traffic, in which not all vehicles are necessarily equipped with V2X technologies. The algorithm is implemented into an holistic simulation framework in order to study the effects of the parameters of the algorithm on the traffic efficiency.

16:25-17:50 TuPosterBT3.2

An Overtaking Decision Algorithm for Networked Intelligent Vehicles Based on Cooperative Perception, pp. 1054-1059

Vasic, Milos	EPFL
Lederrey, Gael	EPFL
Navarro, Inaki	EPFL
Martinoli, Alcherio	EPFL

This paper presents an overtaking decision algorithm for networked intelligent vehicles. The algorithm is based on a cooperative tracking and sensor fusion algorithm that we previously developed. The ego vehicle is equipped with lane keeping and lane changing capabilities, as well as a forward-looking lidar sensor. The lidar data are fed to the tracking module which detects other vehicles, such as the vehicle that is to be overtaken (leading) and the oncoming traffic. Based on the estimated distances to the leading and the oncoming vehicles and their speeds, a risk is calculated and a corresponding overtaking decision is made. We compare the performance of the overtaking algorithm between the case when the ego vehicle only relies on its lidar sensor, and the case in which it fuses object estimates received from the leading car which also has a forward-looking lidar. Systematic evaluations are performed in Webots, a calibrated high-fidelity simulator.

16:25-17:50 TuPosterBT3.3

Cooperative Positioning and Radar Sensor Fusion for Relative Localization of Vehicles, pp. 1060-1065

de Ponte Müller, Fabian	German Aerospace Center (DLR)
Munoz Diaz, Estefania	German Aerospace Center DLR
Rashdan, Ibrahim	German Aerospace Center DLR

Future advanced driver assistance systems require an accurate and up-to-date picture of the surrounding environment for applications such as forward collision assistants or adaptive cruise control. Today, the relative position of other objects with respect to the ego-vehicle is obtained with on-board ranging sensors, such as radar. By adding communication capabilities to future vehicles, cooperative approaches can offer a complementary source of relative position information. This paper proposes a fusion framework in which cooperative positioning information is fused with on-board radar sensor data. The measurement runs recorded on a highway and a rural road, demonstrate that the fusion of both information sources outperforms the positioning estimation using solely the radar sensor. An assessment of the current standard for vehicular communication in real world driving environments shows that a cooperative approach is able to extend the perception range of radar sensors in non-line-of-sight situations.

16:25-17:50 TuPosterBT3.4

Evaluating the Requirements of Communicating Vehicles in Collaborative Automated Driving, pp. 1066-1071

Ozbilgin, Guchan	Ohio State Univ
Ozguner, Umit	Ohio State Univ
Altintas, Onur	Toyota InfoTechnology Center
Kremo, Haris	Toyota InfoTechnologies Center
Maroli, John	The Ohio State Univ

In this paper, we analyze mixed traffic environments consisting of fully autonomous vehicles, vehicles capable of communication only, and manually driven vehicles to determine what self-generated content should be shared among peer vehicles for increased traffic intelligence. For this purpose, we present information sharing utility-cost tables for a variety of communication strategies. These tables are used to determine communication requirements in terms of bandwidth, distance, packet delay and loss rate tolerance. We specifically evaluate vehicle lane change events due to their role as foundational building blocks in most other traffic scenarios. The presented work demonstrates requirements for the communication systems in mixed-traffic environments based on sharing and fusing necessary sensor information using occupancy grid mapping.

16:25-17:50 TuPosterBT3.5

Cooperative Road Condition Estimation for an Adaptive Model Predictive Collision Avoidance Control Strategy, pp. 1072-1077

Jalalmaab, Mehdi	Univ. of Waterloo
Pirani, Mohammad	Univ. of Waterloo
Fidan, Baris	Univ. Ofg Waterloo
Jeon, Soo	Univ. of Waterloo

This paper proposes a model predictive collision avoidance scheme for use in autonomous driving based on cooperative on-line estimation of unknown and time varying road conditions. The autonomous vehicle is linearly modelled with constraints dependent on the road condition parameter. The proposed model predictive controller (MPC) is designed to be adaptive to this parameter. To accommodate this adaptive design, a particular method is developed for estimating the road friction coefficient cooperatively, by disseminating individual estimates in a vehicular network and using a consensus algorithm to converge these estimates to the maximum likelihood value. Presented simulation results demonstrate that the cooperative consensus scheme improves estimation significantly, and accordingly, the adaptive MPC incorporates road condition properly in collision avoidance planning.

16:25-17:50	TuPosterBT3.6

Cooperation of Autonomous Vehicles Using a Hierarchy of Auction-Based and Model-Predictive Control, pp. 1078-1084

Rewald, Hannes	Univ. of Kassel
Stursberg, Olaf	Univ. of Kassel

This paper proposes an approach to establish cooperative behavior within traffic scenarios involving only autonomously driving vehicles. The main idea is to employ principles of auction-based control to determine driving strategies by which the vehicles reach their driving goals, while adjusting their paths to each other and adhering to imposed constraints like traffic rules. Driving plans (bids) are repetitively negotiated among the control units of the vehicles (the auction) to obtain a compromise between separate (local) vehicle goals and the global objective to resolve the considered traffic scenario. The agreed driving plans serve as reference trajectories for local model-predictive controllers of the vehicles to realize the driving behavior. The approach is illustrated for a cooperative over-taking scenario comprising three vehicles.

16:25-17:50	TuPosterBT3.7

Vehicle Infrastructure Cooperative Localization Using Factor Graphs, pp. 1085-1090

Gulati, Dhiraj	Fortiss GmbH
Zhang, Feihu	TU Munich
Clarke, Daniel Stephen	Fortiss GmbH - an Inst. of the Tech. Univ. of Munic
Knoll, Alois	Tech. Univ. München

Highly assisted and Autonomous Driving is dependent on the accurate localization of both the vehicle and other targets within the environment. With increasing traffic on roads and wider proliferation of low cost sensors, a vehicle-infrastructure cooperative localization scenario can provide improved performance over traditional mono-platform localization. The paper highlights the various challenges in the process and proposes a solution based on Factor Graphs which utilizes the concept of topology of vehicles. A Factor Graph represents probabilistic graphical model as a bipartite graph. It is used to add the inter-vehicle distance as constraints while localizing the vehicle. The proposed solution is easily scalable for many vehicles without increasing the execution complexity. Finally simulation indicates that incorporating the topology information as a state estimate can improve performance over the traditional Kalman Filter approach.

16:25-17:50	TuPosterBT3.8

GPS Spoofing Detection and Mitigation Using Cooperative Adaptive Cruise Control System, pp. 1091-1096

Carson, Nathaniel	Auburn Univ
Martin, Scott	Auburn Univ
Starling, Joshua	Auburn Univ
Bevly, David	Auburn Univ

Global Navigation Satellite Systems (GNSS) like the Global Positioning System (GPS) are susceptible to electronic interference which threatens the reliability of the systems outputs, precise time and localization. Interference comes from natural and predatory sources in the form of increased in-band noise and structured attacks. The structured attack, called spoofing, is designed to trick the receiver into reporting an incorrect navigation solution as if it were accurate. Modern automobiles are becoming more reliant on GPS for localization, automation, and safety. Vehicles are also equipped with a variety of sensors (e.g. Radars, Lidars, wheel encoders) that provide situational awareness which may be leveraged in a GPS spoofing detection scheme. The proposed spoofing detection and mitigation system relies on an existing Cooperative Adaptive Cruise Control (CACC) system to provide inter-vehicle ranging and data sharing. The inter-vehicle ranges are used to detect a spoofing attack, and the mitigation system removes the attacking signal from the incoming data stream. The spoofing detection and removal system is tested using data recorded with a fielded CACC system on two commercial trucks. Intermediate frequency (IF) GPS data is collected during the test. Since live sky spoofing is legal, the IF data recording allows for post process spoofing injection in a controlled environment. In post process, the spoofing signal is shown to “capture” the onboard GPS receiver. The proposed system uses the spoofed IF GPS data along with recorded observables from the CACC system to detection and remove the attack.

16:25-17:50	TuPosterBT3.9

Impact Analysis of AUTOSAR Energy Saving Mechanisms for Automotive Networks, pp. 1097-1102

Hong, Wei	FZI Res. Center for Information Tech
Viehl, Alexander	Forschungszentrum Informatik Karlsruhe
Lin, Juguang	JEE Automation Equipment Co.LTD
Bringmann, Oliver	Eberhard Karls Univ. Tübingen
Rosenstiel, Wolfgang	Eberhard Karls Univ. Tübingen

In this paper we perform an impact analysis of the AUTOSAR energy saving mechanisms partial networking and pretended networking for automotive networks. We developed novel energy management strategies by exploiting these mechanisms. The strategies are integrated in a multi-level power management framework, which consists of three levels. Based on these strategies, we performed experiments on two production-class Electric Vehicles (EVs) measuring the energy consumption of the Electronic Control Units (ECUs). Results show up to 75.4% energy saving impact on the ECUs energy consumption on our test drives.

16:25-17:50	TuPosterBT3.10

Unified Predictive Fuel Efficiency Optimization Using Traffic Light Sequence Information, pp. 1103-1108

Guan, Tianyi	Fraunhofer IOSB
Frey, Christian	Fraunhofer IOSB

Energy efficiency has become a major issue in trade, transportation and environment protection. While the next generation of zero emission propulsion systems still have difficulties in reaching similar travel distances as power-trains with combustion engines, it is already possible to increase fuel efficiency in regular vehicles by applying a more fuel efficient driving behavior. The rise of V2X technologies have opened up new possibilities for safety and energy efficiency applications. This publication proposes a model predictive approach that makes use of a power-train model and a sequence of traffic lights over a finite optimization horizon. The optimization problem is solved in a unified manner, i.e. power-train properties and traffic light phases are not considered separately but evaluated in a single cost function. A stage-wise forward-backward Dynamic Programming approach involving cost reutilization is used for optimization. In order to further decrease the search space, certain continuous entities are not explicitly regarded as a state component, but rather calculated during optimization.

16:25-17:50	TuPosterBT3.11

Safety, Mobility and Environmental Sustainability of Eco-Approach and Departure Application at Signalized Intersections: A Simulation Study, pp. 1109-1114

Li, Weixia	Tsinghua Univ
Wu, Guoyuan	Univ. of California-Riverside
Zhang, Yi	Tsinghua Univ
Barth, Matthew	Univ. of California-Riverside

Safety, mobility and environmental sustainability represent three cornerstones when evaluating the effectiveness of an intelligent transportation system. However, very few studies have conducted a holistic performance assessment for a connected vehicle (CV) based application. In this study, an environment-focused CV application, called Eco-Approach and Departure (EAD) application at signalized intersections, is used as an example. Its safety, mobility and environmental sustainability parameters are carefully

evaluated through comprehensive simulation analyses over a real-word network. A variety of scenarios have been tested and the impact analysis is conducted from two perspectives: 1) EAD-equipped vehicles vs. non-equipped vehicles; and 2) overall traffic. The results indicate that the benefits of mobility and environmental sustainability show more consistent patterns across different scenario while safety impacts are more scenario-dependent.

16:25-17:50	TuPosterBT3.12

*The Impacts of Highly Automated Vehicles on Safety and Stability of Freeway Traffic Flow**

Motamedidehkordi, Nassim	Tech. Univ. of Munich
Margreiter, Martin	Tech. Univ. of Munich
Hoffmann, Silja	Tech. Univ. München, Chair of TrafficEngineering and Control

16:25-17:50	TuPosterBT3.13

Car Type Recognition with Deep Neural Networks, pp. 1115-1120

Huttunen, Heikki	Tampere Univ. of Tech
Shokrollahi Yancheshmeh, Fatemeh	Tampere Univ. of Tech
Chen, Ke	Tampere Univ. of Tech

In this paper we study automatic recognition of cars of four types: Bus, Truck, Van and Small car. For this problem we consider two data driven frameworks: a deep neural network and a support vector machine using SIFT features. The accuracy of the methods is validated with a database of over 6500 images, and the resulting prediction accuracy is over 97%. This clearly exceeds the accuracies of earlier studies that use manually engineered feature extraction pipelines.

16:25-17:50	TuPosterBT3.14

Coping with Non-Recurring Congestion with Distributed Hybrid Routing Strategy, pp. 1121-1127

Seredynski, Marcin	Luxembourg Inst. of Science and Tech
Grzybek, Agata	Univ. of Luxembourg

In case of congestion drivers typically select an alternative route on the basis of the shortest travel time principle. However, if drivers are informed with the same traffic conditions, their routing decisions can create a new congestion on the alternative route. The simplest method to reduce the risk of such an event has drivers choose another route with a certain probability associated with the latest reported travel time on the route. Nevertheless, this strategy has two drawbacks. Firstly, it is efficient only during the congestion period. Secondly, it presumes that some drivers select a route which is not optimal from their point of view. In this paper we demonstrate that these drawbacks can be eliminated when a hybrid approach is used. That is, an in-vehicle system detects a period when capacity of a route is reduced, and only then it requests drivers to follow the probabilistic approach. Otherwise the conventional shortest-time principle is applied. Each vehicle acts as a traffic sensor, and travel times are disseminated by means of connected vehicle technology. In addition, a simple road user charging mechanism is used to motivate free-riders to select routes contributing to system optimum. System evaluation is carried out using realistic network (NS-3) and traffic (SUMO) simulations and a two-route example.

Book of Abstracts: Wednesday June 22, 2016

WeKeynoteP	Conference Hall
Keynote: TNO (Plenary Session)	
Chair: Sotelo, Miguel A.	Univ. of Alcala

08:45-09:30 WeKeynoteP.1

*I-GAME: From Platooning to Cooperative Automated Maneuvering**

Ploeg, Jeroen — TNO

i-GAME is an international project, supported by the European Commission in the scope of the 7th Framework Programme, with consortium members being TNO, Eindhoven University of Technology, Viktoria Swedish ICT, and IDIADA. The i-GAME project aims to facilitate development and real-life implementation of automated driving with a focus on cooperation supported by wireless communication between vehicles and between vehicles and road-side equipment. To this end, an event is organized as part of the project, in which international teams are challenged to cooperatively perform a number of traffic scenarios, among which the automated merging of two platoons into one, and the automated execution of a T-crossing. The specific scenarios are presented in some detail, after which the most relevant requirements for participation in the challenge are summarized, including the methods used to assess the team vehicles, both regarding hardware and software.

The execution of the selected traffic scenarios does not only require vehicle-level control systems for longitudinal and lateral automation, but also interaction protocols, prescribing the message-action sequence so as to safely and successfully execute the scenario at hand. This presentation will provide ample insight in the interaction protocol design as performed by the consortium members, the implementation thereof by the consortium in their benchmark vehicles, and the various implementations by the teams. The main results, obtained during the challenge, will be illustrated by measurements and movies. In addition, the message sets used in i-GAME will be presented, which clearly indicates that the standardized messages need to be extended in order to support complex traffic scenarios.

WeOralAT	Conference Hall
Advanced Driver Assistance Systems (Regular Session)	
Chair: Vlacic, Ljubo	Griffith Univ
Co-Chair: Selpi, Selpi	Chalmers Univ. of Tech

09:30-09:47 WeOralAT.1

A Bayesian Framework for Preventive Assistance at Road Intersections, pp. 1128-1134

Armand, Alexandre — Renault SA
Filliat, David — ENSTA ParisTech
Ibanez Guzman, Javier — Renault S.A.S,

Modern vehicles embed an increasing number of Advanced Driving Assistance Systems (ADAS). Whilst such systems showed their capability to improve comfort and safety, most of them provide assistance only as a last resort, that is, they alert the driver or trigger automatic braking only when collision is imminent. This limitation is mainly due to the difficulty to accurately anticipate risk situations in order to provide the driver with preventive assistance, i.e. assistance allowing for comfortable reaction. This paper presents a Bayesian framework which aims to detect risk situations sufficiently early to trigger conventional curative assistance as well as preventive assistance. By taking into consideration the context, the vehicle state, the driver actuation and the manner how the driver usually negotiates given situations, the framework allows to infer which type of assistance is the most pertinent to be provided to the driver. The principles of this framework are applied to a fundamental case study, the arrival to a stop intersection. Results obtained from data recorded under controlled conditions are presented. They show that the framework allows to coherently detect risk situations and to identify what assistance, including preventive assistance, is the most appropriate for the situation.

09:47-10:04 WeOralAT.2

Preliminary Potential Crash Prevention Estimates for an Intersection Advanced Driver Assistance System in Straight Crossing Path Crashes, pp. 1135-1140

Scanlon, John Michael — Virginia Tech
Gabler, Hampton Clay — Virginia Tech
Sherony, Rini — Toyota Motor Engineering and Manufacturing North America

Intersection crashes are among the most frequent and lethal crash modes in the United States. Accounting for over one-third of all intersection crashes, Straight crossing path (SCP) crashes are the most common intersection crash mode. Intersection Advanced Driver Assistance Systems (I-ADAS) have the potential to prevent SCP crashes by detecting imminent collisions and either alerting the driver and/or taking autonomous crash avoidance action. The objective of this study was to estimate how many SCP intersection crashes could be potentially prevented in the U.S. if every vehicle was equipped with I-ADAS. Three steps were performed in this study. First, a simulation case set was generated from 459 real world SCP intersection crashes collected as part of NHTSA's National Motor Vehicle Crash Causation Survey (NMVCCS) database. Second, the pre-crash kinematics of each vehicle was reconstructed using information from the crash investigation, pre-crash driver models, and reconstructed impact speeds. Third, the crashes were simulated as if both vehicles had been equipped with I-ADAS. Three critical time-to-collision (TTC) thresholds were evaluated in this study, including 2.0, 2.5, and 3.0 seconds. The model predicted that 19% to 35% of all SCP crashes have the potential to be prevented if all vehicles in the U.S. were equipped with I-ADAS. Nearly twice as many crashes were predicted to be prevented if a TTC threshold of 3.0 s was used rather than 2.0 s. When at least one of the vehicles stopped prior to entering the intersection, the model estimated that 24% to 49% of crashes have the potential to be prevented by I-ADAS. In contrast, when neither vehicle stopped, the model estimates that 13% to 17% of crashes could potentially be prevented. It is important to note that the mo

10:04-10:21 WeOralAT.3

Probabilistic Situation Assessment Framework for Multiple, Interacting Traffic Participants in Generic Traffic Scenes, pp. 1141-1148

Klingelschmitt, Stefan — Tech. Univ. of Darmstadt
Damerow, Florian — Tech. Univ. of Darmstadt
Willert, Volker — TU Darmstadt
Eggert, Julian — Honda Res. Inst. Europe GmbH

Situation recognition is a prerequisite for many advanced driver assistance systems as well as for partially and fully automated vehicles. Current situation recognition approaches focus mainly on estimating maneuvers of single scene entities. However, assessing multiple, possibly interacting, traffic participants simultaneously is crucial in complex traffic scenes and has hardly been investigated. Considering the variability and combinatorics of such scenarios, having specialized situation recognition systems covering each case directly is unrealistic. In this paper, we present a flexible framework for assessing generic traffic scenes with multiple interacting traffic participants. It is able to construct a fully interaction-respecting probabilistic situation assessment, while relying on reusable state-of-the-art single-entity-based maneuver predictions. The benefits and applicability are presented on a real-world data set. The evaluation indicates that the approach is not only able to reconstruct underlying interdependent probability distributions; it outperforms specially designed models, due to the reduced complexities of the single-entity-based recognition models.

10:21-10:38 WeOralAT.4

A Model-Based Scenario Specification Method to Support Development and Test of Automated Driving Functions, pp. 1149-1155

Bach, Johannes — FZI Res. Center for Information Tech

Otten, Stefan	FZI Res. Center for Information Tech
Sax, Eric	FZI Res. Center for Information Tech

Research and evaluation of algorithms and system architectures for automated driving advanced to a stage where transition from prototyping to series development seems practicable in some extent. While particular systems for environmental perception play a key role in advanced driving assistance systems, we still lack feasible methods for specification and validation of complex driving scenarios. This leads to increased effort in testing and inconsistent requirement definition along different development phases. In this paper we propose a methodology for abstract positional and temporal description of driving scenarios. The approach utilizes a movie related and omniscient view composed of sequential acts. Each act combines both states and interactions of distinct participants as well as the rudimental scenery. Selective events trigger changes in conduct leading to transitions between acts. Graphical visualization provides simple presentation of complex scenarios. Rule sets provide consistency checks and support semi-automated generation of test cases. The presented methodology facilitates model based test specification and requirements design constituting a consistent characterization of system environment from early concept and development to validation.

WePosterAT1 Open Arena

Poster V: Advanced Driver Assistance Systems (Poster Session)

Chair: Willemsen, Dehlia	TNO
Co-Chair: Sjoberg, Jonas	Chalmers Univ

11:00-12:25 WePosterAT1.1

Path Tracking and Stabilization for a Reversing General 2-Trailer Configuration Using a Cascaded Control Approach, pp. 1156-1161

Evestedt, Niclas	Linköpings Univ
Ljungqvist, Oskar	Linköping Univ
Axehill, Daniel	Linköping Univ

In this paper a cascaded approach for stabilization and path tracking of a general 2-trailer vehicle configuration with an off-axle hitching is presented. A low level Linear Quadratic controller is used for stabilization of the internal angles while a pure pursuit path tracking controller is used on a higher level to handle the path tracking. Piecewise linearity is the only requirement on the control reference which makes the design of reference paths very general. A Graphical User Interface is designed to make it easy for a user to design control references for complex manoeuvres given some representation of the surroundings. The approach is demonstrated with challenging path following scenarios both in simulation and on a small scale test platform.

11:00-12:25 WePosterAT1.2

Integrated Adaptive Cruise Control Design Considering the Optimization of Switching between Throttle and Brake, pp. 1162-1167

Luo, Lihua	Shanghai Maritime Univ
Chen, Jihong	Shanghai Maritime Univ
Zhang, Fangwei	Shanghai Maritime Univ

In the Adaptive Cruise Control (ACC) system, the switching between throttle and brake is critical, and the threshold switching logic is used in most existing references, which will possibly cause the frequent switching, resulting in the mechanical damage of vehicle components, fluctuations of the vehicle dynamics, increased fuel consumption, un-comfort and un-satisfaction from passengers and car owners. In this paper, the integrated ACC controller that optimizes the switching between throttle and brake is designed. The ACC system, which consists of the continuous-time vehicle longitudinal dynamics (throttle and brake models) and the discrete-event dynamics (logic switching rule between throttle and brake), is modeled in Mixed Logic Dynamical (MLD) approach. Then the ACC controller is designed in Model Predictive Control (MPC) framework, and the requirements of spacing control, rear-end collision avoidance (safety), optimal switching between throttle and brake, and vehicle capabilities are considered as the control objectives and constraints, respectively. In MPC framework, the ACC controller design is finally transformed to an online Mixed-Integer Quadratic Programming (MIQP). The simulation results show that the proposed ACC controller shows good ability in following the preceding vehicle, prevents rear-end collisions, and it outperforms the traditional ACC controller with the threshold switching rule for providing the smoother vehicle dynamics, less switching between throttle and brake, and more comfortable traveling.

11:00-12:25 WePosterAT1.3

Reliable Routing in Stochastic Time-Dependent Network with the Use of Actual and Forecast Information of the Traffic Flows, pp. 1168-1172

Agafonov, Anton	Samara State Aerospace Univ
Myasnikov, Vladislav	Samara State Aerospace Univ

This paper addresses the reliable routing problem in stochastic time-dependent networks using actual and forecast information of the traffic flow parameters. We consider the following optimality criterion: maximization the probability of arriving on time at a destination given a departure time and a time budget. The proposed model is compared with an existing algorithm. Conducted experiments show that the proposed method with a slight increase in computational complexity increases the probability of on-time arriving in a stochastic time-dependent network. The proposed algorithm was implemented and tested using the large transport network of Samara, Russia.

11:00-12:25 WePosterAT1.4

Using Insurance Claims Data to Evaluate the Collision Avoidance and Crash-Mitigating Effect of Collision Warning and Brake Support with Adaptive Cruise Control, pp. 1173-1178

Isaksson-Hellman, Irene	If P&C Insurance
Lindman, Magdalena	Volvo Car Corp

Cars are increasingly equipped with functions that protect drivers from crashes. Forward Collision Warning and Brake Support combined with Adaptive Cruise Control (CWB+ACC) are collision-avoidance features available in modern cars. Previous real-world evaluations have reported on the crash-avoidance performance of these technologies. The objective of this study was to evaluate the safety effect of CWB+ACC in terms of crashes mitigated by reduced impact speed, as well as crashes avoided. The typical conflict situation addressed by the systems is a rear-end frontal collision, i.e. a collision with a vehicle in front of the subject car that is positioned in, or traveling along, the same path. Car–to-pedestrian and car-to-cyclist crashes are also addressed by these systems. For CWB+ACC cars, rear-end frontal collisions were reduced by 37%. A clear mitigating effect was found for different crash-severity levels, and the average number of spare parts used was reduced for CWB+ACC cars. No significant reduction of injured occupants was found for CWB+ACC cars (in striking or struck vehicles). Although an extensive dataset was used for the analysis, there were not enough car-to-pedestrian or car-to-cyclist crashes available to obtain a statistically significant analysis of these events.

11:00-12:25 WePosterAT1.5

A Multi-Domain Simulation Approach to Validate Advanced Driver Assistance Systems, pp. 1179-1184

Feilhauer, Marius	ETAS GmbH
Häring, Dr. Jürgen	ETAS GmbH

This work presents a simulation architecture to validate Advanced Driver Assistance Systems (ADAS). The realization of secure autonomous vehicles is closely connected to the possibility of validating the functionality of ADAS. The high-dimensional parameter range of simulation scenarios, including for example weather conditions, traffic flow or material properties, enforces to shift tests from reality to computer based simulations. To enable tests of physical prototypes in an early stage of development, these devices have to be included in the simulation. An approach how to combine various simulation domains and perform ADAS relevant simulations is presented.

11:00-12:25 WePosterAT1.6

Inferring a Spatial Road Representation from the Behavior of Real World Traffic Participants, pp. 1185-1191

Casapietra, Edoardo — Bielefeld Univ
Weisswange, Thomas H. — Honda Res. Inst. Europe GmbH
Goerick, Christian — Honda Res. Inst. Europe GmbH
Kummert, Franz — Bielefeld Univ

The detection of road area in the surroundings of the ego-vehicle is a key issue for modern ADAS. Camera-based direct detection systems are able to reliably accomplish this task only within a limited spatial range or in simple environments, due to hardware limitations and unfavorable situations, like shadows or occlusions. In complex environments, like inner city, traffic is a real issue, since the mere presence of other cars can significantly restrict the field of view of the ego-vehicle. In order to extend the spatial range of road detection, indirect detection systems are a viable resource. They can complement state-of-the-art direct detection systems and help motion control systems to plan smooth and stable trajectories. In this paper we propose a probabilistic grid-based approach based on the interpretation of the motion of other vehicles in the scene. The approach uses the position and velocity of those vehicles in order to infer the presence and location of occluded road area. We will show that this approach can complement an already established feature-based detection system, taking advantage of those situations that are the most challenging for the latter. Evaluations on real-world scenes show that the union between this approach and direct road detection significantly extends the spatial range of detection, thus is able to provide a motion control system a longer horizon for planning trajectories.

11:00-12:25 WePosterAT1.7

The Narrow Road Assistant - Evolution towards Highly Automated Driving in Inner City, pp. 1192-1198

Michalke, Thomas Paul — Robert Bosch GmbH
Gläser, Claudius — Robert Bosch GmbH
Buerkle, Lutz — Robert Bosch GmbH
Niewels, Frank — Robert Bosch GmbH

With the “narrow road assistant” (NRA), this contribution elaborates on an inner-city ADAS that supports the driver in safely passing narrow road passages. The system offers early scenario-specific information together with automated support in steering and braking. The solved challenges and gathered experiences will ease and accelerate the development of future functions for piloted inner-city driving. In this sense, the function is an important evolutionary step towards highly automated driving in urban areas. The ADAS was realized in the context of the publicly-funded project UR:BAN, which started in 2012. In October 2015 the project UR:BAN reached its peak in a public presentation in Düsseldorf Germany. Numerous driving demonstrations allowed guests an independent evaluation on a larger scale. The Bosch NRA performed in all situations reliably surpassing the expectations of many guests. The focus of the contribution will be on the detailed description of the system and its evaluation.

11:00-12:25 WePosterAT1.8

Probabilistic Distance Estimation for Vehicle Tracking Application in Monocular Vision, pp. 1199-1204

Lessmann, Stephanie — Delphi
Meuter, Mirko — Delphi Electronics & Safety
Mueller, Dennis — Delphi Electronics & Safety
Pauli, Josef — Univ. Duisburg-Essen

Measuring absolute distances in monocular vision is challenging and cannot be solved directly. Conventionally,assumptions like an a priori width of the target object or geometric constraints are made to overcome the problem. In this paper we describe a probabilistic solution that integrates distance estimation in a vehicle tracking environment. This is obtained by using a ground plane angle based estimation together with a width interval constraint utilizing a vehicle classifier. Furthermore the information from a lane departure warning system is fused. We combine width and angular information together utilizing a Bayes estimator. For testing a large video data set with distance ground truth obtained from a radar has been generated. We show that using this estimator enhances the distance estimation in a Kalman filter based vehicle tracker environment compared to the standard constraints widely used. The presented probabilistic integration is very time efficient and has been successfully tested online.

11:00-12:25 WePosterAT1.9

Blurring the Border between Real and Virtual Parking Environments, pp. 1205-1210

Becker, Daniel — Daimler Center for Automotive Information Tech. Innovations
Munjere, Andrew — Fraunhofer FOKUS
Einsiedler, Jens — Fraunhofer Society
Massow, Kay — Fraunhofer Fokus
Thiele, Fabian — Daimler Center for Automotive Information Tech. Innovations
Radusch, Ilja — Fraunhofer FOKUS

Modern multi-level indoor parking environments promise to alleviate the parking problems in modern cities but they are oftentimes stressful for human drivers. Increasing automation of the parking process has the potential for significant gains in efficiency, safety and comfort but requires highly accurate sensing and monitoring of the environment. Another challenge is the appropriate visualization of large amounts of sensor data from disparate sources, in an intuitively understandable way. We address these challenges with our platform VPIPE for realistic visualization of 3D parking environments, parking lots and sensor data of vehicles. As central building block for this platform, we propose a cost-effective camerabased parking lot monitoring system that uses a cascade of Random Forest and Artificial Neural Network classifiers. The achieved detection accuracy in our parking testbed is 94.98%.

11:00-12:25 WePosterAT1.10

Towards Personalized Automated Driving: Prediction of Preferred ACC Behavior Based on Manual Driving, pp. 1211-1216

de Gelder, Erwin — TNO
Cara, Irene — TNO
Uittenbogaard, Jeroen — TNO
Kroon, Liselotte — TNO
van Iersel, Sven — TNO
Hogema, Jeroen — TNO

More and more Advanced Driver Assistance Systems (ADASs) are entering the market for improving both safety and comfort. Adaptive Cruise Control (ACC) is an ADAS application that has high interaction with the driver. ACC systems use limited sensor input and have only few configuration possibilities. This may result in the behaviour of the ACC not matching user's preferences in all cases, resulting in lower acceptance of the system. In this work, we examine the possibilities for a Personalised ACC (PACC), which adapts the ACC settings such that it matches the driver preference in order to increase the acceptance. The driver preferred ACC behaviour is predicted using machine learning techniques and manual driving data. On-road experiments showed that the method is promising as it is able to discriminate between two preference clusters with an accuracy of 85%.

11:00-12:25 WePosterAT1.11

Variable-Sensitivity Road Departure Warning System Based on Static, Mapped, Near-Road Threats, pp. 1217-1223

Arora, Prashant — The Pennsylvania State Univ
Corbin, David — The Pennsylvania State Univ
Brennan, Sean — The Pennsylvania State Univ

The severity of a road departure event strongly depends on the features around the roadway: trees and other “hard” fixed objects represent a severe collision hazard, steep slopes nearby may be representing rollover threats or frontal impact hazards, and sharp

road-edge drop-offs may exist that prevent high-speed road recovery. But the near-road area may also contain traversable shoulders and medians, such that a road departure can be a fully safe and recoverable event. This paper presents a simulated road departure warning system, sensitive to severity of hazards based on near-road terrain geometry analysis and subsequent threat assessment. To serve as a demonstration, many random 3D models of a highway road and near-road features following AASHTO guidelines were generated. Near-road features were subdivided into three categories corresponding to high, medium or low severity based on their geometries. We assume that geometric parameters of features used in this study are available from pre-processed LIDAR or other map data. Due to unavailability of threat correlation between different types of features, a relative threat index defined as Normalized Average Severity index is used to determine threats associated with a feature. To simulate a driver-warning system, geometries and hazards were tagged with different colors on the generated 3D model. The 3D model is designed to serve as an additional visual warning system for the driver providing information about risk zones nearby the present vehicle position.

11:00-12:25	WePosterAT1.12

Multi-Level Cooperation between the Driver and an Automated Driving System During Lane Change Maneuver, pp. 1224-1229

Benloucif, Mohamed Amir	LAMIH, UVHC-CNRS UMR 8201 Univ. of Valenciennes
Popieul, Jean-Christophe	Univ. De Valenciennes
Sentouh, Chouki	LAMIH/CNRS Univ. of Valenciennes

This article presents an automated driving system that ensures cooperation with the driver. The system architecture is structured in hierarchical levels to allow suitable interaction with the driver on multiple driving levels. A multi-level cooperative interaction concept is developed to continuously share control and dynamically manage interferences and decision authority between the driver and the system according to the situation. The system extends the lane keeping function with an active lane change assistance function. The necessary components for the multi-level cooperation concept are presented and experimental results show a good and intuitive interaction for active lane change assistance.

11:00-12:25	WePosterAT1.13

Improving Robustness for Real-Time Vehicle Egomotion Estimation, pp. 1230-1235

Lessmann, Stephanie	Delphi Electronics & Safety
Siegemund, Jan	Univ. of Bonn
Meuter, Mirko	Delphi Electronics & Safety
Westerhoff, Jens	Bergische Univ. Wuppertal
Pauli, Josef	Univ. Duisburg-Essen

Knowledge about the host egomotion can help to stabilize and improve many applications in the advanced driver assistance domain. It can be a crucial feature for object tracking and calibration. In this paper we describe a novel approach which is fast to compute and robust. We utilize a depth prior for the translation and integrate robust estimation techniques, like MSAC and an M-estimator. The MSAC is further improved by imposing prior information directly into the MSAC step. We can show that using this scheme is fast and enhances our results. For testing we utilize a large video dataset from which we also have computed the pose estimates via sparse bundle adjustment. Using a loop-closing sequence we also qualitatively analyze our results. The presented approach has been tested online on a car PC and as such can be computed in real time.

11:00-12:25	WePosterAT1.14

Learning-Based Trajectory Generation for Intelligent Vehicles in Urban Environment, pp. 1236-1241

Guo, Chunzhao	Toyota Central R&D Labs., Inc
Kidono, Kiyosumi	Toyota Central R&D Labs., Inc
Ogawa, Masaru	Toyota Central R&D Labs., Inc

Recent technologies of intelligent vehicles are getting more attentions with promising deployment to commercial cars. In this paper, we present a learning-based trajectory generation approach for implementing an ADAS system with the lane keep assist and adaptive cruise control functions in urban environment. More specifically, a number of objects of interest, including the road and lane boundaries, as well as the surrounding vehicles, are detected and tracked. Particularly, the leader vehicle in the host lane, if available, is detected to provide the real-time, on-site and validated information, including both movements and decisions of how it copes with the current traffic situation, which is subsequently learnt by the ego vehicle for the control purposes. By combining the prior and ``live'' information of the road environment, a safe, smooth and reasonable trajectory is finally generated based on a cubic spline model with the Mass-Spring-Damper (MSD) system. Experimental results in various typical but challenging urban traffic scenes have substantiated the effectiveness of the proposed system.

WePosterAT2	Pascal
Poster V: Situation Analysis and Planning (Poster Session)	
Chair: Brennan, Sean	The Pennsylvania State Univ
Co-Chair: Fredriksson, Jonas	Chalmers Univ. of Tech

11:00-12:25	WePosterAT2.1

Combing Task and Motion Planning for Intersection Assistance Systems, pp. 1242-1247

Chen, Chao	Fortiss GmbH
Rickert, Markus	Fortiss GmbH
Knoll, Alois	Tech. Univ. München

A hybrid planning approach is developed for intersection assistance systems up to fully automated driving through intersections. Route planning, task planning and motion planning methods are integrated in a hierarchical planning framework to deal with the various information and constraints in different layers. The navigation agent provides a global driving direction at an intersection according to the selected route. The task planner decides a sequence of actions to accomplish the driving mission taking into consideration traffic rules and semantic conditions. The motion planner generates detailed trajectories to execute the tasks. Meanwhile, the task sequence and the motion trajectory are verified periodically against the actual traffic situation, and re-planning is triggered when necessary in the motion planning or task planning level.

The hierarchical planning framework is evaluated in several intersection scenarios. The result shows that it can handle the complex planning problems with dynamic objects and provide a modular solution for automated driving that can be easily extended for different traffic rules and applications.

11:00-12:25	WePosterAT2.2

Temporal Logic for Finding Undesired Behaviors of Autonomous Vehicles in a State Space Explored by Dynamic Analysis, pp. 1248-1253

Minnerup, Pascal	Fortiss GmbH
Knoll, Alois	Tech. Univ. München

Repeatedly starting and stopping in a parking maneuver is an undesired behavior of an autonomous vehicle, although every single state of it is acceptable. Finding such latent behavior requires to provoke the behavior and to recognize its occurrence. Prior research has shown how to provoke such behavior for complex systems, but concentrated on identifying single undesired states. This paper applies temporal logic to a search graph created by dynamic analysis. This way it directly tests the planning and control software instead of an abstraction that is suited for formal verification. Two approaches, one using NuSMV, the other one using small automata are evaluated and compared. NuSMV offers the power of Computation Tree Logic, while the second approach is fast enough to interactively specify patterns of undesired behavior. The resulting sequences can be replayed in a simulation environment allowing to attach a debugging tool to it.

11:00-12:25	WePosterAT2.3

A Markov Decision Process-Based Approach for Trajectory Planning with Clothoid Tentacles, pp. 1254-1259

Mouhagir, Hafida	Heudiasyc-UTC
Talj, Reine	Univ. De Tech. De Compiègne, Heudiasyc
Cherfaoui, Véronique	Univ. DE Tech. DE COMPIEGNE
Guillemard, Franck	PSA Peugeot Citroen, Velizy, France
Aioun, Francois	PSA Peugeot Citroen, Velizy, France

The work presented in this paper focuses on reactive local trajectory planning which plays an essential role for future autonomous vehicles. The challenge is to avoid obstacles in respect to road rules while following a global reference trajectory. The planning approach used in this work is the method of clothoid tentacles generated in the egocentered reference frame related to the vehicle. Generated tentacles represent feasible trajectories by the vehicle, and in order to choose the right one, we formulate the problem as a Markov Decision Process.

11:00-12:25 WePosterAT2.4

Extracting Path Graphs from Vehicle Trajectories, pp. 1260-1264

Ulbrich, Fritz	Freie Univ. Berlin
Rotter, Simon	Freie Univ. Berlin
Goehring, Daniel	Freie Univ. Berlin
Raul, Rojas	Freie Univ. Berlin

In this paper we present an approach for building a graph of drivable paths from the reconstructed trajectories of vehicles detected by lidar and radar sensors mounted in an autonomous car. The perceived objects are tracked, and their trajectories are merged, clustered and labeled with meta information. A graph of the underlying road infrastructure can be generated with this information. We report on the results of testing the validity and accuracy of the method. The generated path graph can be used either to update high precision maps or for generating local temporary maps, both of them useful for autonomous driving.

11:00-12:25 WePosterAT2.5

A Novel Rear-End Collision Warning System Using Neural Network Ensemble, pp. 1265-1270

An, Jhonhyun	Yonsei Univ
Choi, Baehoon	Yonsei Univ
Hwang, Taehun	Hyundai Mobis
Kim, Euntai	Yonsei Univ

Negligence of a driver or a sudden stop of a forward vehicle can cause rear-end collision. In this paper, we propose a new situation assessment algorithm to determine collision probability to prevent the rear-end collision. The proposed algorithm consists of two phases: coarse assessment and fine assessment. In the coarse assessment, the algorithm selects a target vehicle with the highest possibility of collision by using fuzzy logic. In fine assessment, it determines collision probability based on a statistical approach considering driving maneuvers; it models the driving maneuvers to enable the driver to operate the vehicle in conditions toward the collision and calculates the collision probability as the ratio between the total driving maneuvers and the driving maneuvers in possible collisions. To reduce the simulation time complexity, we adapt a neural network. Since there exist variance of widths for different vehicles, we also apply neural network ensemble to cope with the variance. Numerical evaluation of the proposed method is provided through simulations and practical tests.

11:00-12:25 WePosterAT2.6

Understanding Interactions between Traffic Participants Based on Learned Behaviors, pp. 1271-1278

Kuhnt, Florian	FZI Forschungszentrum Informatik
Schulz, Jens	BMW Group Res. and Tech
Schamm, Thomas	FZI Forschungszentrum Informatik
Zöllner, J. Marius	FZI Res. Center for Information Tech. KIT Karlsruhe In

Predicting vehicles' behaviors in a traffic scene can be very challenging due to many influences. Especially interactions with other traffic participants like vehicles or pedestrians are very crucial for the future movement while they are hard to model even with expert knowledge.

In this paper we propose an object-oriented probabilistic approach that detects interactions between vehicles and is able to infer possible routes of traffic participants. Using the Object-Oriented Probabilistic Relational Modelling Language (OPRML), the interactions between vehicles can be modeled in an intuitive direct way. The probabilistic component allows Bayesian Inference on noisy sensor data and uncertain dependencies, while the object-orientation makes the model flexible to a varying number of traffic participants. Street-dependent as well as interaction-dependent motion models are learned from simulated situations and recordings of real traffic scenes.

Finally, route prediction is evaluated at an exemplary intersection showing how the awareness of interactions reduces route prediction uncertainty and wrong predictions.

11:00-12:25 WePosterAT2.7

Adaptive Vehicle Longitudinal Trajectory Prediction for Automated Highway Driving, pp. 1279-1284

Guo, Chunshi	Renault
Sentouh, Chouki	LAMIH/CNRS Univ. of Valenciennes
Soualmi, Boussaad	IRT Systemx
Haue, Jean-Baptiste	UCSD
Popieul, Jean-Christophe	Univ. De Valenciennes

This paper describes an adaptive vehicle longitudinal trajectory prediction method for automated highway driving applications. A major strength of this method is that it can cope with highly dynamic situations in which the constant acceleration (CA) assumption cannot guarantee long term prediction accuracy. In this method, a quintic polynomial is used to model the longitudinal dynamics of a vehicle that is maneuvering. The decision to switch to it from the CA model is formulated as a maneuver detection problem. A maneuver is detected through monitoring measurement innovations of a Kalman filter that tracks target longitudinal states. The longitudinal jerk, as a dynamic characteristic of a maneuver is also estimated from measurement innovations. Finally the estimated jerk and context information are incorporated into the quintic polynomial model. The overall approach was tested on recorded human driving data from a simulator in a dynamic highway merging scenario. The results show the proposed method has higher prediction accuracy than the CA based method in such a dynamic scenario.

11:00-12:25 WePosterAT2.8

Probability Estimation for Predicted-Occupancy Grids in Vehicle Safety Applications Based on Machine Learning, pp. 1285-1292

Nadarajan, Parthasarathy	Tech. Hochschule Ingolstadt
Botsch, Michael	Tech. Hochschule Ingolstadt

This paper presents a method to predict the evolution of a complex traffic scenario with multiple objects. The current state of the scenario is assumed to be known from sensors and the prediction is taking into account various hypotheses about the behavior of traffic participants. This way, the uncertainties regarding the behavior of traffic participants can be modelled in detail. In the first part of this paper a model-based approach is presented to compute Predicted-Occupancy Grids (POG), which are introduced as a grid-based probabilistic representation of the future scenario hypotheses. However, due to the large number of possible trajectories for each traffic participant, the model-based approach comes with a very high computational load. Thus, a machine-learning approach is adopted for the computation of POGs. This work uses a novel grid-based representation of the current state of the traffic scenario and performs the mapping to POGs. This representation consists of augmented cells in an occupancy grid. The adopted machine-learning approach is based

on the Random Forest algorithm. Simulations of traffic scenarios are performed to compare the machine-learning with the modelbased approach. The results are promising and could enable the real-time computation of POGs for vehicle safety applications. With this detailed modelling of uncertainties, crucial components in vehicle safety systems like criticality estimation and trajectory planning can be improved.

11:00-12:25 WePosterAT2.9

Wiggling through Complex Traffic: Planning Trajectories Constrained by Predictions, pp. 1293-1300

Schlechtriemen, Julian — Daimler AG
Wabersich, Kim Peter — Univ. of Stuttgart
Kuhnert, Klaus-Dieter — Univ. of Siegen, Germany

The vision of autonomous driving is piecewise becoming reality. Still the problem of executing the driving task in a safe and comfortable way in all possible environments, for instance highway, city or rural road scenarios is a challenging task. In this paper we present a novel approach to planning trajectories for autonomous vehicles. Hereby we focus on the problem of planning a trajectory, given a specific behavior option, e.g. merging into a specific gap at a highway entrance or a roundabout. Therefore we explicitly take arbitrary road geometry and prediction information of other traffic participants into account. We extend former contributions in this field by providing a flexible problem description and a trajectory planner without specialization to distinct classes of maneuvers beforehand. Using a carefully chosen representation of the dynamic free space, the method is capable of considering multiple lanes including the predicted dynamics of other traffic participants, while being real-time capable at the same time. The combination of those properties in one general planning method represents the novelty of the proposed method. We demonstrate the capability of our algorithm to plan safe trajectories in simulation and in real traffic in real-time.

11:00-12:25 WePosterAT2.10

Runtime-Bounded Tunable Motion Planning for Autonomous Driving, pp. 1301-1306

Gu, Tianyu — Carnegie Mellon Univ
Dolan, John — Carnegie Mellon Univ
Lee, Jin-Woo — General Motors Res. and Development

Trajectory planning methods for on-road autonomous driving are commonly formulated to optimize a Single Objective calculated by accumulating Multiple Weighted Feature terms (SOMWF). Such formulation typically suffers from the lack of planning tunability. Two main causes are the lack of physical intuition and relative feature prioritization due to the complexity of SOMWF, especially when the number of features is big. This paper addresses this issue by proposing a framework with multiple tunable phases of planning, along with two novel techniques: 1. Iteration-free trajectory smoothing/nudging. 2. Sampling-based trajectory search with cascaded ranking.

11:00-12:25 WePosterAT2.11

The Multilayer Perceptron Approach to Lateral Motion Prediction of Surrounding Vehicles for Autonomous Vehicles, pp. 1307-1312

Yoon, Seungje — KOREA ADVANCED Inst. OF SCIENCE AND Tech. (KAIST)
Kum, Dongsuk — Korea Advanced Inst. of Science & Tech

For safe and reliable autonomous driving systems, prediction of surrounding vehicles' future behavior and potential risks are critical. The state-of-the-art prediction algorithms tend to show limited performance on long-term predictions due to their deterministic nature. In this paper, a probabilistic lateral motion prediction algorithm is proposed based on multilayer perceptron (MLP) approach. The MLP model consists of two parts; target lane and trajectory models. In order to develop an intuitive and accurate prediction algorithm, a lane-based trajectory prediction model is introduced based on the fact that vehicles drive within a lane except for during lane changes. More specifically, a set of three representative trajectories with different levels of lane-change positions are generated for each target lane, and real-world traffic data is categorized by each trajectory for MLP training. These target lane and trajectory models enable the stochastic MLP modeling and training. The proposed MLP model outputs probabilities of how likely a vehicle will follow each trajectory and each lane for a given input of vehicle position history including current position. For training the MLP model, Next Generation Simulation traffic data are used. Simulation results show that the proposed algorithm detects lane-changes one to one and a half second earlier than existing methods and three seconds before lane crossing with about ninety percentages accuracy

11:00-12:25 WePosterAT2.12

Driving Word2vec: Distributed Semantic Vector Representation for Symbolized Naturalistic Driving Data, pp. 1313-1320

Fuchida, Yusuke — Ritsumeikan Univ
Taniguchi, Tadahiro — Ritsumeikan Univ
Takano, Toshiaki — Ritsumeikan Univ
Mori, Takuma — Ritsumeikan Univ
Takenaka, Kazuhito — DENSO Corp
Bando, Takashi — DENSO International America, Inc

This study describes driving word2vec (DW2V), a new method for forming semantic representations of naturalistic driving data (NDD). To use big NDD for developing driver assistance systems or other information services, it is important to compress large amounts of data into an abstract and compact representation without losing semantic information. For this purpose, this study uses a symbolization method using a double articulation analyzer (DAA) assuming that NDD and human speech signals share an analogous structure, called a double articulation structure. The DAA can encode driving behavior data into sequences of driving words. However, the amount of semantic information contained in these sequences has not been clarified. Very few attempts have been made to develop a method for obtaining an adequate semantic representation of driving words that explains the relationship between different driving words. DW2V uses word2vec, proposed by Mikolov et al., to make a system learn the distributed semantic vector representation of symbolized naturalistic driving data (SNDD). Through experiments, we show that DW2V can restore the semantic relationships between different driving scenes from only a set of sequences of driving words, i.e., SNDD. In addition to quantitative analysis, a qualitative analysis of DW2V and its potential applications are discussed.

11:00-12:25 WePosterAT2.13

SMARTcycling: Assessing Cyclists' Driving Experience, pp. 1321-1326

Vieira, Pedro Sousa — Inst. Superior Técnico
Costeira, João P. — IST/UTL
Brandao, Susana — Inst. Superior Tecnico
Marques, Manuel — Inst. Superior Técnico

Due to economic and environmental issues, bicycles have been regaining their significance as a transportation vehicle in urban scenarios. To further drive this desirable trend, policy makers must have the tools to access current bicycle infrastructures and road safety concerns. Fundamental for this assessment is a deeper understanding of how cyclists use current infrastructures, if the cycling experience results in stressful events, and the conditions of the current infrastructure. We here introduce a new platform, SMARTcycling, that, by taking advantage of the mobile power available to a smartphone, captures and stores data from several sensors, namely an action camera, a cardio signal acquisition belt, and smartphone's Global Positioning System (GPS) coordinates. The data is further processed and, through visual cues, we access the cyclist driving events and road condition cues. SMARTcycling also detects the cyclist stress using the electrocardiograms (ECG) from the belt. We further contribute by making available a dataset containing the sensors data from 10 paths over two cities in Portugal. On this dataset, we show our initial promising results on event detection, road condition identification and stress assessment.

WePosterAT3	Conference Hall
Poster V: HMI and Factors & Driver State and Intent (Poster Session)	

Chair: Hammarstrand, Lars	Chalmers Univ. of Tech
Co-Chair: Morris, Brendan	Univ. of Nevada, Las Vegas

11:00-12:25 WePosterAT3.1

Driving Automation & Changed Driver's Task - Effect of Driver-Interfaces on Intervention, pp. 1327-1332

van den Beukel, Arie Paul — Univ. of Twente
van der Voort, Mascha C. — Univ. of Twente

Driving automation leads to a changed role for drivers, i.e. supervision, including now and then intervention – a role that humans are not particularly good at. New driver-vehicle interfaces can support drivers in their changed role. We tested three interface-concepts incorporating different type of stimuli to steer attention and evoke response. This study examined specifically the effects on driver-intervention to avoid collision after automation was terminated. Neither the audio-tactile interface combined with illumination, nor the audio-visual interface, revealed to provide additional intervention-support compared to a base-line audio interface. The results contribute to a better understanding of applying multimodality for developing adequate support and suggest that richer stimuli might negatively influence performance due to startle-responses and/or distraction. Richer stimuli feedback might however be beneficial within the broader spectrum of the changed driver's role (e.g. supervision) – for which further research is planned.

11:00-12:25 WePosterAT3.2

A Brain Signals-Based Interface between Drivers and In-Vehicle Devices, pp. 1333-1337

He, Tenghuan — Beijing Inst. of Tech
Bi, Luzheng — Beijing Inst. of Tech
Lian, Jinling — Beijing Inst. of Tech
Sun, Huafei — Beijing Inst. of Tech

In this paper, we propose a novel interface between drivers and in-vehicle devices by using steady-state visual evoked potential (SSVEP) of brain signals. The SSVEP is recognized by a canonical correlation analysis (CCA) classifier and applied to turn on and turn off in-vehicle devices. The proposed interface is developed and tested online in a driving simulator by requiring drivers to use the interface to interact with the in-vehicle device while performing the primary driving tasks including lane keeping and avoiding obstacle. The pilot experimental results suggest that the proposed interface is feasible.

11:00-12:25 WePosterAT3.3

Discriminative Dictionary Learning Sparse Coding for Person Re-Identification, pp. 1338-1343

Sheng, Hao — Beihang Univ
Zhang, Beichen — Beihang Univ
Huang, Yan — Beihang Univ
Zheng, Yanwei — Beihang Univ
Xiong, Zhang — Beihang Univ

Person re-identification is one of the most important issues in intelligent transportation systems. Recently, the widespread availability of cameras and a growing need for public safety have increasingly motivated interest in the problem of person re-identification in multi-camera networks. The main difficulty of person re-identification arises from the variations in human pose, different viewpoint in multi-camera, cluttered background, occlusion, and low image resolution, which lead person re-identification to a challenging problem. This paper presents a method based on sparse coding for person re-identification. To apply sparse coding method, we firstly solve the problem of aligning person images, and to enhance the discrimination of dictionary, a dictionary learning model is added into our method. Experiments on benchmark dataset (CAVIARa, ETZH, i-LIDS) demonstrate that the proposed method outperforms the state-of-the-art approaches.

11:00-12:25 WePosterAT3.4

Public Perception of V2X-Technology – Evaluation of General Advantages, Disadvantages and Reasons for Data Sharing with Connected Vehicles, pp. 1344-1349

Schmidt, Teresa — RWTH Aachen Univ
Philipsen, Ralf — RWTH Aachen Univ
Themann, Philipp — Inst. Für Kraftfahrzeuge, RWTH Aachen Univ
Ziefle, Martina — RWTH Aachen Univ

This work aims at an evaluation of vehicle-to-infrastructure (V2X)-technology through the users' perspective. The technical opportunities of connected vehicles are affected by the acceptance of the technology and possible draw-backs on the privacy and data-security side. With a three-tiered research approach, this work identified beforehand argument lines in focus group discussions, which enabled a quantitative approach to evaluate positively and negatively perceived features of V2X-technology. Also gender related differences can be displayed. Further, the results of the second quantitative study indicate that although users who already have experience with driver assistance systems are more willing to share (personal) data to use V2X-technology, the overall sample is very reserved with respect to sharing driver-related data. Future research on user diversity and cultural differences is outlined.

11:00-12:25 WePosterAT3.5

Towards Selecting Robust Hand Gestures for Automotive Interfaces, pp. 1350-1357

Gupta, Shalini — NVIDIA
Molchanov, Pavlo — NVIDIA
Yang, Xiaodong — NVIDIA
Kim, Kihwan — NVIDIA Res
Tyree, Stephen — NVIDIA
Kautz, Jan — NVIDIA

Driver distraction is a serious threat to automotive safety. The visual-manual interfaces in cars are a source of distraction for drivers. Automotive touch-less hand gesture-based user interfaces can help to reduce driver distraction and enhance safety and comfort. The choice of hand gestures in automotive interfaces is central to their success and widespread adoption. In this work we evaluate the recognition accuracy of 25 different gestures for state-of-the-art computer vision-based gesture recognition algorithms and for human observers. We show that some gestures are consistently recognized more accurately than others by both vision-based algorithms and humans. We further identify similarities in the hand gesture recognition abilities of vision-based systems and humans. Lastly, by merging pairs of gestures with high miss-classification rates, we propose ten robust hand gestures for automotive interfaces, which are classified with high and equal accuracy by vision-based algorithms.

11:00-12:25 WePosterAT3.6

Take the Wheel: Effects of Available Modalities on Driver Intervention, pp. 1358-1365

Mok, Brian — Stanford Univ
Johns, Mishel — Stanford Univ
Gowda, Nikhil — Renault Innovation Silicon Valley
Sibi, Srinath — Stanford Univ
Ju, Wendy — Stanford Univ

While automated driving systems will become increasingly capable and common in the future, there will still be instances when human drivers want or need to make corrections to the car's automated driving behavior. We conducted two studies exploring how driving interfaces could be designed to better execute the drivers' intentions. In our first study, adult participants (N=40) experienced a simulated driving scenario that varied the behavior of the car's automation (perfect driving and imperfect driving) and the intervention modalities (takeover and takeover+influence). At certain segments, the car's automation would drive perfectly or

weave within the lane. During those times, participants could intervene using the available modalities. When experiencing instances of imperfect driving, drivers who had the ability to takeover+influence intervened more often than drivers who were only given the option to takeover. As intervening would require them to resume full control, drivers in the takeover condition were more tolerant of the imperfect driving. Also, most drivers tried to intervene initially by influencing the car, even those drivers who were only given the ability to takeover. In our second study, we examined how participants (N=40) of different demographics (high school students and seniors) would respond when they were subjected to the imperfect driving scenarios. High school drivers intervened just as much as the adult drivers. However, senior drivers intervened far less. These two studies suggest that when intervention is necessary, human drivers have a desire for shared control, which allows them to act as supervisors rather than operators of automated vehicles.

11:00-12:25 WePosterAT3.7

Enhancing Telepresence During the Teleoperation of Road Vehicles Using HMD-Based Mixed Reality, pp. 1366-1373

Hosseini, Amin — Tech. Univ. of Munich
Lienkamp, Markus — Tech. Univ. München

A lack of telepresence is one of the main challenges of vehicle teleoperation, which degrades the task performance of the human operator. This paper introduces a novel human-machine interface (HMI) using a head-mounted display (HMD) to improve the situation awareness and, consequently, the telepresence of the human operator. The proposed HMI concept uses the transmitted data of the camera as well as LiDAR sensors of the remote vehicle to illustrate the 360° vehicle surroundings as a mixture of the real and virtual environments to the human operator. The resulting system provides the possibility to precisely control the remote vehicle with a low additional load to the transmitted data. The developed concept is evaluated by experienced operators within different test scenarios. The results of the test drives show a significant improvement of the task performance as well as a reduction of the workload of the human operators using the proposed HMI concept during control of the teleoperated vehicle.

11:00-12:25 WePosterAT3.8

Validation of a HMI Concept Indicating the Status of the Traffic Light Signal in the Context of Automated Driving in Urban Environment, pp. 1374-1379

Kettwich, Carmen — German Aerospace Centre (DLR)
Haus, Raphael — Mobfish GmbH
Temme, Gerald — Organisation
Schieben, Anna — Senior Res

Vehicle-to-infrastructure communication in combination with vehicle automation opens up new vistas to improve traffic flow efficiency at signalised intersections. Manoeuvres of automated vehicles can be adjusted according to information on the traffic light signal status and its phase change. However, even when driving automated the driver on-board needs to be informed about planned manoeuvres. This paper describes a study on evaluating a human-machine interface (HMI) concept that offers information about the traffic light signal status while approaching an intersection with activated longitudinal vehicle automation. Three different HMI concepts are visualised and evaluated that should help the driver to comprehend the selected manoeuvres of the automated vehicle. Based on the results of the usability study the final HMI concept is presented.

11:00-12:25 WePosterAT3.9

Correlation between Subjective Driver State Measures and Psychophysiological and Vehicular Data in Simulated Driving, pp. 1380-1385

Schmidt, Elisabeth — Bmw Ag
Decke, Ralf — BMW Forschung Und Tech
Rasshofer, Ralph — BMW Forschung Und Tech. GmbH

Advanced driver assistance systems require better knowledge of the driver's state. This would allow for adapting driving support functions, e.g. adaptive automation. To detect the emotional and cognitive state of the driver, it is necessary to know which signals contain accurate information about the state. In this paper the results of a driving simulator study, in which different emotional and cognitive states were induced in 46 subjects via traffic scenarios, are presented. In the study, psychophysiological and vehicular data was measured in addition to subjective state estimations of the subjects. A correlation analysis confirmed that physiological data can potentially predict subjective driver states.

11:00-12:25 WePosterAT3.10

Driver State Estimation for Prediction of Vehicle States within Control Systems, pp. 1386-1391

Fünfgeld, Sebastian — Dr. Ing. H.c. F. Porsche AG
Holzaepfel, Marc — Dr. Ing. H.c. F. Porsche AG
Frey, Michael — Karlsruhe Inst. of Tech. Inst. of Vehicle System T
Gauterin, Frank — Inst. of Vehicle System Tech. Karlsruhe Inst. Te

In this paper we present an online learning approach to predict driver behavior and resulting vehicle states. The driver is represented by driver states x and a control function fc. Kernel Density Estimation is used for online estimation of current driver states. Data sampling methods are introduced to observe the virtual driver states. The driver states are used as input for the control function to predict resulting vehicle states. To consider environmental influence on driver behavior a context-separated learning approach is presented. The system is tested with real drive test data from different drivers on a specified test route. Different settings regarding learning speed and type of context-separation are investigated. Results show, that consideration of environmental influences on the driver states lead to a better identification of the current behavior but prediction on a longer time horizon does not necessarily improve correspondingly.

11:00-12:25 WePosterAT3.11

Towards Hybrid Driver State Monitoring: Review, Future Perspectives and the Role of Consumer Electronics, pp. 1392-1397

Melnicuk, Vadim — Univ. of Warwick
Birrell, Stewart — Univ. of Warwick
Crundall, Elizabeth — Bright Eyes Scientific Services
Jennings, Paul — WMG, Univ. of Warwick

The purpose of this paper is to bring together multiple literature sources which present innovative methodologies for the assessment of driver state, driving context and performance by means of technology within a vehicle and consumer electronic devices. It also provides an overview of ongoing research and trends in the area of driver state monitoring. As part of this review a model of a hybrid driver state monitoring system is proposed. The model incorporates technology within a vehicle and multiple brought-in devices for enhanced validity and reliability of recorded data. Additionally, the model draws upon requirement of data fusion in order to generate unified driver state indicator(-s) that could be used to modify in-vehicle information and safety systems hence, make them driver state adaptable. Such modification could help to reach optimal driving performance in a particular driving situation. To conclude, we discuss the advantages of integrating hybrid driver state monitoring system into a vehicle and suggest future areas of research.

11:00-12:25 WePosterAT3.12

Fusion of Driver-Information Based Driver Status Recognition for Co-Pilot System, pp. 1398-1403

Kim, Jinwoo — ETRI
Kim, Ki Tae — Univ. of Science and Tech

This paper presents a driver status recognition method based on data fusion that changes the autonomous driving mode in our co-pilot system. Our research has the following two novelties: first, the fusion of information-based driver-status recognition between a direct method using the states of the driver's face and eyes and an indirect method of recognition based on the driver's driving

patterns using vehicle information; and second, the ability to transfer from the driving mode to an autonomous mode through fusion of the information of the two methods. Four parameters are calculated in the fusion of these direct and indirect methods: the percent of eye closure, gaze direction, steering wheel angle, and vehicle speed. These parameters are combined to infer the level of drowsiness and attention dispersion of the driver. The system was tested under different circumstances for day and night driving conditions using different driving scenarios on a roadway. Our driver status recognition method utilized a smart device connected to our prototype autonomous vehicle.

11:00-12:25 WePosterAT3.13

Comparing Datasets for Generalizing Models of Driver Intent in Dynamic Environments, pp. 1404-1409

Driggs-Campbell, Katherine Univ. of California, Berkeley
Bajcsy, Ruzena Univ. of California, Berkeley

In light of growing attention of intelligent vehicle systems, we have present an assessment of methods for driver models that predict driver behaviors. This work looks at varying datasets to see the affects on intent detection algorithms. The motivation is to understand and assess how data is mapped from datasets to discrete states or modes of intent. Using a model of a human driver's decision making process to estimate intent, we build techniques for analyzing and learning human behaviors to improve understanding. We derive models based off of human perception and interaction with the environment (e.g. other vehicles on the road), that is generalizable and flexible enough to detect intent across different drivers. The resulting detection scheme is able to determine driver intent with high accuracy across multiple drivers, relying on a large dataset consisting of lane changes under varying environmental constraints. By comparing different labeling methods, we assess the effectiveness of learned models under different class variations. This allows us to derive accurate and general models for detecting intent that rely on the subtle variations and behaviors that humans exhibit while driving.

11:00-12:25 WePosterAT3.14

The Rhythms of Head, Eyes and Hands at Intersections, pp. 1410-1415

Martin, Sujitha Univ. of California, San Diego
Rangesh, Akshay Univ. of California, San Diego
Ohn-Bar, Eshed Univ. of California San Diego
Trivedi, Mohan M. Univ. of California at San Diego

In this paper, we study the complex coordination of head, eyes and hands as the driver approaches a stop-controlled intersection. The proposed framework is made up of three major parts. The first part is the naturalistic driving dataset collection: synchronized capture of sensors looking-in and looking-out, multiple drivers driving in urban environment, and segmenting events at stop-controlled intersections. The second part is extracting reliable features from purely vision sensors looking in at the driver: eye movements, head pose and hand location respective to the wheel. The third part is in the design of appropriate temporal features for capturing coordination. A random forest algorithm is employed for studying relevance and understanding the temporal evolution of head, eye, and hand cues. Using 24 different events (from 5 drivers resulting in 12200 frames analyzed) of three different maneuvers at stop-controlled intersections, we found that preparatory motions range in the order of a few seconds to a few milliseconds, depending on the modality (i.e. eyes, head, hand), before the event occurs.

Closing Conference Hall

Closing Session (Plenary Session)

12:25-12:40

Closing Speeches

Nilsson-Ehle, Anna SAFER
Sjoberg, Jonas Chalmers Univ

AUTHOR INDEX

KEYWORD INDEX

Photo: Dick Gillberg

CONFERENCE INFORMATION

Conference Venue

The IV'16 conference is being held at Lindholmen Conference Centre, located in Lindholmen Science Park – Gothenburg's most knowledge-intensive and growing area. Organizations located in Lindholmen Science Park are Volvo Group, Volvo Cars, SAFER, Chalmers, University of Gothenburg, Ericsson, VTI, and many more.

Address: Lindholmen Conference Centre, Lindholmspiren 3-5, Gothenburg, Sweden.

Visitors Centre: Phone number +46 31 764 70 00

Nearest bus stop: Lindholmen or Lindholmsplatsen

Nearest ferry stop: Lindholmspiren

Website: www.lindholmen.se
www.chalmerskonferens.se/en/

Registration & badges

Pick up your name badge at the Registration desk at Lindholmen Conference Centre, which is open on Sunday June 19 at 08:30-18:00 and Monday June 20 from 07:45. Please wear your badge during the conference and the social events. This is your ticket for the events and also for the catering during the conference.

Lunch and coffee breaks

Lunch and coffee/tea are served in the mingle/exhibition area outside the main conference room Lindholmen Conference hall.

Internet access – Wifi

Wireless internet is available in all areas at the conference venue. Please note that there is different network on the ground floor and 2nd floor.

Login

Lindholmen Conference Centre, ground floor

Network: Chsrab-C

Password: ChalmersKonferens

Open Arena Lindholmen, 2nd floor:

Network: LSPOpen

User: Lindholmen

Password: visitor

Exhibition

The exhibition is located in the mingle area and outdoor. Please visit our sponsor's and exhibitor's booths in the breaks.

Best Paper Awards

In three categories, Best Paper Awards, first and second prize, will distinguished.

Best Paper Award – First Prize
Best Paper Award – Second Prize

Best Poster Award – First Prize
Best Poster Award – Second Prize

Best PhD Paper Award – First Prize
Best PhD Paper Award – Second Prize

Proceedings

Proceedings are available on the USB stick in the conference bag you received at the registration desk.

Download the conference app

In the conference app you find a lot of useful information such as the program, abstracts, papers, sponsors & exhibitors, floor plans and much more. There is also a very good networking function available for you to connect with other delegates and you can make your personal program!

To download the app:
Search for IV2016 in App Store or Google Play depending on our device.

Social Media

Follow the IV16 conference in social media and get instant updates of what is happening at the conference!

Twitter: #IEEEIV16

WELCOME RECEPTION

Date: Sunday June 19, 2016

Time: 18:30–20:00

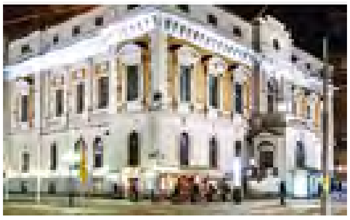
Place: Valand, Vasagatan 41, Gothenburg

Fee: The Welcome Reception is hosted by the City of Gothenburg and free of charge (pre-registration is mandatory)

Nearest bus/tram stop: Valand

The City of Gothenburg has the pleasure to invite you to attend the Welcome reception. Lord Mayor Lena Malm will welcome you to the city of Gothenburg and you will find ample opportunity to meet old friends and make new acquaintances.

The Welcome reception will take place at Valand, a grandiose house dating from 1886. The house is located in the middle of the city at the parade street Avenyn.
The Welcome reception includes a mingle plate with food and wine. Pre-registration is mandatory.



City of Gothenburg

CONFERENCE BANQUET

Date: Tuesday June 21, 2016

Time: 19:30–23:00

Place: Maskingatan 10, Gothenburg

Fee: Included in the registration fee (pre-registration is mandatory)

Accompanying person: Welcome Reception and Conference Banquet SEK 1000, incl VAT

Transport: Sightseeing boats will take you there after a 1,15 hr trip through the city (optional). Gathering outside of Radisson Hotel at 18:00. A ferry will take you back to Lindholmen and the city centre, leaving at 23:00 and 23:40. Alternative is to use public transport (bus) at any time.

Nearest bus stop: Eriksbergstorget

Nearest ferry stop: Eriksbergs färjeläge

Eriksbergshallen once housed the shipbuilding company Eriksbergs Mekaniska Verkstad, and is located right next to Quality Hotel 11, with views of the river at Gothenburg's Norra Älvstranden district.
On the way to the banquet you will experience Gothenburg by sea in sightseeing boats "Paddan" for 1,15 hrs (optional). Return to the city centre after the banquet with chartered ferry or by public transport (bus).

The Conference Banquet includes a 3 course dinner including beverages.

STUDENT ACTIVITY

Volvo Networking Event for students at the Volvo Museum with food and drinks – courtesy of Volvo Group and Volvo Cars.

Date: Monday June 20, 2016

Time: 18:00 –21:00

Place: Volvo Museum, Gothenburg

Fee: Included in the full registration fee. Limited seating (pre-registration is mandatory)

Transport: Buses will take you there and back.
Gathering: In front of Lindholmen Conference Centre at 18:00.

In a historical Volvo environment you have the opportunity to meet the people behind the technology of Volvo's intelligent vehicle systems and learn more about Volvo Group and Volvo Cars. How does Volvo work to increase the safety in and around the vehicles? What can be expected of the Volvo's of the future? These and many other questions will be answered on this evening.

Buses will pick you up after the day program at Lindholmen Conference Center has ended and also take you back after the event. Exact timings for transfers and for the event will be presented closer to the event.

Please note that there are limited seating and a separate confirmation will be e-mailed to you closer to the event. Students have priority, leftover seats will be drawn to other interested. Please indicate in the registration if you are interested in the activity and IV16 will contact you if you have a seat or not.

TECHNICAL DEMOS AT ASTAZERO

IV'16 will end with demos at AstaZero on the afternoon of Wednesday June 22. The latest technology in e.g. active safety and autonomous driving is demonstrated.

Date: Wednesday June 22, 2016

Time: 13:00-17:15

Place: AstaZero Active Safety Test Area, Hällered

Fee: Included in the registration fee (pre-registration is mandatory)

Transportation: Buses will take you there and back, either to Lindholmen Conference Centre, or to Landvetter Airport, arriving at 17:15.

Gathering: In front of Lindholmen Conference Centre. Lunch will be provided on the bus.

ASTAZERO
ACTIVE SAFETY TEST AREA

GOTHENBURG INFORMATION

From/To Landvetter Airport (GOT)
Airport busses "Flygbussarna Airport Coaches" depart from Landvetter Airport every 15-20 minutes. It takes 30 minutes to/from the central station "Nils Ericson Terminalen". The fee is SEK 105 single, SEK 195 return, and tickets can be bought on the bus with credit card.

For tickets and timetable visit the website:
www.flygbussarna.se

Airport taxi costs approximately SEK 450.
Ask for fixed price.

Public transportation
The Lindholmen Conference Centre is located at Lindholmen. Bus No. 16, 31, 55, 99 and Gul Express stop here. You can buy tickets in most convenience stores such as Pressbyrån, 7-eleven etc. No payment is possible on the buses.

For information and travel planner visit the website:
www.vasttrafik.se

Taxi
There are several companies to choose from. You can phone for a taxi or hail one on the street. The driver should have a taxi ID card clearly displayed in the vehicle. Service is included in the taximeter price. Avoid unlicensed taxis.

Taxi Göteborg: +46 (0)31-650 000
Taxi Kurir: +46 (0)31-27 27 27

All major credits cards are accepted. If you go to/from Landvetter Airport, ask for the fixed price rate.

Bike rental: Styr & Ställ
Gothenburg is a bike friendly city. Throughout the city you will find bike stands with rental bikes. For only SEK 75 you can rent a bicycle as often as you wish. The first half hour of each journey is always free, regardless of the number of journeys per day. Short time visitors can choose the 3-Day Pass, which can be purchased from any of the credit card terminals for just SEK 25. It is also included in the Göteborg City Card.

More information: www.goteborgbikes.se

Göteborg City Card
Göteborg City Card gives you free admission to lots of entertainment, sights, excursion, Liseberg amusement park and many museums. Parking and travel with trams, buses and boats are included. You'll also get shopping booklets with discounts in selected stores. Maximise your stay in Gothenburg. The card is valid for 24, 48 or 72 h.

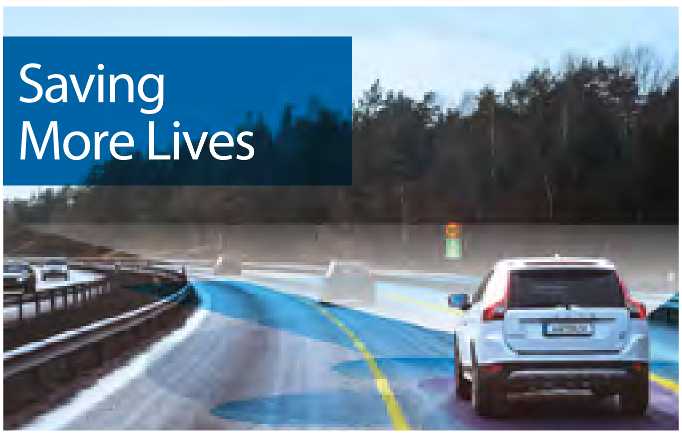
More information: www.goteborg.com/citycard

NOTES

Welcome to experience a live demonstration June, 22 at Asta Zero

V2V, EEBL – Emergency Electronic Brake Lights system

By letting vehicles communicate with each other, many accidents can be avoided.
Autoliv in cooperation with Kapsch, will demonstrate how queue crashes caused by hard braking could be avoided.



Autoliv


VOLVO
GREAT MINDS DON'T THINK ALIKE
Who builds the best cars?
The Germans? The Americans? The Italians? The Koreans?
Or is it the Swedes?
Truth is, it's none of those. It's all of them.
Together. Ever since the 50's we've brought
people here from all over the world to develop
and build our cars. Not because we're a caring and
human company, but because we know it makes
us better. Diversity sparks creativity. It pushes
innovation. It helps us to build safer and smarter
cars, designed around peoples everyday life. So if
you ever wondered who makes the best cars,
you know now.
It´s people.
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