IV2015

2015 IEEE Intelligent Vehicles Symposium

Final Program

June 28 – July 1, 2015
COEX, Seoul, Korea
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Welcome Message from General Chairs

As representatives of the Organizing Committee, we wholeheartedly welcome everyone attending to the 2015 IEEE Intelligent Vehicles Symposium at COEX, Seoul, Korea. As this premier conference grew 26 years, the idea of intelligent vehicles has become to play one of pivotal roles in facing transportation challenges such as safety, sustainability and effectiveness to name a few. We firmly believe that the contributions from scientific and industrial participants provided valuable foundations of the growth. Hence, it has a special meaning for us to accommodate the Intelligent Vehicles Symposium in Korea for the first time ever.

The host city, Seoul has been the capital of Korea since 1394 when the Chosun Dynasty designated it as the new national capital. During your visit, you will be able to observe multiple facets of Seoul such as mountains & rivers, natural & human-creations, traditional & contemporary developments, and, especially, public & private measures of transportations. This could be particularly interesting because Seoul is now 4th in the world in population densely and 15th in population, globally. Also Seoul houses headquarters and facilities for research, development and manufacturing of major Korean manufacturers related to intelligent vehicle technologies. For the international participants, the Inchon International Airport would serve as the primary portal to Seoul and COEX, the symposium venue, can be reached via motor vehicles or railroad.

We would like to thank the Organizing committee who tirelessly put their efforts for the Symposium. Special thanks to Prof. Chung Choo Chung, Prof. Alberto Broggi, and Dr. Masao Nagai and International Program Committee for their efforts on reviewing more than 340 submitted papers for the oral and poster sessions in parallel with plenary lectures and a special session on the autonomous vehicle technologies. Also, thanks to Prof. In-Soo Suh for arranging six workshops that will be held on June 28th prior to the main symposium. We expect more than three hundred participants from various countries of the world to seek solutions to the present and future transportation challenges. We hope discussions and interconnections made during the sessions, welcome reception, and banquet could help finding the breakthroughs. We also appreciate generous support from the Korean automotive industry, academia, and the governments. Lastly, we would like to thank our support staffs including the student volunteers.

We hope your safe and comfortable trip and wish you have a good time during your stay in Korea.

Kyongsu Yi and Seung-Woo Seo
General Chairs
As the International Program Committee (IPC) Chairs of IEEE IV2015, we are very pleased to welcome you to the symposium in Seoul, Korea. The Program Committee has organized a single-track technical program which is a three-day symposium bringing together researchers and practitioners to present the current state-of-the-art and progress in research and development of intelligent vehicles.

Overall, 226 papers were accepted based on the evaluation of the international program committee. The technical program is constituted by 6 oral sessions, 1 special session, and 5 poster sessions. In addition to the three day sessions, there are six workshops. Sessions focus on all aspects of intelligent vehicles e.g., Advanced Driver Assistance Systems, Autonomous/Intelligent Robotic Vehicles, Collision Avoidance, Image, Radar, Lidar Signal Processing, Vehicle Control, Vehicle Environment Perception, Cooperative Vehicle Highway System, Active and Passive Safety, etc. The technical program is enriched with three plenary sessions. We have invited four plenary speakers for three plenary sessions. Two distinguished speakers are from academia: Prof. Bart van Arem from Delft University of Technology, Netherlands, and Prof. Ryan Eustice, Dept. of Naval Architecture and Marine Engineering, University of Michigan, USA. And the other two plenary speakers are from industry and government, respectively: Mr. Yong-Seog Park, Director General for Motor Vehicle Policy Bureau, Ministry of Land, Infrastructure and Transport, Korea, and Mr. Dongil Park, Vice President, Hyundai Motor Company, Korea. This year, we organized one special session on Autonomous Driving Vehicles. Five distinguished speakers are invited to share their experience and wisdom in Autonomous Driving Vehicles: Prof. J. Christian Gerdes, Stanford University, USA, Dr. Philipp Bender, FZI Forschungszentrum Informatik, Germany, Dr. Danil Prokhorov, Toyota Research Institute, USA, Prof. Seung-Woo Seo and Prof. Kyungsu Yi, Seoul National University, Korea.

We would like to thank everyone who contributed to the IV2015 program for their enthusiastic involvement and substantial efforts. I gratefully acknowledge my colleagues of the International Program Committee (the associate editors) and the reviewers for their reading and evaluation of the papers. Without help of Prof. In-Soo Suh and contribution of workshop organizers, the six workshops would not be possible. Many thanks to the General Chairs, Prof. Kyungsu Yi and Prof. Seung-Woo Seo for their continuous support and suggestions since the very beginning of IV2015 symposium. A special word of thanks goes to Pradeep Misra for providing prompt technical support with very kind help.

We hope that this premier annual symposium will provide you the opportunity to extend your knowledge, your networking and your ideas along many fruitful research and development discussions. Enjoy your stay in Seoul, the heart of K-POP and the 26th year of IEEE Intelligent Vehicles Symposium.
Organizing Committee

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   Seung-Woo Seo (Seoul National University)

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   Jae Kwan Lee (KATECH)

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Dominique Gruyer (IFSTTAR)
Pujitha Gunaratne (Toyota Research Institute North America)
Chunzhao Guo (Toyota Central R&D Labs., Inc.)
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Nazli E. Kahveci (Middle East Technical University)
Shiho Kim (Yonsei University)
Whoi-Yul Kim (Hanyang University)
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Kyoungchul Kong (Sogang University)
Dongsuk Kum (KAIST)
Jean-Philippe Lauffenburger (Université de Haute-Alsace)
Kwangwon Lee (Korea Polytechnic University)
Lingxi Li (Indiana University-Purdue University Indianapolis)
Yiting Liu (The Ohio State University)
Seiichi Mita (Toyota Technological Institute)
Reza Monir Vaghefi (Virginia Tech)
Fawzi Nashashibi (INRIA)
Eduardo Nebot (ACFR University of Sydney)
Sergiu Nedevschi (Technical University of Cluj-Napoca)
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Ufuk A Peker (Infotech Inc.)
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Danil Prokhorov (Toyota Research Institute North America)
Jonas Sjoberg (Chalmers University)
Kazuya Takeda (Nagoya University)
Rafael Toledo-Moreo (Universidad Politécnica de Cartagena)
Mohan M. Trivedi (University of California at San Diego)
Ljubo Vlacic (Griffith University)
Toshihiro Wakita (Toyota Central R&D Labs., Inc.)
Jianqiang Wang (Tsinghua University)
Denis Wolf (University of Sao Paulo)
Keiichi Yamada (Meijo University)
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Seongjin Yim (Seoul National University of Science and Technology)
Fenghua Zhu (Chinese Academy of Sciences)
J. Marius Zöllner (FZI Forschungszentrum Informatik)
# Program at a Glance

## Sunday, June 28, 2015

<table>
<thead>
<tr>
<th>Time</th>
<th>Room</th>
<th>E1 (3F)</th>
<th>E2 (3F)</th>
<th>E3 (3F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00-18:00</td>
<td></td>
<td>Registration (Lobby, 3F)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09:00-12:00</td>
<td>NDD</td>
<td>2nd Workshop on Naturalistic Driving Data Analytics</td>
<td>Workshop on Environment Perception for Automated On-road Vehicles</td>
<td>2nd Workshop on Benchmarking Road Terrain and Lane Detection Algorithms for In-Vehicle Application</td>
</tr>
<tr>
<td>18:00-20:00</td>
<td></td>
<td>Welcome Reception (E6, 3F)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Coffee breaks: 10:30-10:45 / 14:30-14:45

## Monday, June 29, 2015

<table>
<thead>
<tr>
<th>Time</th>
<th>Room</th>
<th>E1+2+3 (3F)</th>
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</thead>
<tbody>
<tr>
<td>08:00-18:00</td>
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<td>Registration (Lobby, 3F)</td>
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<tr>
<td>10:00-18:00</td>
<td></td>
<td>Exhibition (Lobby, 3F)</td>
</tr>
<tr>
<td>08:30-08:50</td>
<td></td>
<td>Opening Ceremony</td>
</tr>
<tr>
<td>08:50-09:50</td>
<td></td>
<td>Plenary 1 MoPLT1 Automated Driving: the Future of Transport starts today! Bart van Arem</td>
</tr>
<tr>
<td>09:50-10:50</td>
<td></td>
<td>Regular Session MoOrAT1 Collision Avoidance</td>
</tr>
<tr>
<td>10:50-12:30</td>
<td></td>
<td>Poster Session 1 MoPoAT1 (E4, 3F)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&amp; Coffee Break</td>
</tr>
<tr>
<td>12:30-14:00</td>
<td></td>
<td>Lunch</td>
</tr>
<tr>
<td>14:00-15:20</td>
<td></td>
<td>Regular Session MoOrMT1 Vehicle Control</td>
</tr>
<tr>
<td>15:20-17:00</td>
<td></td>
<td>Poster Session 2 MoPoPT1 (E4, 3F)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&amp; Coffee Break</td>
</tr>
<tr>
<td>17:00-18:20</td>
<td></td>
<td>Regular Session MoOrPT1 Vehicle Environment Perception</td>
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### Tuesday, June 30, 2015

<table>
<thead>
<tr>
<th>Time</th>
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<tbody>
<tr>
<td>08:00-18:30</td>
<td>Registration (Lobby, 3F)</td>
</tr>
<tr>
<td>10:00-18:30</td>
<td>Exhibition (Lobby, 3F)</td>
</tr>
<tr>
<td>08:30-09:00</td>
<td><strong>Plenary 2 TuPLT1</strong>&lt;br&gt;The Policy for Autonomous Driving Vehicle&lt;br&gt;Yong-Seog Kim</td>
</tr>
<tr>
<td>09:00-09:30</td>
<td><strong>Plenary 3 TuPLT1</strong>&lt;br&gt;Hyundai Motor's View on Automotive Electronics for Human Caring&lt;br&gt;Dongil Park</td>
</tr>
<tr>
<td>09:30-10:50</td>
<td>Regular Session TuOrAT1&lt;br&gt;Image, Radar, Lidar Signal Processing</td>
</tr>
<tr>
<td>10:50-12:30</td>
<td>Poster Session 3 TuPoAT1 (E4, 3F) &amp; Coffee Break</td>
</tr>
<tr>
<td>12:30-14:00</td>
<td>Lunch</td>
</tr>
<tr>
<td>14:00-16:00</td>
<td>Special Session TuSST1&lt;br&gt;Autonomous Driving Vehicles</td>
</tr>
<tr>
<td>16:00-17:40</td>
<td>Poster Session 4 TuPoPT1 (E4, 3F) &amp; Coffee Break</td>
</tr>
<tr>
<td>18:30-20:30</td>
<td>Banquet (E5+6, 3F)</td>
</tr>
</tbody>
</table>

* Demonstration (COEX east gate square, 1F): 10:50-12:30 / 16:00-17:40

### Wednesday, July 1, 2015

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>08:00-15:00</td>
<td>Registration (Lobby, 3F)</td>
</tr>
<tr>
<td>10:00-15:00</td>
<td>Exhibition (Lobby, 3F)</td>
</tr>
<tr>
<td>08:30-09:30</td>
<td><strong>Plenary 4 WePL1</strong>&lt;br&gt;University of Michigan’s Work toward Autonomous Cars&lt;br&gt;Ryan Eustice</td>
</tr>
<tr>
<td>09:30-10:50</td>
<td>Regular Session WeOrA1&lt;br&gt;Advanced Driver Assistance Systems</td>
</tr>
<tr>
<td>10:50-12:30</td>
<td>Poster Session 5 WePoA1 (E4, 3F) &amp; Coffee Break</td>
</tr>
<tr>
<td>12:30-14:00</td>
<td>Lunch</td>
</tr>
<tr>
<td>14:00-15:20</td>
<td>Regular Session WeOrM1&lt;br&gt;Autonomous / Intelligent Robotic Vehicles</td>
</tr>
</tbody>
</table>
Floor Map

IV2015 will be held at Hall E Area (3F).
Floor Map (cont.)

Hall E Area (3F)

<table>
<thead>
<tr>
<th>Room</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1</td>
<td>Workshop</td>
</tr>
<tr>
<td>E2</td>
<td>Workshop</td>
</tr>
<tr>
<td>E3</td>
<td>Workshop</td>
</tr>
<tr>
<td>E4</td>
<td>Poster Session</td>
</tr>
<tr>
<td>E5</td>
<td>Welcome Reception</td>
</tr>
<tr>
<td>E6</td>
<td>Banquet</td>
</tr>
<tr>
<td>E8</td>
<td>Secretariat</td>
</tr>
<tr>
<td>Lobby</td>
<td>Exhibition Registration Desk</td>
</tr>
</tbody>
</table>
**General Information**

**Official Language**
The official language of the conference is English.

**Registration Desk**
The registration desk on the main lobby (3F) in the venue will be open as follow:
- Sunday, June 28, 2015 08:00-18:00
- Monday, June 29, 2015 08:00-18:00
- Tuesday, June 30, 2015 08:00-18:30
- Wednesday, July 1, 2015 08:00-15:00

**Wireless Internet Access**
Wireless internet access will be available free of charge for all participants in COEX (venue). Those wishing to use this wireless network are required to use their own laptops equipped with wireless LAN card.

**Social Events**

**Welcome Reception**
**Date:** Sunday, June 28, 2015  
**Time:** 18:00 -20:00  
**Place:** E6 (3F)

The welcome reception will be held at Hall E6 (3F) in the COEX. An invitation to the welcome reception is extended to the regular and student registrants.

**Banquet**
**Date:** Tuesday, June 30, 2015  
**Time:** 18:30 -20:30  
**Place:** E5+6 (3F)

We hope this banquet will offer you a good opportunity to promote friendship with participants. Delicious food and Korean traditional performance will be offered at the banquet. An invitation to the banquet is extended to the regular and student registrants.
Guidelines for Presentation

Oral Presentation
Oral session room is equipped with LCD projector and Windows Laptop, with PowerPoint and Acrobat PDF reader. Please make your best to use the room laptop and upload your PPT file on it before the beginning of the session. If you really need to use your laptop (only in the case you need special software for your presentation or in case of major compatibility problems), check the connection with the projector before the session starts. Notice: time lost in setting up your laptop during the session cannot be recovered: this will end up in a shorter time available for yours presentation. Greet/meet the session chair before the session starts. Please arrive early enough, to find out the session chair and to tell him/her your name, affiliation and the title of your paper. The presentation time is 20 minutes. This includes speaker transition, the setting of your computer (if needed), and question & answers. So each speaker should finish his/her talk within 15 or 16 minutes to have a time for question & answers.

Poster Presentation
Presenters are also responsible for mounting their own poster to the poster board prior to the opening of the poster session. All presenters must remain by their poster during the poster session.

A. Poster Specification
Posters must be designed to fit a 90cm wide x 130cm tall board. Posters may be prepared as a single poster or as several smaller sections (using A4 or letter sized papers) mounted together. The heading of the poster should list the paper title, author(s) name(s), and affiliation(s). The content of the poster should include introduction, related work, proposal, development/experimental results, and conclusion.

B. Poster Setup and Removal
Posters may be attached to the boards by push pins, which will be provided on site. Posters must be set up by presenter at least 10 minutes before the poster session starts. Posters must be taken down by presenter right after the poster session is over. Posters not removed by 10 minutes after the session is over will be removed by staff.

Exhibitions
Dates: Monday, June 29, 2015 ~ Wednesday, July 1, 2015
Time: 10:00am~18:00pm
Place: Lobby (3F)

MDS Technology
http://www.mdstec.com/en

FORUM8 KOREA
http://www.forum8.co.jp/english
Autonomous Vehicle Demonstrations

Date: Tuesday, June 30, 2015
Time: 10:50~12:30 & 16:00~17:40 (during poster sessions)
Location: COEX east gate square (1F)

This exhibition presents five autonomous vehicles, developed by Hyundai/KIA Motor Company (HMC), MOBIS, Electronics and Telecommunications Research Institute (ETRI), Seoul National University (SNU), and Hanyang University respectively. The exhibition includes autonomous vehicles, demo video, and posters that present key functions and features of the presented vehicles. Vehicle model, sensors, and key functions of the presented autonomous vehicles are summarized as follows.

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Developer</th>
<th>Make/Model</th>
<th>Sensors</th>
<th>Key Functions and Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV-1</td>
<td>HMC/MBIS</td>
<td>HMC Sonata LF</td>
<td>2D Lidar, Front Radar, Rear-side Radar, Front Camera, V2X Device, GPS</td>
<td>Lane Keeping, Car-following, Emergency Brake, V2X-based traffic Information and Warning</td>
</tr>
<tr>
<td>Co-Pilot System</td>
<td>ETRI</td>
<td>KIA Sorento</td>
<td>3D Lidar (360 deg), 2D Lidar, 77GHz Front Radar, Camera</td>
<td>High-speed autonomous Drive (Path Tracking, Lane Change, Overtaking), Driver/System Cooperative Drive (Drowsiness Detection and Autonomous Switching, Emergency Shoulder Induction)</td>
</tr>
<tr>
<td>SNU Automated Drive</td>
<td>SNU VIL Lab</td>
<td>HMC Genesis</td>
<td>3D Lidar, Camera</td>
<td>High-precision Map Based Autonomous Drive, Lane Keeping, Automated Emergency Brake, Autonomous Urban Driving</td>
</tr>
<tr>
<td>ADV-3</td>
<td>SNU VDC Lab</td>
<td>KIA K7</td>
<td>Automobile-grade Front Radar, Rear-side Radar, Lidar, Camera</td>
<td>Lane Keeping, Car-following, Emergency Brake, Auto Parking</td>
</tr>
<tr>
<td>Intellion-2</td>
<td>Hanyang University Systems &amp; Control Lab.</td>
<td>HMC Tucson</td>
<td>Long Range Front Radar, Rear-side Radars, Front Camera, AVM, IMU, DGPS, RTK</td>
<td>Lane Keeping System, Lane Change System: Front Camera for Lane Detection from MANDO, Short Range Radars from MANDO HELLA</td>
</tr>
</tbody>
</table>
Plenary Speakers

Date: Monday, June 29, 2015
Time: 08:50-09:50
Room: E 1+2+3

Chair: Seung-Woo Seo (Seoul National University)
Co-Chair: Alberto Broggi (University of Parma)

Automated Driving: the Future of Transport starts today!

Bart van Arem
Professor, Delft University of Technology, Netherlands

Automated Driving has been receiving a huge interest from industry, government and academia. High expectations rest on Automated Driving to deliver benefits in terms of traffic safety and efficiency. Forecasts claim the market introduction of hands, feet and brain-off automated vehicles before 2025. Automated Driving is going to fundamentally change the way we travel. Will it?

This keynote will review past and current research about the implications of Automated Driving on transport. It will discuss how vehicle automation changes traffic flow characteristics and under which conditions vehicle automation can reduce congestion. Next, it will explore the changes that Automated Driving may trigger in travel behavior. Finally, it will review scenarios for Automated Driving that run up to 20-30 years and the consequences of these scenarios for decision makers in governments.

Biography

Bart van Arem is a full professor of Transport Modeling at Delft University of Technology. His research and teaching responsibilities include impacts of intelligent vehicles and cooperative road vehicle systems and modeling of driver and travel behavioral adaptation to ITS. He served the IEEE Intelligent Transport Systems Society as Editor In Chief of the ITSS Newsletter and as general chair of the IV 2008 and ITSC 2013 conferences. He currently works on control algorithms and behavioral adaptation of intelligent vehicles for the Dutch National Science Foundation as well as several international public and private clients. In 2013 he founded the Dutch Automated vehicle Initiative (DAVI), resulting in a breakthrough for the interest in automated driving in the Netherlands. His recent work focuses on spatial and transport system level implications of automated driving.
Plenary Speakers (cont.)

Date: Tuesday, June 30, 2015  
Time: 08:30-09:00  
Room: E 1+2+3

Chair: Kyongsu Yi (Seoul National University)  
Co-Chair: Chung Choo Chung (Hanyang University)

The Policy for Autonomous Driving Vehicle

Yong-Seog Kim  
Director General for Motor Vehicle Policy Bureau, Ministry of Land, Infrastructure and Transport, Korea

The automotive industry is evolving into an autonomous vehicle that integrates existing mechanical engineering and cutting-edge technologies such as information and communication, sensor and GPS. Some forecast that the global market of autonomous driving system would amount to $ 1 trillion by 2035, and relevant industry is expected to be invigorated accordingly. Autonomous driving technology is predicted not alone to create jobs by revitalizing relevant industries but also reduce traffic accidents by improving vehicle running stability. The Ministry of Land, Infrastructure and Transport of Korea has recently developed the "Autonomous Vehicle Commercialization Support Plan" and announced its plan to modify the legal system and build infrastructure with the aim of commercializing autonomous vehicles by 2020. The speech will first give the overview of current status of the motor vehicle industry and its development progress. The autonomous driving technology-related laws and policies will then follow. Lastly, the government's plan to support autonomous vehicle commercialization in terms of permission for test driving and infrastructure development such as precise digital map will be discussed.

Biography

Yong-Seo Kim has joined the Ministry of Transport (at the present time, Ministry of Land, Infrastructure and Transport), Republic of Korea, right after he had passed the 35th Senior Public Officials Entrant in Exam in 1991. He started his career as a deputy director in the Transport Safety Policy Division, Ministry of Transport. After that, he had an opportunity for oversea study under government grant and graduated in the Cranfield University with a master degree of Logistics & Transportation in School of management (SOM), UK in 1998. He also worked in the field of Urban Railway, Transport & Logistics Policy during 1998-2002. And he worked for the Ministry of Construction and Transportation as a director in the Budget Office, Logistics Policy Team (Presidential Committee), Metropolitan Transport Division, Policy Coordination Team and Public Transport Division, Transport Policy Coordination Division during 2003-2015. And he specially experienced the diplomat life as a counselor in the economic affairs, Korean Embassy in Azerbaijan during 2006-2011 (5 years). He has been now working for the Motor Vehicle Policy Bureau in the Ministry as a Director General since Feb. 2015. And he was awarded the Official Commendation of the Prime Minister (2002), Prize of Best Diplomat for oversea construction (2010) and Medal of Merit (2012). And he wrote his diplomat experience and knowledge about Azerbaijan as a book, <AZERBAIJAN, a Resource Wealthy Country in the Caspian Sea> in 2011.
Hyundai Motor's View on Automotive Electronics for Human Caring

Dongil Park
Vice President, Hyundai Motor Company, Korea

Recently, intelligent safety technology and its development have become important issues among automakers. Hyundai Motor Company has also been preparing to keep up with ever-changing trends in the automotive industry. In this speech, I will present intelligent safety systems from the perspective of Human Caring which is an underlying concept of Hyundai’s brand identity “Modern Premium”. Moreover, 2-Track development strategy for autonomous vehicles will be explained.

From the technical side, I will introduce the ADAS system recently applied to the Genesis, its current development status and future development directions. Future development directions will be about strategies coping with rising autonomous vehicle issues from the customer’s point of view such as enhancing reliability of the systems, letting drivers know intuitively about the vehicle’s safety functions while autonomous driving and preventing vehicles from getting hacked.

Biography

Dongil Park. Vice President at Hyundai Motor Company, has been working for HMC since 1986 and through 30 years of hard work, he was appointed as the director of Electronics Technology Center in Research and Development Division in 2013. He is currently responsible for the development and validation of vehicle electronics including electric architecture design, network, body control module, power management, active safety systems, driver assistance systems, biometric sensors.
Plenary Speakers (cont.)

Date: Wednesday, July 1, 2015  
Time: 08:30-09:30  
Room: E 1+2+3

Chair: Whoi-Yul Kim (Hanyang University)  
Co-Chair: Hwasoo Yeo (KAIST)

University of Michigan’s Work toward Autonomous Cars

Ryan Eustice  
Professor, University of Michigan, USA

Self-driving test vehicles have become a reality on roadways and there is an ever present push toward making them a consumer product in the not so distant future. In this talk, I will give an overview of some of our on-going work (in collaboration with Ford Motor Company) in full-scale automated driving. In particular, we’ll look some of our successes in high definition map building and precision localization, including our recent work in cross-modality localization using vision within a priori LIDAR maps. We’ll also review our work in multipolicy decision making in dynamic environments and discuss our new unique M-City test facility for connected and automated driving.

Biography

Ryan M. Eustice is an Associate Professor in the Department of Naval Architecture and Marine Engineering at the University of Michigan where he additionally holds joint appointments in the Department of Electrical Engineering and Computer Science, and the Department of Mechanical Engineering. He is the Director of the Perceptual Robotics Laboratory (PeRL), a mobile robotics laboratory focused on algorithm development in the areas of robotic perception, navigation, and mapping. His active research projects include applications to autonomous underwater ship hull inspection, multi-vehicle cooperative underwater navigation, benthic high-resolution mapping, and automotive active safety and self-driving capabilities.

Prior to joining the University of Michigan in 2006, he was a Postdoctoral Scholar at the Dynamical Systems and Controls Lab at The Johns Hopkins University and holds a B.S. degree in Mechanical Engineering from Michigan State University (1998) and a Ph.D. in Ocean Engineering from the MIT/WHOI Joint-Program (2005). He is recipient of a NSF CAREER Award and ONR Young Investigator Award, and is an Associate Editor for IEEE Transactions on Robotics and IEEE Journal of Oceanic Engineering. His work on self-driving cars is in cooperation with Ford Motor Company on the Next Generation Vehicle project.
Special Session: Autonomous Driving Vehicles

Date: Tuesday, June 30, 2015
Time: 14:00-16:00
Room: E 1+2+3

Chair: Seung-Woo Seo (Seoul National University)
Co-Chair: Chung Choo Chung (Hanyang University)

14:00-14:30

Should Automated Vehicles Drive like Humans or Robots?

J. Christian Gerdes
Professor, Stanford University, USA

While automated vehicles have advantages with sensor range and reaction time, human drivers have the ability to put complex driving scenes into context and apply judgement to unexpected situations. This sometimes leads them to choose solutions that conflict with established laws for motor vehicle operation but satisfy the human needs for mobility and safety. Should automated vehicles have this same capability and, if not, will human drivers be able to safely share the road with them? This talk explores differences between human driving and automated driving from the race track to suburban streets and the ethical decisions that programmers of automated vehicles must make.

Biography

Professor Gerdes' research centers on the application of dynamic modeling to problems in nonlinear control, estimation and diagnostics. Specific areas of interest include the development of driver assistance systems for lane keeping and collision avoidance, modeling and control of novel combustion processes for Internal Combustion engines and diagnostics for automotive drive-by-wire systems. Prior to joining Stanford, Professor Gerdes was the project leader for vehicle dynamics at the Vehicle Systems Technology Center of Daimler-Benz Research and Technology North America. His work at Daimler focused on safety analysis and simulation-based design of heavy trucks for the Freightliner Corporation.
From Perception to Planning: A Glance at Selected Building Blocks

Philipp Bender
FZI Forschungszentrum Informatik, Germany

Systems like intelligent vehicles are very hard to grasp without breaking them down into small building blocks. In this talk we'd like to present our approach to what we have identified as some of the most important blocks. We briefly present our research activities in camera calibration and image preprocessing, stereo image processing, mapping, localization and planning. After that, we introduce our next great challenge, which is mastering the Grand Cooperative Driving Challenge in the Netherlands in 2016.

Biography

Philipp Bender received his Master's degree in Mechanical Engineering from the KIT and is now PhD candidate at FZI Karlsruhe. During his work, he was team member of the 2013 Bertha Benz Autonomous Drive from Mannheim to Pforzheim. His research interests are centered around behavior generation and trajectory planning for intelligent vehicles.
Special Session: Autonomous Driving Vehicles (cont.)

15:00-15:30

How to be Intelligent – in the 2020’s

Danil Prokhorov  
Toyota Research Institute North America, USA

The emergence of advanced technologies is radically reshaping the transportation landscape. Vehicles with Advanced Driver Assistance Systems, Connectivity, and Automation coupled with trends toward “Internet of Things” and the “Quantified-Self” will bring opportunities and challenges for increased highway safety in the 2020’s. Research direction to make the transition to this mobility safely and intelligently will be discussed. Current projects from Toyota’s Collaborative Safety Research Center will also be presented.

Biography

Dr. Danil V. Prokhorov is the IEEE Senior Member, received his Diploma in Robotics with Honors from the St. Petersburg State University of Aerospace Instrumentation (formerly LIAP), Russia, in 1992. He worked in the St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences. After receiving Ph.D. in EE from Texas Tech University in 1997, he joined the staff of Ford Scientific Research Laboratory, Dearborn, MI.

While at Ford he was engaged in application-driven studies of intelligent technologies, developing new and improving existing machine learning/computational intelligence algorithms and applying them to problems in system modeling, control, diagnostics and optimization. Dr. Prokhorov is a recipient of the 1999 INNS Young Investigator Award for his contributions to approximate (neuro) dynamic programming, recurrent neural networks and learning algorithms.

He is honored to serve the research community as a panel expert for the National Science Foundation, as an Associate Editor of IEEE Trans. Neural Networks and Learning Systems, IEEE Trans. Autonomous Mental Development, and Neural Networks, as well as a reviewer and a member of Organizing and/or Program Committees of many international journals (e.g., IEEE Trans. CST, AC, ITS, Neurocomputing) and conferences (e.g., IJCNN, WCCI, SMC, ACC, CDC, IVS, ITSC).

In addition to serving on the IEEE ITSS Board of Governors, he is also serving as the International Neural Network Society (INNS) President. He has authored more than 100 scientific publications, as well as 15 patents. He has been involved in intelligent technologies research at Toyota Tech Center (TTC), Ann Arbor, MI since joining TTC in 2005, and in particular, research on highly automated vehicles. Since 2011 he is a head of future mobility research department at Toyota Research Institute North America (TRINA), an advanced research division within TTC. One of Toyota vehicles featuring TRINA experimental technologies was revealed to the public at the CES 2013 in Las Vegas, USA.
Automated Driving in Urban Environments and Related Research Activities in SNU

Seung-Woo Seo
Professor, Seoul National University, Korea

Kyongsu Yi
Professor, Seoul National University, Korea

Automated driving in urban environments is typically a very challenging job. One critical necessary component is the capability to simultaneously seek multiple objectives such as avoiding obstacles and/or deciding optimal action policy. Others include the technologies on highly accurate mapping and localization. In this talk, we will discuss our approaches for building these blocks and introduce some key technologies we have developed in the Intelligent Vehicle IT (IVIT) Research Center in SNU. We will also demonstrate a vehicle called the ‘SNU Automated Drive’, and show some test results in diverse urban scenarios.

Biography

Seung-Woo Seo is the professor in the Department of Electrical and Computer Engineering in Seoul National University, Seoul, Korea, and the Director of Intelligent Vehicle IT (IVIT) Research Center funded by Korean Government and Automotive Industries. He received his Ph.D. from Pennsylvania State University, University Park, USA, and B.S. & M.S. degrees from Seoul National University, Seoul, Korea, all in Electrical Engineering. He was with the Faculty of the Department of Computer Science and Engineering, Pennsylvania State University, and served as a Member of the Research Staff in the Department of Electrical Engineering in Princeton University, Princeton, NJ. In 1996, he joined the Faculty of Seoul National University. He has served as Chair or a Committee Member in various international conferences and workshops including INFOCOM, GLOBECOM, PIMRC, VTC, MobiSec, Vitae, ICEIC, etc. He is the general co-chair of IEEE Intelligent Vehicle Symposium in 2015. He also served for five years as a Director of the Information Security Center in Seoul National University. His research areas include automated driving, vehicular communication & network security, and system optimization.

Kyongsu Yi is a Professor with the School of Mechanical and Aerospace Engineering, Seoul National University, Seoul, Korea. He received the B.S. and M.S. degrees in mechanical engineering from Seoul National University, Seoul, Korea, in 1985 and 1987, respectively, and the Ph.D. degree in mechanical engineering from the University of California, Berkeley, in 1992.

Dr. Yi served as the program chair of the IEEE ITSC 2011 and the program co-chair of the IEEE ITSC 2014. Currently he is the general chair of the IEEE Intelligent Vehicle Symposium 2015. He is the vice chair of KSME IT Division and a member of AVEC Board. He has served as a member of the editorial boards of the KSME, IJAT and ICROS journals. His research interests include control systems, vehicle dynamics and control, driver assistant systems, active safety systems and automated driving of a ground vehicle.
Understanding driver behaviors in real world driving context is a key component for development of intervening technologies for Intelligent Vehicles. Recent advancements in vehicle automation have raised the surge in understanding the driver state, driving environment, and the capabilities of intervention for safe and effective deployment of such technologies. To understand driver behaviors in real world driving context, researchers from different disciplines have investigated Naturalistic Driving across population of drivers. Such Naturalistic Driving data are often collected with low fidelity cameras and sensors due to large deployments, thus pose challenges to computer vision and machine learning techniques to deduce valuable inferences. Therefore, this workshop is aimed at investigating the challenges posed by naturalistic driving data to understand driver behaviors and driving context, and explores opportunities to develop ITS applications for Intelligent Vehicles.

09:00-09:10
**Introduction**
Pujitha Gunaratne, Kazuya Takeda

09:10-09:30
**Ongoing METI Project for NDS-Based Driver Modeling**
Chiyomi Miyajima (Nagoya University)

09:30-09:50
**Overview and Supporting Data and Research in Automation for the SHRP-2 Naturalistic Driving Study**
Thomas P. Karnowski (Oak Ridge National Laboratory)

09:50-10:10
**Video Analytics for Enhanced Safety: From Computer Vision Research to Automated Tools for Naturalistic Driving Studies**
Mohan M Trivedi (University of California at San Diego)

10:10-10:40
**Break: Poster & Demo presentation**

10:40-11:00
**Current European NDS project UDRIVE and the FOT-Net Data Sharing Framework**
Helena Gellerman (SAFER Vehicle and Traffic Safety Center at Chalmers Gothenburg)

11:00-11:20
**TASI 110-Car Naturalistic Driving Study: Implications to Vehicle-Pedestrian Crash Testing Scenarios and Pedestrian Crash Dummy Development**
Renran Tian, Yaobin Chen (Indiana University Perdue University Indianapolis)

11:20-12:30
**Panel Discussion**
Workshop: EP

Workshop on Environment Perception for Automated On-road Vehicles

Date: Sunday, June 28, 2015
Time: 09:00-12:00
Room: E2

Organizers:
Danil Prokhorov (Toyota Research Institute North America), Chunzhao Guo (Toyota Central R&D Labs., Inc.)

Future cars will be highly or fully automated operating on regular roads. This could greatly improve driving comfort and road safety, thereby potentially saving lots of lives. Environment perception is known to be a major challenge in development of automation technologies for driving in daily traffic. While finding objects of interest on well-structured roads is already available in modern vehicles, it remains an unsolved problem in terms of system performance and reliability, e.g., processing information in spite of all the noises brought by various illumination and weather conditions, reconstructing the scene geometry for different road types, and interpreting as well as predicting the behaviors of all traffic participants. In this workshop we would like to highlight important advances made in this wide area of research.

09:00-09:05
Opening
Danil Prokhorov (Toyota Research Institute North America)

09:05-09:55, Keynote
Several difficult problems to be solved for car environment recognition and our efforts toward solving them
Seiichi Mita (Toyota Technological Institute)

09:55-10:25, Presentation of TRINA
Perception for Automated Vehicles
Danil Prokhorov (Toyota Research Institute North America)

10:25-10:45
Coffee Break

10:45-11:15, Presentation of TCRDL
Research Efforts for Road Environment Perception
Chunzhao Guo (Toyota Central R&D Labs., Inc.)

11:15-11:30, Workshop Paper 1
A Proposal for Neuro-ITS over the Connected Vehicles Network
Mikio Sasaki (Denso Corporation)

11:30-11:45, Workshop Paper 2
Pedestrian Orientation Classification Utilizing Single-Chip Coaxial RGB-ToF Camera
Fumito Shinnmura, Yasutomo Kawanshi, Daisuke Deguchi, Ichiro Ide, Hiroshi Murase (Nagoya University), Hironobu Fujiyoshi (Chubu University)

11:45-12:00, Workshop Paper 3
Grid Map based Free Space Estimation using Stereo Vision
Hannes Harms, Eike Rehder, Martin Lauer (Karlsruhe Institute of Technology)
Workshop: LDA

2nd Workshop on Benchmarking Road Terrain and Lane Detection Algorithms for In-Vehicle Application

Date: Sunday, June 28, 2015
Time: 09:00-12:00
Room: E3

Organizers: José M. Álvarez (NICTA), Jannik Fritsch (Honda Research Institute Europe)

Following the large interest in the first workshop at IV2014 in Detroit and the many results submitted to the KITTI-ROAD benchmarking website since then, this workshop aims to continue bringing researchers active in this field together for building up a community.

The task of detecting the road area and ego-lane ahead of a vehicle is central to modern driver assistance systems and autonomous vehicles. While lane-detection on well-marked roads is already available in modern vehicles, finding the boundaries of unmarked or weakly marked roads and lanes as they appear in inner-city and rural environments remains an unsolved problem due to the high variability in scene layout and illumination conditions, amongst others. While recent years have witnessed great interest in this subject, to date no commonly agreed upon benchmark exists, rendering a fair comparison amongst methods difficult.

This workshop has two main goals. The first goal is to enable a better comparison of approaches by encouraging submissions operating on the KITTI-ROAD public benchmark (http://www.cvlibs.net/datasets/kitti/eval_road.php) in order to foster research progress in road terrain and lane detection algorithms for application in real vehicles driving on arbitrary non-highway roads. The second goal is to overcome the shortcomings of the currently available benchmarks by encouraging researchers to create and promote new, broad, large benchmarks for road terrain and lane detection. This point is especially relevant in light of the recently promoted huge single image benchmarks for object detection which foster interest in data-intensive recognition algorithms. In order to take advantage of this ongoing algorithmical progress, larger road scene databases are needed. A related aspect is the question of how to best evaluate road terrain and lane detection algorithms, as classical image processing measures seem to be not well suited for assessing the performance of an overall in-vehicle system.

09:00-09:15
Opening and presentation

09:15-09:40, Invited talk
An Auto Exposure Control Algorithm based on Lane Recognition for on-board Camera
Tong Li, Yan Song, Tao Mei (Chinese Academy of Sciences)

09:40 -10:05, Invited talk
Accurate Ego-Lane Recognition utilizing Multiple Road Characteristics in a Bayesian Network Framework
Soomok Lee, Seung-Woo Seo (Seoul National University), Seong-Woo Kim (Singapore-MIT Alliance for Res. and Tech)

10:05-10:20
Break

10:20-10:45, Invited talk
Road Detection with Thermal Cameras through 3D Information
Gustavo Pelaez, Fernando Garcia, Arturo de la Escalera (Carlos III University of Madrid), Daniel Bacara (Signum Bildtechnik), Cristina Olaverri Monreal (AIT)

10:45-11:05, Invited talk
Efficient Scene Parsing by Sampling Unary Potentials in a Fully-Connected CRF
Lachlan Horne, José M. Alvarez, Mathieu Salzmann, Nick Barnes (NICTA)

11:05-11:20
Short break

11:45-12:00
Closing remarks and discussion
The IEEE Workshop on Human Factors in Intelligent Vehicles (HFIV’15) allocated with the 2015 IEEE Intelligent Vehicles Symposium, to be held in Seoul, Korea, June 28- July 1, 2015, is the fourth edition of its series. The HFIV’15 welcomes and encourages contributions reporting on original research, work under development and experiments of different fields related to Human Factors. The IEEE Workshop series on Human Factors in Intelligent Vehicles aims to foster discussion on issues related to the analysis of human factors in the design and evaluation of intelligent vehicles technologies, in a wide spectrum of applications and in different dimensions. It is expected to build upon a proper environment to disseminate knowledge and motivate interactions among the technical and scientific communities, practitioners and students, allowing state-of-the-art concepts and advances to be further developed and enhanced. IV technologies have experienced a great improvement in the last couple of decades, turning vehicles into more interactive counterparts in transportation and mobility systems. However, analyzing the impact of such technologies on traffic awareness for the drivers and their behavior towards improving driving performance while reducing road accidents as well as psycho and physical exhaustion, still demands proper tools and approaches. Whereas the feasibility of incorporating new technology-driven functionalities to vehicles has played a central role in the automotive design, not always safety issues related to interaction with the new in-vehicle systems have been taken into consideration. Additionally, other aspects are equally important and need to be accounted for, such as the impact technologies that support specific driving functions play on the primary task of driving the vehicle, as well as their impact on overall performance of transportation systems. Besides current industrial achievements that feature today’s vehicles with a number of important driving assistance systems, the perspective of autonomous driving vehicles populating urban settings pose even more challenging issues. Also, the information and functionalities that rely on new ways of communication have to be presented in a non-intrusive way while complying with specific design requirements. A system that guarantees efficiency of use, comfort and user satisfaction is inarguably an important contribution towards a more conscious driving behavior that directly results from the adoption of IV technologies.

13:30-14:00
Smartphone-Based Modeling and Detection of Aggressiveness Reactions in Senior Drivers
Dong-Woo Koh, Hang-Bong Kang (Catholic University of Korea)

14:00-14:30
Intent-aware Interactive Displays in Vehicles: A Novel Concept to Reduce Distractions
Bashar I. Ahmad, Patrick M. Langdon (University of Cambridge)

14:30-14:45
Coffee Break

14:45-15:15
Human Factors Challenges in Highly Automated Driving
Joonwoo Son (Daegu Gyeongbuk Institute of Science & Technology)

15:15-15:45
Form follows function – changing the steering wheel shape to indicate the driving mode and increase driver comfort
Philipp Kerschbaum, Lutz Lorenz (BMW Res. & Tech.), Klaus Bengler (Technische Universität München)

15:45-16:15
Armadillo-T, a foldable 4WD EV, in human interaction
In-Soo Suh (KAIST)

16:15-16:30
Open Discussion and workshop closing
Vision-based analysis of driver and surround plays a key role in the future of automotive technology. The large number of road-related crashes and fatalities around the world every year resulted in large safety solutions efforts in both the research and industry communities. Efforts are currently targeted at creating more intelligent vehicles that can understand, prevent, and mitigate potentially dangerous situations. Intelligent vehicles may sense, model, and predict surround parameters by looking out of the vehicle using passive and active vision sensors. Additionally, in order to best assist drivers and minimize human error, systems that look inside the cabin have also been proposed. The Laboratory for Intelligent and Safe Automobiles (LISA) at UCSD has set a goal of sharing on-road, naturalistic data for facilitating the development of video-based driver assistance systems. The data is shared with other researchers in order to allow for collaboration and benchmarking, which are important in propelling the field of vision-based driver assistance forward. The dataset contains challenges that are unique to the driving environment, as opposed to general vision datasets. This requires methods to perform in a robust manner under a wide array of environments, illumination, and occlusion settings. The dataset follows the widely successful KITTI dataset, but contains complementary vision tasks which are not found in KITTI.

The goal of this workshop is to gather researchers who work on vision for intelligent vehicles as well as sensors and applications related to intelligent vehicles. The current shared datasets support benchmarking for US traffic sign detection, hand detection and tracking, and driver face detection and head pose estimation. Challenges in each of these tasks will be discussed and winning submissions to the online evaluation server will be announced. The dataset will be expanded in upcoming years to include more diverse tasks.

13:30-13:45
**Welcome and Introduction**
Mohan M. Trivedi (UC San Diego)

13:45-14:15
**VIVA-Hand Off - Challenges of in-vehicle study of hands, competition and dataset details**
Eshed Ohn-Bar (UC San Diego)

14:15-14:45
**VIVA-Face Off - Challenges of in-vehicle study of faces, competition and dataset details**
Sujitha Martin (UC San Diego)

14:45-15:15
**VIVA-Sign Off - Challenges in US traffic sign recognition, competition and dataset details**
Andreas Møgelmose (Aalborg University/UC San Diego)

15:15-16:15
**Coffee Break with Demonstrations and Poster Session**

16:15-17:30
**Panel Discussion, Concluding Remarks, Competition Finalists, and Awards**
Workshop: IPN

Indoor Positioning and Navigation

Date: Sunday, June 28, 2015
Time: 13:30-16:30
Room: E3

Organizers:
Shiho Kim (Yonsei University)
Wan Sik Choi (ETRI)
Ki-Joune Li (Pusan National University)

The Workshop on Indoor positioning and Navigation allocated with the 2015 IEEE Intelligent Vehicles Symposium, to be held in Seoul, Korea, June 28- July 1, 2015. Navigation and Tracking in Indoor space become a key component for developing autonomous vehicle technologies for the urban environment. The Workshop on Indoor positioning and Navigation aims to foster discussion on issues related to the Technologies for Positioning and Tracking for seamless Location Based Service and as well as new standards for indoor space. In indoor location based service, it is important to manage a lot of indoor map data and indoor positioning reference data efficiently. Therefore, it is aimed at investigating the challenges to autonomous indoor navigation, and explores opportunities to develop indoor autonomous parking services for Intelligent Vehicles. This workshop is expected to build upon a proper environment to disseminate knowledge and motivate interactions among the engineering communities, practitioners and students.

13:30-14:20
Technologies for Autonomous navigation and Tracking in indoor space
Shiho Kim, Jaeyoung Moon, Il Bae (Yonsei University)

14.20-14.45
Coffee Break

14:50-15:30
Positioning Technologies for seamless LBS
Wan Sik Choi (ETRI)

15:30-16:10
IndoorGML, a Standard for Indoor Spatial Information
Ki-Joune Li (Pusan National University)

16.10-16.30
Open Discussion and workshop closing
Monday, June 29, 2015

**MoOrAT1: Collision Avoidance**

09:50-10:50 E1+2+3 (3F)

Chair: J Christian Gerdes (Stanford University)
Co-Chair: Bongsob Song (Ajou University)

09:50-10:10, MoOrAT1.1
1. Improving Yaw Stability Control in Severe Instabilities by Means of a Validated Model of Driver Steering
   Gustav Markula, Johan Eklöv, Leo Laine, Erik Wikhened (Volvo Group Trucks Tech), Niklas Fröjd (Volvo AB)

10:10-10:30, MoOrAT1.2
   Donghoon Lee, Hwasoo Yeo (KAIST)

10:30-10:50, MoOrAT1.3
3. Creating Predictive Haptic Feedback for Obstacle Avoidance Using a Model Predictive Control (MPC) Framework
   Avinash Balachandran, Matthew Brown, Stephen M. Erlien, Chris Gerdes (Stanford University)

Monday, June 29, 2015

**MoPoAT1: Poster Session 1**

10:50-12:30 E4 (3F)

Chair: Shihoh Kim (Yonsei University)
Co-Chair: Cristina Olaverri Monreal (AIT)

10:50-12:30, MoPoAT1.1
   Zhilu Chen, Xinning Huang (WPI), Quan Shi (Nantong University)

10:50-12:30, MoPoAT1.2
2. Multi-Type Road Marking Recognition Using Adaboost Detection and Extreme Learning Machine Classification
   Wei Liu, Jin Lv, Weidong Shang, Huai Yuan (Northeastern University), Bing Yu (Neusoft Corp)

10:50-12:30, MoPoAT1.3
3. Full Spectrum Camera Simulation for Reliable Virtual Development and Validation of ADAS and Automated Driving Applications
   Rene Molenaar, Arthur van Bilsen, Robin van der Made, Raymond de Vries (TASS International)

10:50-12:30, MoPoAT1.4
   Mengmeng Yu, Guanglin Ma (Delphi China Technology Center)

10:50-12:30, MoPoAT1.5
5. Vehicle Trajectory Prediction for Adaptive Cruise Control
   Sung Gu Yi, Chang Mook Kang, Seung-Hi Lee, Chung Choo Chung (Hanyang University)

10:50-12:30, MoPoAT1.6
6. Sideslip Estimation for Articulated Heavy Vehicles in Low Friction Conditions
   Graeme Morrison, David Cebron (University of Cambridge)

10:50-12:30, MoPoAT1.7
7. Grid-Based Online Road Model Estimation for Advanced Driver Assistance Systems
   Julian Thomas, Kai Stens, Sebastian Rauch (BMW Group Forschung & Tech. GmbH), Raúl Rojas (Berlin University)

10:50-12:30, MoPoAT1.8
8. Dynamic Obstacles Avoidance Based on Image-Based Dynamic Window Approach for Human-Vehicle Interaction
   Yue Kang, Danilo Alves de Lima, Alessandro Correa Victorino (UTC)

10:50-12:30, MoPoAT1.9
9. Ontology-Based Decision Making on Uncontrolled Intersections and Narrow Roads
   Lihua Zhao (Toyota Tech. Inst), Ryutaro Ichise (National Inst. of Informatics), Tatsuya Yoshikawa, Takeshi Naito, Toshiaki Kakinami (AISIN SEIKI Co., Ltd), Yutaka Sasaki (Toyota Tech. Inst)

10:50-12:30, MoPoAT1.10
10. An Improved 2D Cost Aggregation Method for Advanced Driver Assistance Systems
    JeongMok Ha, Byeongchan Jeon, WooYeol Jun, JoonHo Lee, Hong Jeong (POSTECH)

10:50-12:30, MoPoAT1.11
11. Localization Inside a Populated Parking Garage by Using Particle Filters with a Map of the Static Environment
    Steffen Wahl (STZ-Softwaretechnik), Peter Schlumberger (IT-Designers GmbH), Raúl Rojas (Berlin University), Martin Stämpfle (Esslingen University of Applied Sciences)

10:50-12:30, MoPoAT1.12
12. Sampling Recovery for Closed Loop Rapidly Expanding Random Tree Using Brake Profile Regeneration
    Niclas Evestedt, Daniel Axehill, Fredrik Gustafsson (Linköping University), Marco Trincavelli (Scania CV AB)

10:50-12:30, MoPoAT1.13
13. Trajectories Planning for Multiple UAVs by the Cooperative and Competitive PSO Algorithm
    Jun Liu (China Academy of Railway Sciences)

10:50-12:30, MoPoAT1.14
14. Overtaking Maneuvers by Non Linear Time Scaling Over Reduced Set of Learned Motion Primitives
    Vishakh Duggal, Bipin Kumar, Bharath Gopalakrishnan, K Madhava Krishna, Arun Singh (IIT Hyderabad), Brijendra Kumar Bharti (RNTBCI), Abdelaziz Khiat (Nissan Motor Co., Ltd)

10:50-12:30, MoPoAT1.15
15. Development and Implement of an Inspection Robot for Power Substation
    Haojie Zhang, Bo Su, Haiping Song, Wei Xiong (China North Vehicle Research Institute)

10:50-12:30, MoPoAT1.16
16. A Robust Lane Detection and Departure Warning System
    Mrinal Haloi (IIT Guwahati), Dinesh Babu Jayagopi (IIIT Bangalore)
27. Automatic LED Text Recognition Method on Electronic Road Sign Using Local Spatial Pattern and Random Forest Classifier
Wahyono Wahyono, Alexander Filonenko, Kang-Hyun Jo (University of Ulsan)

28. Saliency-Based Cascade Method for Fast Traffic Sign Detection
Dongdong Wang, Xinwen Hou, Cheng-Lin Liu (Chinese Acad. of Sciences), Shigang Yue, Jiawei Xu (University of Lincoln)

29. Distributed Graph-Based Convoy Control for Networked Intelligent Vehicles
Ali Marjovi, Milos Vasic, Joseph Lemaitre, Alcherio Martinoli (EPFL)

30. Coarse Direction Detection for Facial Data in the SHRP 2
Shokouhi, Lei (Chinese Acad. of Sciences), Kurt Gremigni (Carlos III University of Madrid), Carlos Tena (University of Ulsan)

31. Reduced Effect of Traffic Accidents by Driver's Psychosomatic State Monitoring Function
Masahiro Miyaji (Aichi Prefectural University)

32. Pedestrian Detection Based on Deep Convolutional Neural Network with Ensemble Inference Network
Hiroshi Fukuji, Takayoshi Yamashita, Yuji Yamauchi, Hironobu Fujiyoshi (Chubu University), Hiroshi Murase (Nagoya University)

33. Short-Term Visual Mapping and Robot Localization Based on Learning Classifier Systems and Self-Organizing Maps
Arthur Miranda Neto (Federal University of Lavras)

34. Baseline Face Detection, Head Pose Estimation, and Coarse Direction Detection for Facial Data in the SHRP-2 Naturalistic Driving Study
Thomas Karnowski, Jeffrey Paone, Regina Ferrell, David Bolme, Deniz Aykac (Oak Ridge National Lab)

35. Velodyne-Based Curb Detection up to 50 Meters Away
Tongtong Chen, Bin Dai, Daxue Liu, Jinze Song, Zhao Liu (National University of Defense Technology)

36. Clustering Improved Grid Map Registration Using the Normal Distribution Transform
Matthias Rapp, Michael Barjenbruch, Klaus Dietmayer (University of Ulm), Markus Hahn (Daimler AG), Jürgen Dickmann (Mercedes-Benz AG)

37. Road Detection with Thermal Cameras through 3D Information
Gustavo Pelaez, Fernando Garcia, Arturo de la Escalera (Carlos III University of Madrid), Daniel Bacara (Signum Bildtechnik), Cristina Olaverri Monreal (AIT)

38. Design of an Interactive Multiple Model Based Two-Stage Multi-Vehicle Tracking Algorithm for Autonomous Navigation
Ashesh Goswami, C.S. George Lee (Purdue University)
10:50-12:30, MoPoAT1.39
39. Feature-Based Mapping and Self-Localization for Road Vehicles Using a Single Grayscale Camera
Manuel Stuebler, Juergen Wiest, Klaus Dietmayer (University of Ulm)

10:50-12:30, MoPoAT1.40
40. Building a Probabilistic Grid-Based Road Representation from Direct and Indirect Visual Cues
Edoardo Casapia, Franz Kummert (Bielefeld University), Thomas H. Weisswange, Christian Goerick, Jannik Fritsch (Honda Research Institute Europe GmbH)

10:50-12:30, MoPoAT1.41
41. Integrating Visual Selective Attention Model with HOG Features for Traffic Light Detection and Recognition
Yang Ji, Ming Yang, Zhengchen Lu, Chunxiang Wang (Shanghai Jiao Tong University)

Monday, June 29, 2015
MoOrMT1: Vehicle Control
14:00-15:20
E1+2+3 (3F)

Chair: Ryan Eustice (University of Michigan)
Co-Chair: Dongsuk Kum (KAIST)
14:00-14:20, MoOrMT1.1
1. An Overview of Vehicular Platoon Control under the Four-Component Framework
Shengbo Li, Yang Zheng, Keqiang Li, Jianqiang Wang (Tsinghua University)

14:20-14:40, MoOrMT1.2
2. Stochastic Model Predictive Controller with Chance Constraints for Comfortable and Safe Driving Behavior of Autonomous Vehicles
David Lenz, Tobias Kessler (Fortiss GmbH), Alois Knoll (Technology University München)

14:40-15:00, MoOrMT1.3
3. GPS Waypoint Fitting and Tracking Using Model Predictive Control
Soo Jung Jeon, Chang Mook Kang, Seung-Hi Lee, Chung Choo Chung (Hanyang University)

15:00-15:20, MoOrMT1.4
4. Toward Integrated Motion Planning and Control Using Potential Fields and Torque-Based Steering Actuation for Autonomous Driving
Enric Galceran, Ryan Eustice, Edwin Olson (University of Michigan)

Monday, June 29, 2015
MoPoPT1: Poster Session 2
15:20-17:00
E4 (3F)

Chair: Gyu-In Jee (Konkuk University)
Co-Chair: Ho Gi Jung (Hanyang University)

15:20-17:00, MoPoPT1.1
1. LED Traffic Sign Detection with the Fast Radial Symmetric Transform and Symmetric Shape Detection
Wooyeol Jun, JeongMok Ha, Byeongchan Jeon, JoonHo Lee, Hong Jeong (POSTECH)

15:20-17:00, MoPoPT1.2
2. A Driving Path Based Target Object Prediction
Joeran Zeisler, Juri Chererepanov, Vladimir Haltakov (Bmw Ag)

15:20-17:00, MoPoPT1.3
3. The Foresighted Driver Model
Julian Eggert (Honda Research Institute Europe GmbH), Florian Damerow, Stefan Klingelschmitt (Technology University of Darmstadt)

15:20-17:00, MoPoPT1.4
Andreas Megelmose, Thomas Moeslund (Aalborg University), Mohan M. Trivedi (University of California at San Diego)

15:20-17:00, MoPoPT1.5
5. A Light-Weight Real-Time Applicable Hand Gesture Recognition System for Automotive Applications
Thomas Kopinski, Stéphane Magand, Uwe Handmann (Hochschule Ruhr West), Alexander Gepperth (Ec. Nationale Superieure De Tech. Avancées)

15:20-17:00, MoPoPT1.6
6. Accelerometer Tyre to Estimate the Aquaplaning State of the Tyre-Road Contact
Arto Juhani Niskanen, Ari Juhani Tuuronen (Aalto University)

15:20-17:00, MoPoPT1.7
Juergen Wiest, Karg Matthias Karg, Felix Kunz, Stephan Reuter, Klaus Dietmayer (University of Ulm), Ulrich Kressel (Daimler AG)

15:20-17:00, MoPoPT1.8
8. Multiview Random Forest of Local Experts Combining RGB and LIDAR Data for Pedestrian Detection
Alejandro Gonzalez, Gabriel Villalonga, David Vazquez, Antonio M. Lopez (Autonomous University of Barcelona), Jialong Xu, Jaume Amores (Computer Vision Center)

15:20-17:00, MoPoPT1.9
Carsten Stahlhschmidt, Sebastian von Camen, Alexandros Gavrielidis, Anton Kummert (University of Wuppertal)

15:20-17:00, MoPoPT1.10
10. Stochastic Driver Speed Control Behavior Modeling in Urban Inter-Sections Using Risk Potential-Based Motion Planning Framework
Yasuhiro Akagi, Pongsathorn Raksincharoensak (Tokyo University of Agriculture and Tech)

15:20-17:00, MoPoPT1.11
11. Urban Platooning Using a Flatbed Tow Truck Model
Alan Ali (IRCCYN), Gaëtan Garcia, Philippe Martinet (Ec. Centrale De Nantes)

15:20-17:00, MoPoPT1.12
12. Correspondence between Variational Methods and Hidden Markov Models
Jens Ziehn, Miriam Ruf, Dieter Willersinn, Jürgen Beyerer (Fraunhofer IOSB), Bodo Rosenhahn (Leibniz University Hannover), Heinrich Gotzig (Valeo Schalter Und Sensoren GmbH)

15:20-17:00, MoPoPT1.13
13. Autonomous Lane-Change Controller
Yaqiong Du, Yizhou Wang, Ching-Yao Chan (University of California Berkeley)
15:20-17:00, MoPoPT1.14
Yongbon Koo, JINWOO KIM, Wooyong Han (ETRI)

15:20-17:00, MoPoPT1.15
15. State-Statistical Model Based Trajectory-Band Planning in Urban Environment
Chao Ma, Jing Yang, Jianru Xue, Yuehu Liu, Liang Ma (Xi’an Jiaotong University)

15:20-17:00, MoPoPT1.16
16. Curve Modeled Lane and Stop Line Detection Based GPS Error Estimation Filter
Byung-Hyun Lee, Gyu-In Jee (Konkuk University), Sung-Hyuck Im, Moon-Beom Heo (KARI)

15:20-17:00, MoPoPT1.17
17. Detection and Motion Planning for Roadside Parked Vehicles at Long Distance
Xue Mei, Naoki Nagasaka, Bunyo Okumura, Danil Prokhorov (Toyota Research Institute North America)

15:20-17:00, MoPoPT1.18
Zhongshi Zhang (University of Chinese Academy of Sciences), Junzhi Zhang, Dongsheng Sun, Chen Lv (Tsinghua University)

15:20-17:00, MoPoPT1.19
19. Evolutionary Algorithm Based On-Line PHEV Energy Management System with Self-Adaptive SOC Control
Xuewei Qi, Guoyuan Wu, Kanok Borboonsomsin, Matthew Barth (University of California, Riverside)

15:20-17:00, MoPoPT1.20
20. Optimization of Gear Shift Schedule for Electric Buses Equipped with 4-AMT Using Dynamic Programming
Chang Liu, Yuhui Hu (Beijing Institute of Technology)

15:20-17:00, MoPoPT1.21
21. Investigation on the Occurrence of Mutual Interference between Pulsed Terrestrial LIDAR Scanners
Gunzung Kim, Jeongsook Eom, Yongwan Park (Yeungnam University)

15:20-17:00, MoPoPT1.22
22. Traffic Sign Recognition Using Salient Region Features: A Novel Learning-Based Coarse-To-Fine Scheme
Keren Fu, Irene Y.H. Gu (Chalmers University of Technology), Anders Odblom (Volvo Cars AB)

15:20-17:00, MoPoPT1.23
23. Stereo Vision-Based Subpixel Level Free Space Boundary Detection Using Modified U-Disparity and Preview Dynamic Programming
Ho Gi Jung, Jae Kyu Suhr (Hanyang University)

15:20-17:00, MoPoPT1.24
24. Visual-Based On-Road Vehicle Detection: A Transnational Experiment and Comparison
Chao Wang, Huijing Zhao, Hongbin Zha (Peking University), Chunzhao Guo (Toyota Central R&D Labs., Inc), Seiichi Mita (Toyota Technological Institute)

15:20-17:00, MoPoPT1.25
25. Implementation of a Multi-Criteria Tracking Based on the Dempster-Shafer Theory
Valentin Magnier, Jérôme Godelle (RENAULT), Dominique Gruyer (IFSTTAR)

15:20-17:00, MoPoPT1.26
26. Disparity Refinement with Stability-Based Tree for Stereo Matching
Yuhang Ji, Qieshi Zhang, Kenjiro Sugimoto, Sei-ichiro Kamata (Waseda University)

15:20-17:00, MoPoPT1.27
27. Robust Scale Estimation for Monocular Visual Odometry Using Structure from Motion and Vanishing Points
Johannes Gräter, Tobias Schwarze, Martin Lauer (Karlsruher Institut für Technologie)

15:20-17:00, MoPoPT1.28
28. Estimation of Automotive Pitch, Yaw, and Roll Using Enhanced Phase Correlation on Multiple Far-Field Windows
Marc Barnada, Rudolf Mester, Matthias Ochs, Christian Conrad (Goethe University Frankfurt)

15:20-17:00, MoPoPT1.29
29. Pedestrian Detection from Non-Smooth Motion
Mehmet Kilicarslan, Jiang Yu Zheng, Aied Algarni (IUPUI)

15:20-17:00, MoPoPT1.30
30. Improved Path Tracking Approach for Unmanned Vehicles Based on Clothoid Curve
Bijun Li, Yunxiao Shan, Cheng Chen, Wei Yang (Wuhan University)

15:20-17:00, MoPoPT1.31
31. Coordinated Standoff Tracking of in and Out-Of-Surveillance Targets Using Constrained Particle Filter for UAVs
Hyondong Oh, Cunjia Liu, Wen-Hua Chen (Loughborough University), Seungkeun Kim (Chungnam National University), Hyo-Sang Shin (Cranfield University)

15:20-17:00, MoPoPT1.32
32. An Experiment on Ambient Light Patterns to Support Lane Change Decisions
Andreas Löcken, Susanne Boll (University of Oldenburg), Heiko Müller, Wilko Heuten (Institute for Information Technology)

15:20-17:00, MoPoPT1.33
33. Understanding Surrounding Vehicles in Urban Traffic Scenarios Based on a Low-Cost Lane Graph
Chunzhao Guo, Kiyoumi Kidono, Yoshiko Kojima (Toyota Central R&D Labs., Inc)

15:20-17:00, MoPoPT1.34
34. Fast Pixelwise Road Inference Based on Uniformly Reweighted Belief Propagation
Mario Passani, José Javier Yebes Torres, Luis M. Bergasa (University of Alcala)

15:20-17:00, MoPoPT1.35
35. Urban Road Localization by Using Multiple Layer Map Matching and Line Segment Matching
Keisuke Yoneda, Chenxi Yang, Seiichi Mita (Toyota Technological Institute), Tsubasa Okuya, Kenji Muto (DENS Corp)
15:20-17:00, MoPoPT1.36
36. Obstacle Localization and Recognition for Autonomous Forklifts Using Omnidirectional Stereovision
Arthur Daniel Costea, Andrei Vatavu, Sergiu Nedevschi (Technical University of Cluj-Napoca)

15:20-17:00, MoPoPT1.37
37. Unsupervised Image Transformation for Outdoor Semantical Labelling
German Ros (Computer Vision Center), José M. Alvarez (NICTA)

Monday, June 29, 2015
MoOrPT1: Vehicle Environment Perception
17:00-18:20 E1+2+3 (3F)
Chair: Miguel A. Sotelo (University of Alcala)
Co-Chair: Seung-Woo Seo (Seoul National University)

17:00-17:20, MoOrPT1.1
1. Simultaneous Localization and Mapping Based on the Local Volumetric Hybrid Map
Jaebum Choi, Markus Maurer (TU Braunschweig)

17:20-17:40, MoOrPT1.2
2. Predicting Driving Behavior Using Inverse Reinforcement Learning with Multiple Reward Functions towards Environmental Diversity
Masamichi Shimosaka, Kentaro Nishi, Junichi Sato (The University of Tokyo), Hirokatsu Kataoka (Keio University)

17:20-17:40, MoOrPT1.3
3. Exploiting 3D Semantic Scene Priors for Online Traffic Light Interpretation
Dan Barnes, William Paul Maddern, Ingmar Posner (The Univ. of Oxford)

Tuesday, June 30, 2015
TuOrAT1: Image, Radar, Lidar Signal Processing
09:30-10:50 E1+2+3 (3F)
Chair: Uwe Franke (Daimler AG)
Co-Chair: Seongjin Yim (Seoul National University of Science and Technology)

10:30-10:50, TuOrAT1.1
1. A Multi-Block-Matching Approach for Stereo
Nils E inneke, Julian Eggert (Honda Research Institute Europe GmbH)

10:50-11:00, TuOrAT1.2
2. How to Predict Real Road State from Vehicle Embedded Camera?
Nicolas Gimonet, Aurelien Cord, Guillaume Saint Pierre (IFSTTAR)

10:00-10:30, TuOrAT1.3
3. Low-Level Fusion of Color, Texture and Depth for Robust Road Scene Understanding
Timo Schaarwaechter, Uwe Franke (Daimler AG)

10:30-10:50, TuOrAT1.4
4. Vehicle Localization Using Mono-Camera and Geo-Referenced Traffic Signs
Xiaozhi Qu, Bahman Soheilian, Nicolas Paparoditis (Univ. Paris-Est)
10:50-12:30, TuPoAT1.6
6. Probabilistic Threat Assessment with Environment Description and Rule-Based Multi-Traffic Prediction for Integrated Road Management System
Beomjun Kim, Kyongsu Yi (Seoul National University), YoungSeop Son (Mando)

10:50-12:30, TuPoAT1.7
7. Identifying a Gap in Existing Validation Methodologies for Intelligent Automotive Systems: Introducing the 3xD Simulator Siddartha Khastgir, Stewart Birrell, Gunwant Dhadyalla, Paul Jennings (University of Warwick)

10:50-12:30, TuPoAT1.8
8. Drive Quality Analysis of Lane Change Maneuvers for Naturalistic Driving Studies Ravi Kumar Satzoda, Mohan M. Trivedi (University of California at San Diego), Pujitha Gunaratne (Toyota Research Institute North America)

10:50-12:30, TuPoAT1.9
9. Snap-DAS: A Vision-Based Driver Assistance System on a Snapdragon Embedded Platform Ravi Kumar Satzoda, Sean Lee, Frankie Lu, Mohan M. Trivedi (University of California at San Diego)

10:50-12:30, TuPoAT1.10
10. Autonomous Driving at Ulm University: A Modular, Robust, and Sensor-Independent Fusion Approach Felix Kunz, Dominik Nuss, Juergen Wiest, Hendrik Deusch, Stephan Reuter, Alexander Scheel, Manue Stuebler, Cornelius Wild, Klaus Dietmayer (University of Ulm), Franz Gritschneder, Martin Bach, Patrick Hatzelmann (Inst. of Measurement, Control and Microtechnology)

10:50-12:30, TuPoAT1.11
11. Local Trajectory Planning and Tracking for Autonomous Vehicle Navigation Using Clothoid Tentacles Method Alia Chebly, Gilles Tagne, Reine Talj, Ali Charara (Université de Technologie de Compiègne)

10:50-12:30, TuPoAT1.12
12. Lane Map Building and Localization for Automated Driving Using 2D Laser Rangefinder Dongwook Kim, Kyongsu Yi (Seoul National University), Taeyoung Jung (Hyundai Mobis)

10:50-12:30, TuPoAT1.13
13. Robust Stereo Visual Odometry from Monocular Techniques Mikael Persson, Tommaso Piccini, Michael Felsberg (Linköping University), Rudolf Mester (University of Frankfurt)

10:50-12:30, TuPoAT1.14
14. The Deeva Autonomous Vehicle Platform Alberto Broggi, Stefano Debbatist, Paol Grisleri, Matteo Pancirolli (University of Parma)

10:50-12:30, TuPoAT1.15
15. A Constrained VFH Algorithm for Motion Planning of Autonomous Vehicles Panrang Qu, Jianru Xue, Liang Ma, Chao Ma (Xi’an Jiaotong Univ)

10:50-12:30, TuPoAT1.16
16. Map Free Lane Following Based on Low-Cost Laser Scanner for Near Future Autonomous Service Vehicle Zhwei Song, Weiwei Huang, Ning Wu, Xiaojun Wu, Chern Yuen Anthony Wong, Vincenius Billy Saputra, Benjamin Chia, Jian Simon Chen, Qun Zhang, Susu Yao, Boon Siew Han (Agency for Science, Technology and Research)

10:50-12:30, TuPoAT1.17
17. Evidential Occupancy Grid Mapping with Stereo-Vision Chunlei Yu, Véronique Cherfaoui, Philippe Bonnifait (Université de Technologie de Compiègne)

10:50-12:30, TuPoAT1.18
18. Optimizing Fuel Economy of Hybrid Electric Vehicles Using a Markov Decision Process Model Xue Lin, Yanzi Wang, Paul Bogdan, Massoud Pedram (University of Southern California), Naehyuck Chang (KAIST)

10:50-12:30, TuPoAT1.19

10:50-12:30, TuPoAT1.20
20. Optimal Energy Consumption Algorithm Based on Speed Reference Generation for Urban Electric Vehicles Carlos Flores, Vicente Milanes, Josuhé Perez Rastelli, David Gonzalez Bautista, Fawzi Nashashibi (INRIA)

10:50-12:30, TuPoAT1.21

10:50-12:30, TuPoAT1.22
22. Optimal Parameter Selection of a Model Predictive Control Algorithm for Energy Efficient Driving of Heavy Duty Vehicles Michael Henzler (Daimler AG), Michael Buchholz, Klaus Dietmayer (University of Ulm)

10:50-12:30, TuPoAT1.23
23. Improved Energy Efficiency and Vehicle Dynamics for Battery Electric Vehicles through Torque Vectoring Control Stefan Köhler, Alexander Viehl (Forschungszentrum Informatik Karlsruhe), Oliver Bringmann, Wolfgang Rosenstiel (Eberhard Karls Univ. Tübingen)

10:50-12:30, TuPoAT1.24
24. Estimating the Energy Consumption of a PHEV Using Vehicle and On-Board Navigation Data Abdel-Djallil Ourabah, Benjamin Quost, Thierry Denoeux (Université de Technologie de Compiègne), Atef Gayed (Renault S.A.S)

10:50-12:30, TuPoAT1.25
25. The Development of Optimum Control Strategy for Hybrid EPS System Using Taguchi Method Ji In Park, Kwangki Jeon (Korea Automotive Technology Institute), Kyongsu Yi (Seoul National University)

10:50-12:30, TuPoAT1.26
27. State-Based Power Optimization Using Mixed-Criticality Filter for Automotive Networks
Wei Hong, Otto Hucke, Andreas Burger (FZI Research Center for Information Technology), Alexander Viehl (Forschungszentrum Informatik Karlsruhe), Oliver Bringmann, Wolfgang Rosenstiel (Eberhard Karls University Tübingen)

28. Eco-Driven Signal Control and Eco-Driving of Hybrid City Buses
Michael Haberl, Martin Fellendorf (Graz University of Technology)

29. Intelligent Navigation System-Based Optimization of the Energy Consumption
Adnane Cabani, Khemmar Radouane Khemmar, Jean-Yves Ertaud, Joseph Mouzna (ESIGELEC-IRSEEM)

30. Ecodriving Performances of Human Drivers in a Virtual and Realistic World
Olivier Orfila, Dominique Gruyer, Vincent Judalet, Marc Revilloud (IFSTTAR)

31. Developing a Framework of Eco-Approach and Departure Application for Actuated Signal Control
Peng Hao, Guoyuan Wu, Kanok Boriboonsomsin, Matthew Barth (University of California-Riverside)

32. Fast PatchMatch Stereo Matching Using Multi-Scale Cost Fusion for Automotive Applications
Ji-Ho Cho (Vienna University of Technology), Martin Humenberger (AIT Austrian Institute of Technology)

33. Can Appearance Patterns Improve Pedestrian Detection?
Eshed Ohn-Bar, Mohan M. Trivedi (University of California at San Diego)

34. On Line Mapping and Global Positioning for Autonomous Driving in Urban Environment Based on Evidential SLAM
Guillaume Trehard, Evangeline Pollard, Fawzi Nashashibi (INRIA), Benazouz Bradai ( Valeo Lighting Systems)

35. Efficient Scene Parsing by Sampling Unary Potentials in a Fully-Connected CRF
Lachlan Horne, José M. Alvarez, Mathieu Salzmann, Nick Barnes (NICTA)

36. Robust Profile Face Detection and Rotation Angle Estimation of the Driver’s Head in a Novel Dazzling Avoidance System
Xiangpeng Liu, Qianrui Wang, Jie Zhao, Axel Graeser (University of Bremen)

37. Fast Accurate Contours for 3D Shape Recognition
Muhammad Usman Butt, John Morris, Nitish Patel, Morteza Biglari-Abhari (The University of Auckland)

38. Joint Spatial and Doppler-Based Ego-Motion Estimation for Automotive Radars
Michael Barjenbruch, Dominik Kellner, Klaus Dietmayer (Univ. of Ulm), Jens Klappstein (Daimler AG), Jürgen Dickmann (Mercedes-Benz AG)

39. A Comparative Study of Color and Depth Features for Hand Gesture Recognition in Naturalistic Driving Settings
Eshed Ohn-Bar, Mohan M. Trivedi (University of California at San Diego)

Tuesday, June 30, 2015
TuPoPT1: Poster Session 4
16:00-17:40
E4 (3F)

Chair: Kyoungchul Kong (Sogang University)
Co-Chair: Jianqiang Wang (Tsinghua University)

1. An Auto Exposure Control Algorithm Based on Lane Recognition for On-Board Camera
Tong Li, Yan Song, Tao Mei (Chinese Academy of Sciences)

Florian Damerow (Technical University of Darmstadt), Julian Eggert (Honda Research Institute Europe GmbH)

3. Lane Change Maneuver Recognition Via Vehicle State and Driver Operation Signals – Results from Naturalistic Driving Data
Guofa Li, Shengbo Li, Yuan Liao, Wenjun Wang, Bo Cheng (Tsinghua University), Fang Chen (Chalmers University of Technology)

4. Safety Benefits of Belt Pretensioning in Conjunction with Precrash Braking in a Frontal Crash
Xiao Luo, Wenjing Du, Jinhuan Zhang (Tsinghua University)

5. Quaternion-Based IMU and Stochastic Error Modeling for Intelligent Vehicles
Thomas Brunner, Sébastien Changey (ISL), Jean-Philippe Lauffenburger, Michel Basset (Université de Haute Alsace)

6. Enhanced Maximum Tire-Road Friction Coefficient Estimation Based Advanced Emergency Braking Algorithm
Taewoo Kim, Kyongsu Yi (Seoul National University), Jaewan Lee (Korea Transportation Safety Authority)

7. Problem Formulation Improvement for Multi-Vehicle Collision Avoidance and Impact Mitigation
Ye Yuan, Jianqiang Wang (Tsinghua University), Xiao-Yun Lu (University of California, Berkeley)

Julian Timpner, Johannes van Balen, Lars Wolf (TU Braunschweig), Stephan Friedrichs (Max Planck Institute for Informatics)
16:00-17:40, TuPoPT1.9
9. Multi Trajectory Pose Adjustment for Life-Long Mapping
Marc Sons, Christoph Stiller (Karlsruhe Institute of Technology), Henning Lategahn (Atlatic), Christoph Gustav Keller (Daimler AG)

16:00-17:40, TuPoPT1.10
10. Collision-Free and Kinematically Feasible Path Planning Along a Reference Path for Autonomous Vehicle
Mengyin Fu, Kai Zhang, Yi Yang, Hao Zhu, Meiling Wang (Beijing Institute of Technology)

16:00-17:40, TuPoPT1.11
11. Please Take Over! an Analysis and Strategy for a Driver Take Over Request During Autonomous Driving
Mohammad Bahram, Michael Aebisher (BMW Group Research and Technology), Dirk Wollherr (Technische Universität München)

16:00-17:40, TuPoPT1.12
12. Autonomous Car Following: A Learning-Based Approach
Stéphanie Lefèvre, Ashwin Carvalho, Francesco Borrelli (University of California at Berkeley)

16:00-17:40, TuPoPT1.13
Yonghwan Jeong, Kuywon Kim, Beomjun Kim, Yongsu Yi (Seoul National University), Jihyun Yoon, Hyok-jin Chong, Bongchul Ko (Hyundai Motor Company)

16:00-17:40, TuPoPT1.14
Andreas Reschka, Gerrit Bagschik, Simon Ulbrich, Marcus Nolte, Markus Maurer (TU Braunschweig)

16:00-17:40, TuPoPT1.15
15. Task Planning for Highly Automated Driving
Chao Chen, Andre K Gaschler, Markus Rickert, Alois Knoll (Technische Universität München)

16:00-17:40, TuPoPT1.16
16. The Impact of Driver Cognitive Distraction on Vehicle Performance at Stop-Controlled Intersections
Yuan Liao, Shengbo Li, Wenjun Wang, Guofa Li, Bo Cheng (Tsinghua University), Ying Wang (Beihang University)

16:00-17:40, TuPoPT1.17
17. Estimating Driver Awareness of Pedestrians in Crosswalk in the Path of Right or Left Turns at an Intersection from Vehicle Behavior
Kei Tateiwa, Keiichi Yamada (Meijo University)

16:00-17:40, TuPoPT1.18
18. Face Orientation Estimation for Driver Monitoring with a Single Depth Camera
Zhengcheng Hu, Naoko Uchida (Kumamoto University), Yanming Wang, Yanchao Dong (Tongji University)

16:00-17:40, TuPoPT1.19
19. Predicting the Driver’s Turn Intentions at Urban Intersections Using Context-Based Indicators
Claus Rodemerck, Hermann Winner (Technical University of Darmstadt), Robert Kastner (Honda R&D Europe GmbH)

16:00-17:40, TuPoPT1.20
20. Estimation of Driver Awareness of Pedestrian Based on Hidden Markov Model
Minh-Tien Phan, Vincent Fremont, Indira Thouvenin, Mohamed Sallak, Véronique Cherfaoui (Université de Technologie de Compiègne)

16:00-17:40, TuPoPT1.21
21. Automatic Lane Change Extraction Based on Temporal Patterns of Symbolized Driving Behavioral Data
Masataka Mori, Kazuhiro Takenaka, Takashi Bando (DENSO Corporation), Tadahiro Taniguchi (Ritsumeikan University), Chiyomi Miyajima, Kazuya Takeda (Nagoya University)

16:00-17:40, TuPoPT1.22
22. In-Car Tactical Advice Using Delayed Detector Data
Wouter Schakel, Bart van Arem (Delft University of Technology)

16:00-17:40, TuPoPT1.23
23. Performance Comparison of Two Model Based Schemes for Estimation of Queue and Delay at Signalized Intersections
Anusha S. P, Lelitha Vanajakshi, Shankar Subramanian (Indian Institute of Technology, Madras), Anuj Sharma (Iowa State University)

16:00-17:40, TuPoPT1.24
24. Traffic Density Estimation Using Dimensional Analysis
Amritha Sunny, Lelitha Vanajakshi, Shankar Subramanian (Indian Institute of Technology, Madras)

16:00-17:40, TuPoPT1.25
Jinsoo Kim, Jinhan Jeong, Kyung-young Jhang, Jahng Hyon Park (Hanyang University)

16:00-17:40, TuPoPT1.26
Simone Formentin, Andrea Giovanni Bianchessi, Sergio Savaresi (Politecnico di Milano)

16:00-17:40, TuPoPT1.27
27. Adaptive Dynamic Preview Control for Autonomous Vehicle Trajectory Following with DDP Based Path Planner
Ning Wu, Weiwei Huang, Xiaojun Wu, Zhiwei Song, Qun Zhang, Susu Yao (Institute for Infocomm Research)

16:00-17:40, TuPoPT1.28
28. Torque-Vectoring Stability Control of a Four Wheel Drive Electric Vehicle
Benedikt Jaeger, Peter Neugebauer, Reiner Kriesten, Christian Gutenkunst (University of Applied Sciences), Nejila Parspour (University of Stuttgart)

16:00-17:40, TuPoPT1.29
29. Inverse Model Control Including Actuator Dynamics for Active Dolly Steering in High Capacity Transport Vehicle
Mohammad Manjurul Islam, Bengt Jacobsson (Chalmers University of Technology), Leo Laine (Volvo Group Trucks Technology)
16:00-17:40, TuPoPT1.30
30. **Optimal Tire Force Allocation for Trajectory Tracking with an Over-Actuated Vehicle**
Hyungchul Park, Chris Gerdes (Stanford University)

16:00-17:40, TuPoPT1.31
31. **A Comparative Study of Lane Keeping System: Dynamic and Kinematic Models with Look-Ahead Distance**
Chang Mook Kang, Seung-Hi Lee, Chung Choo Chung (Hanyang University)

16:00-17:40, TuPoPT1.32
32. **Design of Passivity-Based Controllers for Lateral Dynamics of Intelligent Vehicles**
Gilles Tagne, Reine Talj, Ali Charara (Université de Technologie de Compiègne)

16:00-17:40, TuPoPT1.33
33. **A New Model for the Movement Pattern of Vacant Taxi**
Yingnan Guang, Min Yang, Xuedan Zhang (Tsinghua University)

16:00-17:40, TuPoPT1.34
34. **Essential Feature Extraction of Driving Behavior Using a Deep Learning Method**
HaiLong Liu, Tadahiro Taniguchi (Ritsumeikan University), Yusuke Tanaka (Toyota InfoTechnology Center Co., Ltd), Kazuhiro Takenaka, Takashi Bando (DENSO Corporation)

16:00-17:40, TuPoPT1.35
35. **Calibration-Free Correspondence Finding between Vision and LiDAR Sensors**
Egor Sattarov, Sergio Rodriguez, Roger Reynaud (Universite Paris-Sud), Alexander Gepperth (ENSTA ParisTech)

16:00-17:40, TuPoPT1.36
36. **Modeling the Cost and Coverage of an Ad-Hoc Asset Management System Based on Existing Fleet Vehicles**
Dana Pordel, Lars Petersson, Namin Shahin, Adrián Rebola Pardo (NICTA)

16:00-17:40, TuPoPT1.37
37. **Fusion of Laser and Radar Sensor Data with a Sequential Monte Carlo Bayesian Occupancy Filter**
Dominik Nuss, Manuel Stuebler, Stephan Reuter, Klaus Dietmayer (University of Ulm), Ting Yuan (MBRDNA, Inc), Gunther Krehl (Mercedes Benz Res. & Development North America, Inc)

16:00-17:40, TuPoPT1.38
38. **Traffic and Vehicle Speed Prediction with Neural Network and Hidden Markov Model in Vehicular Networks**
Bingnan Jiang, Yunsi Fei (Northeastern University)

16:00-17:40, TuPoPT1.39
Matej Kubicka, Hugues Mounier, Silviu-Iulian Niculescu (CNRS/Supelec), Arben Cela (ESIEE Paris), Philippe Moulin (IFP Energies Nouvelles)

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**Wednesday, July 1, 2015**

**WePoA1: Advanced Driver Assistance Systems**

09:30-10:50 E1+2+3 (3F)

Chair: Hwasoo Yeo (KAIST)
Co-Chair: Whoi-Yul Kim (Hanyang University)

09:30-09:50, WeOrA1.1
1. **Kinematic and Dynamic Vehicle Models for Autonomous Driving Control Design**
Jason Kong, Georg Schildbach, Francesco Borrelli (University of California at Berkeley), Mark Pfeiffer (ETH Zurich)

09:50-10:10, WeOrA1.2
2. **Design of a Robust Yaw Stability Controller for Commercial Vehicles with Parameter Sensitivity Reduction and Stochastic Root Locus**
Baek-soon Kwon, Kyongsu Yi (Seoul National University), Sungsub Kim (Korea Transportation Safety Authority)

10:10-10:30, WeOrA1.3
3. **Surrounding View Based Parking Lot Detection and Tracking**
Kazukuni Hamada, Zhencheng Hu (Kumamoto University), Mengyang Fan, Hui Chen (Tongji University)

10:30-10:50, WeOrA1.4
4. **Performance Bounds on Change Detection with Application to Maneouvre Recognition for Advanced Driver Assistance Systems**
Jan Erik Stellet, Jan Schumacher, Wolfgang Branz (Robert Bosch GmbH), J. Marius Zöllner (FZI Forschungszentrum Informatik)

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**Wednesday, July 1, 2015**

**WePoA1: Poster Session 5**

10:50-12:30 E4 (3F)

Chair: Wooyong Han (ETRI)
Co-Chair: Ji Hyun Yang (Kookmin University)

10:50-12:30, WePoA1.1
1. **Advanced Path Following Control of an Overactuated Robotic Vehicle**
Peter Ritzer, Christoph Winter, Jonathan Brembeck (German Aerospace Center)

10:50-12:30, WePoA1.2
2. **Situation-Aware Decision Making for Autonomous Driving on Urban Road Using Online POMDP**
Wei Liu, Scott Drew Pendleton, Marcelo H Ang Jr (National University of Singapore), Seong-Woo Kim (Singapore-MIT Alliance for Res. and Tech)

10:50-12:30, WePoA1.3
3. **Prioritizing Collision Avoidance and Vehicle Stabilization for Autonomous Vehicles**
Joseph Funke, Matthew Brown, Stephen M. Erlien, Chris Gerdes (Stanford University)

10:50-12:30, WePoA1.4
4. **Multi-Drive Feature Association for Automated Map Generation Using Low-Cost Sensor Data**
Markus Schreiber, André-Marcel Hellmund (FZI Research Center for Information Technology), Christoph Stiller (Karlsruhe Institute of Technology)
5. Path Planning with Orientation-Aware Space Exploration Guided Heuristic Search for Autonomous Parking and Maneuvering
Chao Chen, Markus Rickert (Fortiss GmbH), Alois Knoll (Technische Universität München)

6. General Behavior and Motion Model for Automated Lane Change
Hossein Tehrani Nik Nejad, Masumi Egawa, Kenji Muto (DENSO Corporation), Quoc Huy Do, Keisuke Yoneda, Seiichi Mit (Toyota Technological Institute)

7. A Practical Trajectory Planning Framework for Autonomous Ground Vehicles Driving in Urban Environments
Xiaohui Li, Zhenhong Sun, Qi Zhu, Daxue Liu, Zhen He (National University of Defense Technology)

8. Timing of Unstructured Transitions of Control in Automated Driving
Brian Mok, Mishel John, Hillary Ivey, David Miller, Wendy Ju (Stanford University), Key Jung Lee (Robert Bosch LLC)

9. On Time-Memory Trade-Off for Collision Detection
Albert Rizaldi, Sebastian Söntges, Matthias Althoff (Technische Universität München)

10. Sampling-Based Collision Warning System with Smartphone in Cloud Computing Environment
Hwasoo Yeo, Sehyun Tak, Soomin Woo (KAIST)

11. Uncertainty Propagation in Criticality Measures for Driver Assistance
Jan Erik Stellet, Jan Schuchmacher, Wolfgang Branz (Robert Bosch GmbH), J. Marius Zöllner (FZI Forschungszentrum Informatik)

12. Triggers Algorithm Based on Inevitable Collision States for Autonomous Emergency Braking (AEB) in Motorcycle-To-Car Crashes
Giovanni Savino, Marco Pierini (University of Florence), Julie Brown (University of New South Wales), Matteo Rizzi (Folksam), Michael Fitzharris (Monash University)

13. Impact of Positioning Uncertainty of Vulnerable Road Users on Risk Minimization in Collision Avoidance Systems
Philipp Themann, Jens Kotte, Dominik Raudszus, Lutz Eckstein (RWTH Aachen University)

14. Potential of Intersection Driver Assistance Systems to Mitigate Straight Crossing Path Crashes Using U.S. Nationally Representative Crash Data
John Michael Scanlon, Kristoffer Kusano, Hampton Clay Gabler (Virginia Tech), Rini Sherony (Toyota Motor Engineering and Manufacturing North America)

15. On Threat Assessment and Collision Avoidance for Articulated Machinery in Low-Speed Scenarios
Stefan Bergquist, Christian Grante (Volvo GTT Advanced Technology & Research), Jonas Sjöberg (Chalmers University of Technology)

16. Threat Prediction Algorithm Based on Local Path Candidates and Surrounding Vehicle Trajectory Predictions for Automated Driving Vehicles
Jaehwan Kim, Dongsuk Kum (KAIST)

17. Day and Night-Time Drive Analysis Using Stereo Vision for Naturalistic Driving Studies
Morten Borno Jensen, Mark Philip Philipson, Thomas Moeslund, Andreas Magelmose (Aalborg University), Mohan M. Trivedi, Ravi Kumar Satzoda (University of California at San Diego)

18. Managing the Complexity of Inner-City Scenes: An Efficient Situation Hypotheses Selection Scheme
Stefan Klingelschmitt, Florian Damerow (Technical University of Darmstadt), Julian Eggert (Honda Research Institute Europe GmbH)

19. Predicting Car States through Learned Models of Vehicle Dynamics and User Behaviours
Theodosis Georgiou, Yiannis Demiris (Imperial College London)

20. Guidance Image Based Method for Real-Time Motion Artefact Handling on Time-Of-Flight Cameras
Cedric Schockaert, Frederic Garcia, Bruno Mirbach (IEEE S.A)

21. A Bayesian Filter for Modeling Traffic at Stop Intersections
Thierry Wyder (ETH Zürich), Georg Schildbach, Stéphanie Lefèvre, Francesco Borrelli (University of California at Berkeley)

22. Observing Behaviors at Intersections: A Review of Recent Studies & Developments
Mohammad Shokrolah Shirazi, Brendan Morris (University of Nevada, Las Vegas)

23. A Typical Video-Based Framework for Counting, Behavior and Safety Analysis at Intersections
Mohammad Shokrolah Shirazi, Brendan Morris (University of Nevada, Las Vegas)

24. Driver Behavior Modeling Near Intersections Using SVM Based on Statistical Feature Extraction
Seifemichael Bekele Amsalu, Abdollah Homaifar, Fatemeh Afghah, Saina Ramyar (North Carolina A&T State University), Arda Kurt (The Ohio State University)

25. Classifying Driver’s Uncertainty about the Distance Gap at Lane Changing for Developing Trustworthy Assistance Systems
Fei Yan (University of Oldenburg), Lars Weber, Andreas Luedtke (OFFIS-Institute for Information Technology)
10:50-12:30, WePoA1.26
26. Development of Driver-State Estimation Algorithm Based on Hybrid Bayesian Network
Dong Woon Ryu, Hyeon Bin Jeong, Sang Hun Lee, Woon-Sung Lee, Ji Hyun Yang (Kookmin University)

10:50-12:30, WePoA1.27
27. A Transforming Steering Wheel for Highly Automated Cars
Philipp Kerschbaum, Lutz Lorenz (BMW Research & Technology), Klaus Bengler (Technische Universität München)

10:50-12:30, WePoA1.28
28. Analyzing Driver Gaze Behavior and Consistency of Decision Making During Automated Driving
Chiyoumi Miyajima, Suguru Yamazaki, Hitoshi Terai, Hiroyuki Okuda, Takatsugu Hirayama, Tatsuya Suzuki, Kazuya Takeda (Nagoya University), Takashi Bando, Kentarou Hitomi, Masumi Egawa (DENSO Corporation)

10:50-12:30, WePoA1.29
29. Driver Model with Motion Stabilizer for Vehicle-Driver Closed-Loop Simulation at High-Speed Maneuvering
Youngil Koh, Hyundong Her, Kyongyu Yi (Seoul National University), Kilsu Kim (Hyundai Motor Company)

10:50-12:30, WePoA1.30
30. Using EEG to Recognize Emergency Situations for Brain-Controlled Vehicles
Teng Teng, Luzheng Bi, Xinan Fan (Beijing Institute of Technology)

10:50-12:30, WePoA1.31
31. A 3DoF-Sidestick User Interface for Four Wheel Independent Steering Vehicles
Michael Panzirsch, Bernhard Weber (DLR Oberpfaffenhofen)

10:50-12:30, WePoA1.32
32. An Efficient Multiple Session Key Establishment Scheme for VANET Group Integration
Cheng-Chi Lee (Fu Jen Catholic University), Yan-Ming Lai, Pu-Jen Cheng (National Taiwan University)

10:50-12:30, WePoA1.33
33. Greedy Algorithms for Information Dissemination within Groups of Autonomous Vehicles
Ignacio Llatars, Sebastian Kühlmorgan, Andreas Festag, Gerhard Fettweis (Technische Universität Dresden)

10:50-12:30, WePoA1.34
34. An Efficient Cooperative Lane-Changing Algorithm for Sensor and Communication-Enabled Automated Vehicles
Tanveer Awal, Manzur Murshed, Mortuza Ali (Federation University Australia)

10:50-12:30, WePoA1.35
35. Multi-Vehicle Motion Coordination Using V2V Communication
Xiaotong Shen, Zhuang Jie Chong, Scott Drew Pendleton, Wei Liu, Baoxing Qin, Marcelo H Ang Jr (National University of Singapore), James Guo Ming Fu (Singapore-MIT Alliance for Research and Technology)

10:50-12:30, WePoA1.36
36. Investigating Communications Performance for Automated Vehicle-Based Intersection Control under Connected Vehicle Environment
Joyoung Lee (New Jersey Institute of Technology), Byungkyu (Brian) Park (University of Virginia)

10:50-12:30, WePoA1.37
37. DSRC and Radar Object Matching for Cooperative Driver Assistance Systems
Qi Chen, Ting Yuan, Joerg Hillenbrand, Axel Gern (Mercedes-Benz Research & Development North America), Tobias Roth, Florian Kuhnt, Marius Zoellner (FZI Research Center for Information Technology), Jakob Breu, Miro Bogdanovic, Christian Weiss (Mercedes-Benz Research and Development)

10:50-12:30, WePoA1.38
38. Compensation of Wireless Communication Delay for Integrated Risk Management of Automated Vehicle
Donghoon Shin, Kyongyu Yi (Seoul National University)

10:50-12:30, WePoA1.39
39. Safety Beaconing Rate Control Based on Vehicle Counting in WAVE
Hyogon Kim, Youngtae Park, Piao Haiyue, Byungjo Kim (Korea University)

10:50-12:30, WePoA1.40
40. Adaptive Decision Algorithms for Data Aggregation in VANETs with Defined Channel Load Limits
Josef Jiru, Karsten Roscher (Fraunhofer ESK), Aboobeker Sidhik Koyamparambil Mammu (University of Deusto)

10:50-12:30, WePoA1.41
41. When Will It Change the Lane? a Probabilistic Regression Approach Dealing with Rarely Occurring Events
Julian Schlechtriemen, Andreas Wedel, Gabi Breuel (Daimler AG), Florian Wirthmueller (Illemann University of Technology), Klaus-Dieter Kuhnert (University of Siegen)

Wednesday, July 1, 2015
WeOrM1: Autonomous / Intelligent Robotic Vehicles
14:00-15:20  E1+2+3 (3F)

Chair: Kyoungchul Kong (Sogang University)
Co-Chair: Yeonsik Kang (Kookmin University)

14:00-14:20, WeOrM1.1
1. Context-Aware Tracking of Moving Objects for Distance Keeping
Wenda Xu, Jarrod Snider, Junqing Wei, John Dolan (Carnegie Mellon University)

14:20-14:40, WeOrM1.2
2. The Combinatorial Aspect of Motion Planning: Maneuver Variants in Structured Environments
Philipp Bender, Omer Sahin Tas, Christoph Stiller (FZI Research Center for Information Technology), Julius Ziegler (Atilatec)

14:40-15:00, WeOrM1.3
3. Submap-Based SLAM for Road Markings
Eike Rehder, Alexander Albrecht (Karlsruhe Institute of Technology)

15:00-15:20, WeOrM1.4
4. Turn Prediction at Generalized Intersections
Bo Tang (University of Rhode Island), Salman Khokhar (University of Central Florida), Rakesh Gupta (Honda Research Institute USA Inc)
formed collision and early as possible. Haptic feedback ems. This paper presents a acting and predicting the rear end collision risks. The proposed algorithm could be used for technology enables active steering capability in which the perception is limited due to poor lighting or fog. Steer the environment around them even when human visual eyes have been y. The earlier the system intervenes, the smoother the intervention but the more it interferes with the vehicle trajectory.

An experiment was carried out on a low friction test track, where seven truck drivers repeatedly performed collision avoidance and stabilization with a 4x2 tractor. A previous finding from a simulator study was confirmed: In severe yaw instability, drivers engaged in a yaw rate nulling type of steering behavior, in conflict with the assumptions of conventional electronic stability control (ESC), and the experiment provided indications of conventional ESC behaving suboptimally in these situations. Promising results were obtained for modified versions of the ESC, based on the yaw rate nulling model of steering, but further development work is needed.

A rear-end collision Warning System (CWS) is applied for mitigating collision risk to the front motor vehicle under the traffic conditions. Most of the previous studies have been performed to address the braking behavior related problems based on the deterministic or stochastic parametric methods. However, these algorithms are of doubtful validity in the context of individual driving characteristics such as Perception-Reaction Time (PRT). This paper proposes a framework on Rear-end CWS to take into consideration of PRT effects based on the Artificial Neural Network (ANN). Multi-layer perceptron neural network based rear-end collision warning algorithm (MCWA) is developed and evaluated through a comparison between the conventional algorithms such as Time To Collision (TTC) and Stopping Distance Algorithm (SDA). The comparison study demonstrates that the proposed algorithm outperforms other traditional algorithms for detecting and predicting the rear-end collision risks. The proposed algorithm could be used for rear-end collision warning in car-following case without the influence of different human PRT.

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10:10-10:30, MoOrAT1.2

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10:30-10:50, MoOrAT1.3
3. Creating Predictive Haptic Feedback for Obstacle Avoidance Using a Model Predictive Control (MPC) Framework Avinash Balachandran, Matthew Brown, Stephen M. Erlien, Chris Gerdes (Stanford University)

New sensing technologies allow modern vehicles to perceive the environment around them even when human visual perception is limited due to poor lighting or fog. Steer-by-wire technology enables active steering capability in which the driver's command to the roadwheels is augmented for maintaining safety. Predictive controllers can leverage both of these technologies to create shared control safety systems that work with the driver to ensure a safe and collision-free vehicle trajectory. The earlier the system intervenes, the smoother the intervention but the more it interferes with the driver's control authority. Ideally, predictive controllers should still intervene late but also indicate upcoming environmental threats to the driver as early as possible. Haptic feedback provides a good means of communicating information to the driver early. Together with a controller still providing a late intervention fallback, this regime provides an ideal framework for predictive shared control systems. This paper presents a novel technique for creating haptic steering feedback, based on future differences between the predictive controller and the driver. This feedback mirrors the tension between the sometimes competing controller objectives of following the driver and maintaining a feasible path. The paper uses simulation and experiment to investigate the inherent trade-offs of predictive haptic feedback and qualitatively discuss its impact.

Monday, June 29, 2015
MoPoAT1: Poster Session 1
10:50-12:30

Many traffic accidents occurred at intersections are caused by drivers who miss or ignore the traffic signals. In this paper, we present a new method for automatic detection of traffic lights that integrates both image processing and support vector machine techniques. An experimental dataset with 21299 samples is built from the captured original videos while driving on the streets. When compared to the traditional object detection and existing methods, the proposed system provides significantly better performance with 96.97% precision and 99.43% recall. The system framework is extensible that users can introduce additional parameters to further improve the detection performance.

10:50-12:30, MoPoAT1.1
2. Multi-Type Road Marking Recognition Using Adaboost Detection and Extreme Learning Machine Classification Wei Liu, Jin Lv, Weidong Shang, Huai Yuan (Northeastern University), Bing Yu (Neusoft Corp)

This paper presents a multi-type road marking recognition system by using a monocular camera on a moving platform. The system can detect various road markings. Firstly, an Inverse Perspective Mapping (IPM) transformation is introduced to suppress the perspective effect in the image, and the image slices which potentially belong to road markings are extracted based on high brightness slice filtering. Secondly, the prior knowledge of road making is applied to generate candidate road marking regions. Afterwards, a coarse-to-fine marking recognition method is presented. In the coarse recognition, an Adaboost classifier with Haar-like feature is adopted to fast eliminate non-marking candidates regions. In the fine recognition, an ELM classifier with BW-HOG feature is designed to recognize the types of markings. Finally, we introduce a spatial-temporal fusion method to further enhance the recognition accuracy and reliability of the system. Experimental results demonstrate the effectiveness of the proposed system.
Cameras are an essential component of many Advanced Driver Assistance Systems (ADAS) such as Lane Departure Warning, Lane Keeping Assistance, Automatic Emergency Braking, Traffic Sign Recognition and Night Vision. With the ongoing evolution of ADAS towards Automated Driving, the amount of cameras installed in a vehicle is expected to increase. At the same time, the performance of such cameras needs to match more stringent requirements. Nowadays automotive cameras are typically sensitive beyond the visual range (i.e. into the near infrared range). They may also use up to 20 bits precision for their internal signal. In order to support the development process of ADAS and Automated Driving Systems by means of simulation, it is required to have detailed physically correct simulation models of these automotive cameras. This paper describes the need for physics-based simulation and introduces a new spectral HDR camera model in the ADAS simulation platform PreScan. The traditional RGB-based camera implementation created images limited to the visual spectrum. In contrast, the new PreScan spectral camera model allows for high color depth, broad spectrum and physically correct image generation. The model provides a real-time simulation of light in the 320-1500nm spectral range which traverses through the various media and lenses before the sensor produces the final image signal. Other important features of this new spectral HDR camera model are a depth resolution of 20 bit per waveband as well as an increased dynamic range.

Mengmeng Yu, Guanglin Ma (Delphi China Technology Center)

360 degree surround view system monitoring (SVM) is a very convenient system to help drivers drive through narrow spaces blind-spot-free by looking surround of a vehicle from top view. Nevertheless, it cannot solve the problem of parking. Even with help of 360 degree SVM system, unexperienced drivers still cannot do parking easily. In this paper, we present a parking guidance for SVM system which guides drivers to do parking step by step easily. One of key technologies of parking guidance or intelligent parking system is the path planning. This paper mainly describes two-arc parking path planning scheme. How the HMI of parking guidance applied on SVM system is also described.

5. Vehicle Trajectory Prediction for Adaptive Cruise Control
Sung Gu Yi, Chang Mook Kang, Seung-Hi Lee, Chung Choo Chung (Hanyang University)

In this paper, we propose a new vehicle trajectory prediction algorithm for adaptive cruise control (ACC). When vehicle trajectory prediction is not precise enough, it is possible for a neighboring vehicle to be detected as a target. Thus, we propose a new method using both yaw rate and curvature rate to precisely predict vehicle trajectory and to resolve an undesirable case in ACC system. The proposed method was validated via CarSim and MATLAB/Simulink. Also, we validated the proposed method via experimental results with a test vehicle on highway system for the practicality.

6. Sideslip Estimation for Articulated Heavy Vehicles in Low Friction Conditions
Graeme Morrison, David Cebon (University of Cambridge)

Active safety systems for Heavy Goods Vehicles (HGVs), like passenger cars, often require an accurate estimate of sideslip angle. However, there has been very little research published on sideslip estimation for HGVs in low friction conditions. This paper proposes three nonlinear Kalman Filters to estimate the tractor sideslip angle of a tractor-semitrailer combination. Their performance is compared in simulation to a linear Kalman Filter in both high and low friction conditions. It is found that an Unscented Kalman Filter using a yaw-roll vehicle dynamics model and nonlinear truck tire model can accurately estimate sideslip in all maneuvers simulated, significantly outperforming the linear Kalman Filter.

7. Grid-Based Online Road Model Estimation for Advanced Driver Assistance Systems
Julian Thomas, Kai Stens, Sebastian Rauch (BMW Group Forschung & Tech. GmbH), Raúl Rojas (Berlin University)

The information about the road course and individual lanes is an important requirement in driver assistance systems and for automated driving applications. It is often stored in a highly accurate offline map so that the road and the lanes are known in advance. However, there exist situations where an offline map can become unusable or invalid. This paper presents a novel approach for a road model estimation solely based on online measurements from sensors mounted on the ego vehicle. It combines perception data like detected lane markings, the movement history of dynamic objects in the vehicle’s environment and detected road boundaries into a grid-based road model. This approach allows for an estimation of the road model even when one source of information is not available and offers a redundant source of information about the road, which is necessary in critical applications such as automated driving. The presented approach was tested and evaluated with a prototype vehicle and real sensor data from German highway scenarios.

8. Dynamic Obstacles Avoidance Based on Image-Based Dynamic Window Approach for Human-Vehicle Interaction
Yue Kang, Danilo Alves de Lima, Alessandro Correa Victorino (UTC)

This paper presents an approach for the development of Advanced Driving Assistance System (ADAS) based on the human-vehicle interaction using Image-based Dynamic Window Approach (IDWA). The IDWA is associated to a method for dynamic obstacles avoidance in order to prevent human driving errors, in the context of intelligent robotic vehicles. The human-vehicle interaction is presented by the correction of the Human Driving Behavior (HDB) controller for driving defaults of human drivers, with respect to referential paths that intimate the average driving path in real circumstances. The performance of the proposed human-vehicle interaction methodology, based on autonomous embedded functionalities, is simulated and verified in different bypass scenarios.
Many Advanced Driver Assistance Systems (ADAS) have been developed to improve car safety. However, it is still a challenging problem to make autonomous vehicles to drive safely on urban streets such as uncontrolled Intersections (without traffic lights) and narrow roads. In this paper, we introduce a decision making system that can assist autonomous vehicles at uncontrolled Intersections and narrow roads. We constructed a machine understandable ontology-based Knowledge Base, which contains maps and traffic regulations. The system makes decisions in comply with traffic regulations such as Right-Of-Way rules when it receives a collision warning signal. The decisions are sent to a path planning system to change the route or stop to avoid collisions.

In advanced driver assistance systems, the stereo matching algorithm is the key resource to obtain depth information of outdoor scenes. Semi-Global Matching (SGM) is currently the most efficient stereo matching algorithm for outdoor environments. However, because the number of pixels is large, SGM uses only a subset of them when estimating the disparity of a pixel. To overcome this limitation, Cost Aggregation Table (CAT) was proposed which uses two-dimensional cost aggregation so as to utilize whole image information. In this paper, we propose improved global 2D cost aggregation methods by loosening aggregation constraints. It aggregates every cost in the whole image to estimate each disparity. Although our method aggregates every cost in the image, the computational complexity is the same as that of SGM and CAT. The proposed cost aggregation method achieves superior disparity accuracy compared to the SGM.

For a vehicle driving safe inside a parking garage autonomously, it is necessary to build a map with its surroundings and also to localize itself within this map. This is known as Simultaneous Localization And Mapping (SLAM). To enable the vehicle to drive autonomously to an assigned parking slot, a parking area, or the exit, the vehicle also needs knowledge about the whole map of the parking garage. This map only contains static elements of the parking garage. Variable elements are not known to the parking garage and therefore are not contained in this static map. In order to reach a target, the vehicle needs to localize itself with respect to this static map. In this contribution the use of such a static map is proposed to support SLAM. This enables SLAM to determine poses related to a static map. Also the performance of SLAM is improved.

In this paper an extension to the sampling based motion planning framework CL-RRT is presented. The framework uses a system model and a stabilizing controller to sample the perceived environment and build a tree of possible trajectories that are evaluated for execution. Complex system models and constraints are easily handled by a forward simulation making the framework widely applicable. To increase operational safety we propose a sampling recovery scheme that performs a deterministic brake profile regeneration using collision information from the forward simulation. This greatly increases the number of safe trajectories and also reduce the number of samples that produce infeasible results. We apply the framework to a Scania G480 mining truck and evaluate the algorithm in a simple yet challenging obstacle course and show that our approach greatly increases the number of feasible paths available for execution.

By the cooperative and competitive PSO algorithm, the goal of this study is to provide the cooperative trajectories of multiple UAVs in the three dimensional space. To effectively reduce the dimension of this problem, the optimization process is mainly divided into two substages to reduce the difficulty of selecting the weights of objectives and constraints in the considered objective function. Considering several objectives and constraints, the cooperative trajectories in the first substage are given by the cooperative and competitive PSO algorithm in the two dimensional space. In the second substage, the altitude of cooperative trajectories is adjusted according to the considered objectives and constraints. In the complicated scenarios, simulation results demonstrate the effectiveness and the robustness of the cooperative and competitive PSO algorithm, which possibly provides one guideline for optimal cooperative planning trajectories of multiple UAVs in the three-dimensional space.

Overtaking of a vehicle moving on structured roads is one of the most frequent driving behavior. In this work, we have described a Real Time Control System based framework for overtaking maneuver of autonomous vehicles. Proposed framework incorporates Intelligent Planning and Modular control modules. Intelligent Planning module of the framework enables the vehicle to intelligently select the most appropriate behavioral characteristics given the perceived operating environment. Subsequently, Modular control module reduces the search space of overtaking trajectories through an SVM based learning approach. These trajectories are then examined for possible future time collision using Velocity Obstacle. It employs non linear time scaling that provides for continuous trajectories in the space of linear and angular velocities to achieve continuous curvature overtaking.
maneuvers respecting velocity and acceleration bounds. Further time scaling also can scale velocities to avoid collisions and can compute a time optimal trajectory for the learned behavior. The preliminary results show the appropriateness of our proposed framework in virtual urban environment.

10:50-12:30, MoPoAT1.15
15. Development and Implement of an Inspection Robot for Power Substation
Haojie Zhang, Bo Su, Haiping Song, Wei Xiong (China North Vehicle Research Institute)

Along with the development demand of intelligent power substation, mobile robot is implemented to serve power substations. The robot is equipped with inspecting sensors, such as CCD camera and thermal infrared imager which are together referred to as workload. These inspecting sensors are used to detect the environment parameters e.g. reading meter, measuring temperature etc., inside the substation. However, due to the strong electromagnetic interference inside substation, accurate localization of the workload and inspection robot is still a difficult problem to be solved. Existing methods solve the problem by paving magnetic strips or rail. However, in this way, the working area of the robot is limited by the paved infrastructures. In this paper, an inspection robot system is developed for working in substation. In the proposed system, the localization of the robot is realized using adaptive Monte-Carlo localization based on the known environment model. A visual servo system is designed to realize the high accuracy localization of the workload. The proposed robot system should guarantee to obtain fine inspecting results of equipments in substation.

10:50-12:30, MoPoAT1.16
16. A Robust Lane Detection and Departure Warning System
Mrinal Haloi (IIT Guwahati), Dinesh Babu Jayagopi (iiIT Bangalore)

In this work, we have developed a robust lane detection and departure warning technique. Our system is based on single camera sensor. For lane detection a modified Inverse Perspective Mapping using only a few extrinsic camera parameters and illuminant Invariant techniques is used. Lane markings are represented using a combination of 2nd and 4th order steerable filters, robust to shadowing. Effect of shadowing and extra sun light are removed using Lab color space, and illuminant invariant representation. Lanes are assumed to be cubic curves and fitted using robust RANSAC. This method can reliably detect lanes of the road and its boundary. We have experimented this algorithm in Indian road conditions and the result obtained is very good. For lane departure angle an optical flow based method is used.

10:50-12:30, MoPoAT1.17
17. 360° Detection and Tracking Algorithm of Both Pedestrian and Vehicle Using Fisheye Images
Antonio Priolletti, Pietro Versari, Massimo Bertozzi, Luca Castangia, Stefano Cattani (University of Parma)

All-around view is a mandatory element for autonomous vehicles. The European V-Charge project seeks to develop an autonomous vehicle using only low-cost sensors. This paper presents a detection and tracking algorithm that covers all the area around the vehicle using 4 fisheye cameras only. The algorithm is able to detect pedestrians and vehicles and track them, using cylindrical images. This paper presents the whole pipeline, from the image un-warping to the classification and the tracking algorithms, together with some results.

10:50-12:30, MoPoAT1.18
18. Distributed Graph-Based Convoy Control for Networked Intelligent Vehicles
Ali Marjovi, Milos Vasic, Joseph Lemaitre, Alcherio Martinoli (EPFL)

This paper presents an approach for formation control of multi-lane vehicular convoys in highways. We extend a Laplacian graph-based, distributed control law such that networked intelligent vehicles can join or leave the formation dynamically without jeopardizing the ensemble’s stability. Additionally, we integrate two essential control behaviors for lane-keeping and obstacle avoidance into the controller. To increase the performance of the convoy controller in terms of formation maintenance and fuel economy, the parameters of the controller are optimized in realistic scenarios using Particle Swarm Optimization (PSO), a powerful metaheuristic optimization method well-suited for large parameter spaces. The performances of the optimized controllers are evaluated in high-fidelity multi-vehicle simulations outlining the efficiency and robustness of the proposed strategy.

10:50-12:30, MoPoAT1.19
19. Dimensions of Cooperative Driving, ITS and Automation
Maytheewat Aramrattana, Tony Larsson (Halmstad University), Jonas Jansson (VTI), Cristofer Englund (Viktoria Swedish ICT)

Wireless technology supporting vehicle-to-vehicle (V2V), and vehicle-to-infrastructure (V2I) communication, allow vehicles and infrastructures to exchange information, and cooperate. Cooperation among the actors in an intelligent transport system (ITS) can introduce several benefits, for instance, increase safety, comfort, efficiency. Automation has also evolved in vehicle control and active safety functions. Combining cooperation and automation would enable more advanced functions such as automated highway merge and negotiating right-of-way in a cooperative intersection. However, the combination have influences on the structure of the overall transport systems as well as on its behaviour. In order to provide a common understanding of such systems, this paper presents an analysis of cooperative ITS (C-ITS) with regard to dimensions of cooperation. It also presents possible influence on driving behaviour and challenges in deployment and automation of C-ITS.

10:50-12:30, MoPoAT1.20
20. The Influence of Traffic on Heavy-Duty Vehicle Platoon Formation
Kuo-Yun Liang, Qichen Deng, Jonas Mårtensson, Xiaoliang Ma, Karl H. Johansson (KTH Royal Institute of Technology)

Heavy-duty vehicle (HDV) platooning is a mean to significantly reduce the fuel consumption for the trailing vehicle. By driving close to the vehicle in front, the air drag is reduced tremendously. Due to each HDV being assigned with different transport missions, platoons will need to be frequently formed, merged, and split. Driving on the road requires interaction with surrounding traffic and road users, which will influence how well a platoon can be formed. In this paper, we study how traffic may affect a merging maneuver of two HDVs trying to form a platoon. We simulate this for different traffic densities and for different HDV speeds. Even on moderate traffic density, a platoon merge could be delayed with 20% compared to the ideal case with no traffic.
Despite the existing regulation efforts and measures, vehicles with dangerous goods still pose significant risks on public safety, especially in road tunnels. Solutions based on cooperative intelligent transportation system (C-ITS) are promising measures, however, they have received limited attention. We propose C-ITS applications that coordinate dangerous goods vehicles to minimize the risk by maintaining safe distances between them in road tunnels. Different mechanisms, including global centralized coordination, global distributed coordination, and local coordination, are proposed and investigated. A preliminary simulation is performed and demonstrates their effectiveness.

Small objects on the road can become hazardous obstacles when driving at high speed. Detecting such obstacles is vital to guarantee the safety of self-driving car users, especially on highways. Such tasks cannot be performed using existing active sensors such as radar or LiDAR due to their limited range and resolution at long distances. In this paper we propose a technique to detect anomalous patches on the road from color images using a Restricted Boltzman Machine neural network specifically trained to reconstruct the appearance of the road. The differences between the observed and reconstructed road patches yield a more relevant segmentation of anomalies than classic image processing techniques. We evaluated our technique on texture-based synthetic datasets as well as on real video footage of anomalous objects on highways.

Novice young drivers are more frequently involved in traffic accidents, and studies have shown that effective supervised driver training is the key in reducing young drivers' risks. Using our previously developed Mobile-UTDrive in-vehicle data acquisition platform, two 16-age novice drivers participated in naturalistic drive training data collection. This paper focuses on analysis of novice driver training signals from an audio processing perspective. Specifically, analysis of supervised driver instruction audio and resulting CAN-Bus maneuver operation is performed. Following a procedure which consists of noise suppression, speech recognition and keyword spotting, five tutorial keywords – Brake, Gas, Left, Right and Stop – are spotted at an overall accuracy rate of 40% versus all spontaneous continuous speech. The time stamps of these keywords are then used as indications of driving maneuvers. As examples of driving performance evaluation, the case of making Left-Turn maneuvers for the two novice drivers are assessed and compared, and the increase of driving skills over experiences are analyzed.

Keeping a driver focused on the road is one of the most critical steps in insuring the safe operation of a vehicle. The Strategic Highway Research Program 2 (SHRP2) has over 3,100 recorded videos of volunteer drivers during a period of 2 years. This extensive naturalistic driving study (NDS) contains over one million hours of video and associated data that could aid safety researchers in understanding where the driver’s attention is focused. Manual analysis of this data is infeasible; therefore efforts are underway to develop automated feature extraction algorithms to process and characterize the data. The real-world nature, volume, and acquisition conditions are unmatched in the transportation community, but there are also challenges because the data has relatively low resolution, high compression rates, and differing illumination conditions. A smaller dataset, the head pose validation study, is available which used the same recording equipment as SHRP2 but is more easily accessible with less privacy constraints. In this work we report initial head pose accuracy using commercial and open source face pose estimation algorithms on the head pose validation data set.

We propose a cascade method for fast and accurate traffic sign detection. The main feature of the method is that mid-level saliency test is used to efficiently and reliably eliminate background windows. Fast feature extraction is adopted in the subsequent stages for rejecting more negatives. Combining with neighbor scales awareness in window search, the proposed method runs at 3~5 fps for high resolution (1360×800) images, 2~7 times as fast as most state-of-the-art methods. Compared with them, the proposed method yields competitive performance on prohibitory signs while sacrifices performance moderately on danger and mandatory signs.
10:50-12:30, MoPoAT1.27
27. CRF Based Road Detection with Multi-Sensor Fusion
Liang Xiao, Bin Dai, Daxue Liu, Tingbo Hu, Tao Wu (National University of Defense Technology)

In this paper, we propose to fuse the LIDAR and monocular image in the framework of conditional random field to detect the road robustly in challenging scenarios. LIDAR points are aligned with pixels in image by cross calibration. Then boosted decision tree based classifiers are trained for image and point cloud respectively. The scores of the two kinds of classifiers are treated as the unary potentials of the corresponding pixel nodes of the random field. The fused conditional random field can be solved efficiently with graph cut. Extensive experiments tested on KITTI-Road benchmark show that our method reaches the state-of-the-art.

10:50-12:30, MoPoAT1.28
28. Automatic LED Text Recognition Method on Electronic Road Sign Using Local Spatial Pattern and Random Forest Classifier
Wahyono Wahyono, Alexander Filonenko, Kang-Hyun Jo (University of Ulsan)

In the field of intelligent transportation systems (ITS), an electronic road sign (ERS) is an important device for giving a real-time traffic-related information. The ERSs generally displays dynamic text information that each character consists of matrix of a light-emitting diodes lamp, named LED text. This paper addresses an LED text detection and recognition method, as an application of intelligent transportation systems (ITS) for assisting the driver. Our method is divided into several main stages. First, the ERS is localized from the input image using color model on the RGB-color space. Second, LED text contained on the ERS are detected based on supporting points. supporting points representing as a center of LED segment on binary map of the input image. Third, each character of LED text is recognized using local spatial pattern feature and random forest classifier. Last, the recognized characters are merged into text line. Experimental results verify that the proposed method is a robust to detect and recognize the LED text.

10:50-12:30, MoPoAT1.29
29. Sparse Depth Map Upsampling with RGB Image and Anisotropic Diffusion Tensor
Yuhang He, Ming Li (Wuhan University), Long Chen (Sun Yat-Sen University)

This paper proposes a novel algorithm for upsampling 2D sparse depth map projected by laser scanner (i.e. Velodyne HDL-64E) using its synchronised RGB image and Anisotropic Diffusion Tensor. We assume each depth-unknown pixel's depth value derives from all depth-known pixels and their affinity can be measured in a geodesic manner. Specifically, for each depth-unknown point, we compute its geodesic distance to all depth-known points, the cost of each geodesic path is calculated by spatial distance, color aberrance and tensor discrepancy, which compacts with the assumption that color homogenous region corresponds to close or smooth depth value, while depth discontinuity often occurs in image edges. To reduce computation complexity, we further introduced a flexible approximation algorithm in which the complexity is linear to image's size and can be further reduced with different accuracy requirement. Finally, we evaluate our algorithm on both KITTI visual benchmark suite and Middlebury dataset. Experiment shows that, while generating smooth and dense upsampling result, our algorithm retains sharp depth discontinuity even in object's boundary of distance location and few laser scanner points cover it. Besides, our algorithm is parameter-insensitive, which frees us from laboriously finding appropriate parameters to get fine result. We hope our work would motivate more research on laser point upsampling and their combination with RGB image, especially in outdoor scenes for autonomous driving.

10:50-12:30, MoPoAT1.30
30. Advanced 3-D Trailer Pose Estimation for Articulated Vehicles
Christian Fuchs, Frank Neuhaus, Dietrich Paulus (University of Koblenz-Landau)

When crafting driver assistance systems designed for truck/trailer combinations, knowledge about the position and orientation of a truck relative to the attached trailer is a vital prerequisite for any kinematic calculation and trajectory estimation. An advanced optical sensor system measuring the 3-D state of an attached two-axle trailer is proposed in this publication. It uses a Kalman filter for enhanced pose estimation and is evaluated against previous versions of the sensor system for the same purpose.

10:50-12:30, MoPoAT1.31
31. Reduction Effect of Traffic Accidents by Driver's Psychosomatic State Monitoring Function
Masahiro Miyaji (Aichi Prefectural University)

Traffic fatalities and injuries in Japan have declined for fourteen years by comprehensive counter-measures. One of efforts has included enhancement of vehicle safety performance in passive and preventive safety. Pertaining to passive safety, major reduction effect has been brought by airbag systems, seat belts and crashworthiness of vehicles. To further reduce the traffic accident, preventive safety may play more important role. Recently driver's psychosomatic state adaptive driving support safety function has been highlighted to further reduce the number of traffic accident. Accordingly reduction effect of psychosomatic adaptive driving support safety function should be clarified to foster its penetration into the market. Statistical analysis of the traffic accident is highly expected to evaluate reduction effect of the traffic accident. In this study experiences of traffic incidents was analyzed by using the data collected through Internet. From the results this study focused driver's distraction, which may cause severe traffic accidents. By using pattern recognition, detection accuracy of driver's cognitive distraction was acquired. Reduction rate by using function of driver's distraction detection was estimated by referring the reduction rate of both Advanced Safety Vehicle and Intelligent Transportation Systems.

10:50-12:30, MoPoAT1.32
32. Pedestrian Detection Based on Deep Convolutional Neural Network with Ensemble Inference Network
Hiroshi Fukui, Takayoshi Yamashita, Yuji Yamauchi, Hironobu Fujiyoshi (Chubu University), Hiroshi Murase (Nagoya University)

Pedestrian detection is an active research topic for driving assistance systems. To install pedestrian detection in a regular vehicle, however, there is a need to reduce its cost and ensure high accuracy. Although many approaches have been developed, vision-based methods of pedestrian detection are best suited to these requirements. In this paper, we propose the methods based on Convolutional Neural Networks (CNN) that achieves high accuracy in various fields. To achieve such generalization, our CNN-based method introduces Random Dropout and Ensemble Inference Network (EIN) to the training and classification processes, respectively. Random Dropout selects units that have a flexible rate, instead of the fixed rate in conventional Dropout.
EIN constructs multiple networks that have different structures in fully connected layers. The proposed methods achieve comparable performance to state-of-the-art methods, even though the structure of the proposed methods are considerably simpler.

10:50-12:30, MoPoAT1.33
33. Traffic Trajectory History and Drive Path Generation Using GPS Data Cloud
Ekim Yurtselver, Kazuya Takeda, Chiyomi Miyajima (Nagoya University)

This paper proposes a novel approach for extracting the traffic trajectory history, with the use of GPS data collected over a certain period of time, to be used as an input for driver models. In this approach, driving curvature is distinguished from actual road shape curvature with the use of real driving data. After sufficient amount of drive data has been collected, high degree polynomials are fitted to GPS point cloud. Traffic trajectory history is the tangential unit vectors and curvature values that are calculated from these polynomials. Then a single drivers driving path has been predicted with using traffic trajectory history and road shape curvature for comparison and validation. Experimental results show that the predictions made with categorized traffic trajectory history have less errors than the predictions made with road shape curvature.

10:50-12:30, MoPoAT1.34
34. Short-Term Visual Mapping and Robot Localization Based on Learning Classifier Systems and Self-Organizing Maps
Arthur Miranda Neto (Federal University of Lavras)

Ground wheeled autonomous robots like driverless cars are examples of applications which would assist humans on different tasks. From an explicit or emerging need, these systems have come to replace or assist drivers. Estimating the position is a primary function for intelligent vehicle navigation. Different existing solutions use high-end sensors. This paper proposes to augment the autonomy level of a mobile robot based on learning classifier systems and self-organizing maps. From a simple monocular system, whilst the classifier system leads the robot for topological localization, the neural network is applied as a short-term visual memory for internal representation of the environment. These two concepts are presented as separate approaches, wherein each method performs a specific task for the robot’s trajectory control.

10:50-12:30, MoPoAT1.35
35. Velodyne-Based Curb Detection up to 50 Meters Away
Tongtong Chen, Bin Dai, Daxue Liu, Jinze Song, Zhao Liu (National University of Defense Technology)

Long range curb detection is crucial for an Autonomous Land Vehicle (ALV) navigation in urban environments. This paper presents a novel curb detection algorithm which can detect the curbs up to 50 meters away with Velodyne LIDAR. Instead of building a Digital Elevation Map (DEM) and utilizing geometric features (like normal direction) to extract candidate curb points, we take each scan line of Velodyne LIDAR as a processing unite directly. Some feature points, which are extracted from individual scan lines, are selected as the initial curb points by the distance criterion and Hough Transform (HT). Eventually, iterative Gaussian Process Regression (GPR), which utilizes the above initial curb points as the initial seeds, is exploited to represent both the curved and straight-line curb model. In order to verify the effectiveness of our algorithm quantitatively, 2934 Velodyne scans are collected in various urban scenes with our ALV, and 566 of them are labelled manually. Our algorithm is also compared with two other curb detection techniques. The experimental results on the dataset show promising performance.

10:50-12:30, MoPoAT1.36
36. Clustering Improved Grid Map Registration Using the Normal Distribution Transform
Matthias Rapp, Michael Barjenbruch, Klaus Dietmayer (University of Ulm), Markus Hahn (Daimler AG), Jürgen Dickmann (Mercedes-Benz AG)

Grid map registration is an important field in mobile robotics. Applications in which multiple robots are involved benefit from multiple aligned grid maps as they provide an efficient exploration of the environment in parallel. In this paper, a normal distribution transform (NDT)-based approach for grid map registration is presented. For simultaneous mapping and localization approaches on laser data, the NDT is widely used to align new laser scans to reference scans. The original grid quantization-based NDT results in good registration performances but has poor convergence properties due to discontinuities of the optimization function and absolute grid resolution. This paper shows that clustering techniques overcome disadvantages of the original NDT by significantly improving the convergence basin for aligning grid maps. A multi-scale clustering method results in an improved registration performance which is shown on real world experiments on radar data.

10:50-12:30, MoPoAT1.37
37. Road Detection with Thermal Cameras through 3D Information
Gustavo Pelaez, Fernando Garcia, Arturo de la Escalera (Carlos III University of Madrid), Daniel Bacara (Signum Bildtechnik), Cristina Olaverri Monreal (AIT)

Ground detection algorithms are important for locating the area where a vehicle can travel during autonomous navigation or for collision avoidance Advanced Driver Assistance Systems (ADAS). In order to do this, they must provide a reliable representation of the surroundings that is free of static or dynamic obstacles. With today’s technology, detection results have improved, due to higher quality resolution and increased accuracy of sensors, as well as better computational power increment of the processors. Therefore, more powerful ground detection algorithms can be executed that return a more robust result. Although many algorithms rely on a single camera to detect the ground, they don’t consider the possibility of combining transformation approaches with additional information that could be obtained from another camera mounted on the vehicle. In this paper, we propose an algorithm for ground detection that allows the use of disparity maps and the combination of depth information to enhance road detection. To this end we propose an original approach based on a thermal stereo system to analyze the thermal features of the road that are then complemented by the depth information obtained from the disparity map. We tested the algorithm with a variety of complex scenarios and results showed that the 2D and 3D data enabled accurate detection of the road.

10:50-12:30, MoPoAT1.38
38. Design of an Interactive Multiple Model Based Two-Stage Multi-Vehicle Tracking Algorithm for Autonomous Navigation
Ashesh Goswami, C.S.George Lee (Purdue University)

Information regarding vehicles in neighboring lanes is essential to an autonomous vehicle for decision-making
during lane-change maneuvers. Complete autonomy requires effective velocity estimation of the neighboring vehicles under different road scenarios. A two-stage interactive-Multiple-Model-based (IMM) estimator has been proposed to perform multiple target-tracking with application to vehicles in a lane-changing scenario. The first stage deals with an adaptive-window-based turn-rate estimation for tracking maneuvering targets. The estimator can detect abrupt changes in turn-rates and function independently, and avoids the problem of non-linear vehicle dynamics, thereby facilitating the use of standard Kalman filter. Variable-structure models with updated estimated turn-rate are utilized in the second stage to perform data association followed by IMM-based velocity estimation. The proposed algorithm results in root-mean-squared error of position and velocity to 5 cm and 0.25-0.3 m/s, respectively, and the turn-rate converges up to 10% accuracy within 3-4 s. The algorithm has been validated using simulations and experimentation using mobile robots in a simulated lane environment.

10:50-12:30, MoPoAT1.39
39. Feature-Based Mapping and Self-Localization for Road Vehicles Using a Single Grayscale Camera
Manuel Stuebler, Juergen Wiest, Klaus Dietmayer (University of Ulm)

This paper introduces a precise self-localization method for road vehicles. The presented approach is based on a single grayscale camera in addition with a conventional estimation of the ego motion and a map of the environment. This map is built in advance and independently from the localization process utilizing the same techniques. The proposed algorithm is based on Maximally Stable Extremal Regions which are robust features that are extracted from grayscale images. These features are matched in consecutive images using moment invariants. Together with an estimation of the ego motion, a 3D reconstruction of corresponding landmarks is obtained by applying multiple view geometry. For the unsupervised mapping process, landmarks are tracked and their corresponding global coordinates are stored in a geospatial database using a high-precision real-time kinematic system. The localization process itself is based on a particle filter to estimate the pose of the vehicle by making use of the previously generated map and currently observed landmarks. A standard GPS receiver is used to initialize the pose estimate. The evaluation with real world data shows that this approach achieves very good results despite the marginal sensor setup.

10:50-12:30, MoPoAT1.40
40. Building a Probabilistic Grid-Based Road Representation from Direct and Indirect Visual Cues
Edoardo Casapietra, Franz Kummert (Bielefeld University), Thomas H. Weisswange, Christian Goerick, Jannik Fritsch (Honda Research Institute Europe GmbH)

Detecting the road terrain ahead of the ego-vehicle is an important issue for modern driver assistance systems. In particular, vehicle motion planning in inner city environment requires the detection of road terrain up to 3 seconds in advance. State-of-the-art visual road terrain detection systems have a hard time fulfilling this task, due to their limited range and the presence of occlusions (other vehicles, buildings, etc.), which are expected to occur often in complex scenarios. However, those systems provide significant information where the conditions are favorable (proximity to the ego-vehicle, no occlusions). Therefore, a complementary approach is needed to enhance already existing and established detection systems. In this paper we propose a probabilistic grid-based approach based on the observation and interpretation of other vehicles’ behavior in the scene. It exploits their movements in order to infer the presence and location of occluded road surface. We will show that this approach presents various advantages over current visual road terrain detection systems, especially in those situations that are the most challenging for them. We will illustrate how our approach is designed to work in concert also with other available resources, e.g. offline road maps. Qualitative results on real-world scenes taken from the KITTI benchmark[Geiger et al., 2012] demonstrate that the fusion of this method with visual road terrain detection can potentially extend our time horizon well over the 3 seconds mentioned above. Finally, we will show how our approach is planned to develop into a semantically enriched representation of the road, including road properties such as availability, lanes and directions.

Traffic light detection and recognition play a more important role in Advanced Driver Assistance Systems and driverless cars. This paper presents a method of integrating Visual Selective Attention (VSA) model with HOG features to solve the problem of detecting and recognizing traffic lights in complex urban environment. First of all, the VSA model is used to get candidate regions of the traffic lights. Then, the HOG features of the traffic lights and SVM classifier are used in these candidate regions to get precise regions of traffic lights. Within these regions, the color of traffic light is recognized according to the information in the gray-scale image of channel A. Experimental results show that the proposed method has strong robustness and high accuracy.

Monday, June 29, 2015
MoOrMT1: Vehicle Control
14:00-15:20 E1+2+3 (3F)
Chair: Ryan Eustice (University of Michigan) 
Co-Chair: Dongsuk Kum (KAIST)

1. An Overview of Vehicular Platoon Control under the Four-Component Framework
Shengbo Li, Yang Zheng, Keqiang Li, Jianqiang Wang (Tsinghua University)

The platooning of autonomous ground vehicles has potential to largely benefit the road traffic, including enhancing highway safety, improving traffic utility and reducing fuel consumption. The main goal of platoon control is to ensure all the vehicles in the same group to move at consensual speed while maintaining desired spaces between adjacent vehicles. This paper presents an overview of vehicular platoon control techniques from networked control perspective, which naturally decomposes a platoon into four interrelated components, i.e., 1) node dynamics (ND), 2) information flow topology (IFT), 3) distributed controller (DC) and, 4) geometry formation (GF). Under the four-component framework, existing literature are categorized and analyzed according to their technical features. Three main performance metrics, i.e. string stability, stability margin and coherence behavior are also discussed.
14:20-14:40, MoOrMT1.2
2. Stochastic Model Predictive Controller with Chance Constraints for Comfortable and Safe Driving Behavior of Autonomous Vehicles
David Lenz, Tobias Kessler (Fortiss GmbH), Alois Knoll (Technology University München)

In this paper, we address the application of stochastic model predictive control with chance constraints to autonomous driving. We use a condensed formulation of a linearized vehicle model to setup a quadratic program with nonlinear chance constraints, which can be solved with off-the-shelf optimization algorithms. We further show how obstacle information in the path planning stage can be converted into a set of linear state constraints that can be directly used in the control algorithm. The resulting controller is potentially real-time capable and achieves a tradeoff between safety and comfort in its control behavior.

14:40-15:00, MoOrMT1.3
3. GPS Waypoint Fitting and Tracking Using Model Predictive Control
Soo Jung Jeon, Chang Mook Kang, Seung-Hi Lee, Chung Choo Chung (Hanyang University)

In this paper, we are interested in the situation of the ego vehicle tracking the previous vehicle's GPS waypoint on highway. Even if waypoints are irregular, in order to improve the tracking performance and steering performance of the GPS waypoint tracking, curve fitting and model predictive control have been applied. The improvement of the performance of the waypoint tracking was validated via computational experimental results.

15:00-15:20, MoOrMT1.4
4. Toward Integrated Motion Planning and Control Using Portable Foresighted Torque-Based Steering Actuation for Autonomous Driving
Enric Galceran, Ryan Eustice, Edwin Olson (University of Michigan)

This paper proposes an integrated motion planning and control approach for autonomous car navigation. Existing approaches to autonomous vehicle navigation typically plan a trajectory and pass it on to a steering controller that commands SWA or curvature at every timestep to minimize tracking error. However, this approach exhibits large amounts of control effort, and ignores other criteria such as smoothness or the importance of staying on plan at different times. Conversely, our proposed approach leverages the concept of potential fields to represent a driving corridor with a desired tracking error tolerance and direct torque-based steering control to smoothly steer the vehicle with a much smaller control effort. Further, using potential fields allows us to naturally incorporate obstacles in the driving corridor to circumvent them, with typically no need for explicit trajectory planning. We compare our approach to a standard steering controller in experiments with a real-world autonomous vehicle platform. Results show that our proposed approach achieves similar path tracking performance as a high-gain SWA controller, but with much less actuator effort.

Monday, June 29, 2015

MoPoPT1: Poster Session 2
15:20-17:00 E4 (3F)

Chair: Gyu-In Jee (Konkuk University)
Co-Chair: Ho Gi Jung (Hanyang University)

15:20-17:00, MoPoPT1.1
1. LED Traffic Sign Detection with the Fast Radial Symmetric Transform and Symmetric Shape Detection
Wooyeon Jun, Jeong-Mok Ha, Byeongchan Jeon, Joon-Ho Lee, Hong Jeong (POSTECH)

We present a method that can detect a circular traffic signs and Light Emitting Diode (LED) traffic signs by combining fast radial symmetric transform and a proposed symmetric shape detection method. The proposed method can choose the appropriate size and sign type by computing the confidence of given image to each pre-defined signs. In a real road video that includes LED signs and circular traffic signs, our algorithm scored 94.3 % detection ratio and 0.33 false positive per frame; these results are acceptable in advanced driver assistance systems.

15:20-17:00, MoPoPT1.2
2. A Driving Path Based Target Object Prediction
Joeran Zeisler, Juri Cherepanov, Vladimir Haltakov (Bmw Ag)

The determination of the target object has been a challenging task since the development of Adaptive Cruise Control and is subject to numerous scientific contributions, providing improvements towards predictive detection. Autonomous driving functions have to assure safe and comfortable traveling under all conditions. The recognition of a future target object has to be reliable, independently of the surrounding situation. State-of-the-art systems however, still show difficulties detecting close cut-in maneuvers of other traffic participants in time. In this paper we propose a probabilistic approach to predict the relevance of surrounding vehicles as target object. We model the driving path of the ego vehicle, determined from the vehicle dynamics. By the use of an object oriented Bayesian network we are able to model relations between the derived path and the surrounding vehicles to determine their relevance as target object. The experimental results demonstrate the outcome of our implementation under real world conditions. An average decrease of 40% in detection time, compared to a visible lane marking crossing during a lane change of the vehicles is achieved.

15:20-17:00, MoPoPT1.3
3. The Foresighted Driver Model
Julian Eggert (Honda Research Institute Europe GmbH), Florian Damerow, Stefan Klingelschmitt (Technology University of Darmstadt)

The Intelligent Driver Model (IDM) is a microscopic, time continuous car following model for the simulation of freeway and urban traffic. Its popularity is grounded in its simplicity and its capacity to describe both single vehicle velocity profiles as well as collective traffic behavior. Nevertheless, it lacks a series of properties that would be desirable for more realistic agent models. In this paper, as an alternative and improvement to the IDM, we propose the Foresighted Driver Model (FDM), which assumes that a driver acts in a way that balances predictive risk (e.g. due to possible collisions along its route) with utility (e.g. the time required to travel, smoothness of ride, etc.). Based on a risk concept developed for full behavior planning, we introduce driver model equations from the assumption that a driver will mainly try to avoid risk maxima in time and space. We show how such a
model can be used to simulate driving behavior similar to full behavior planning models and which generalizes and reaches beyond the IDM modeling scenarios.

15:20-17:00, MoPoPT1.4
Andreas Megelmose, Thomas Moeslund (Aalborg University), Mohan M. Trivedi (University of California at San Diego)

This paper presents a monocular and purely vision based pedestrian trajectory tracking and prediction framework with integrated map-based hazard inference. In Advanced Driver Assistance systems research, a lot of effort has been put into pedestrian detection over the last decade, and several pedestrian detection systems are indeed showing impressive results. Considerably less effort has been put into processing the detections further. We present a tracking system for pedestrians, which based on detection bounding boxes tracks pedestrians and is able to predict their positions in the near future. The tracking system is combined with a module which, based on the car’s GPS position acquires a map and uses the road information in the map to know where the car can drive. Then the system warns the driver about pedestrians at risk, by combining the information about hazardous areas for pedestrians with a probabilistic position prediction for all observed pedestrians.

15:20-17:00, MoPoPT1.5
5. A Light-Weight Real-Time Applicable Hand Gesture Recognition System for Automotive Applications
Thomas Kopinski, Stéphane Magand, Uwe Handmann (Hochschule Ruhr West), Alexander Geppert (Ec. Nationale Superieure De Tech. Avancées)

We present a novel approach for improved hand-gesture recognition by a single time-of-flight (ToF) sensor in an automotive environment. As the sensor’s lateral resolution is comparatively low, we employ a learning approach comprising multiple processing steps, including PCA-based cropping, the computation of robust point cloud descriptors and training of a Multilayer perceptron (MLP) on a large database of samples. A sophisticated temporal fusion technique boosts the overall robustness of recognition by taking into account data coming from previous classification steps. Overall results are very satisfactory when evaluated on a large benchmark set of ten different hand poses, especially when it comes to generalization on previously unknown persons.

15:20-17:00, MoPoPT1.6
6. Accelerometer Tyre to Estimate the Aquaplaning State of the Tyre-Road Contact
Arto Juhani Niskanen, Ari Juhani Tuononen (Aalto University)

Ever increasing amount of Advanced Driver Assisting Systems (ADAS) are being developed to improve the safety of the vehicles. However, the direct information of the tyre-road contact is not available for these systems. An intelligent tyre has been proposed to provide that information in many studies. This paper focuses on water and aquaplaning detection with an intelligent tyre with three triaxial accelerometers attached on the inner liner. A method to detect the tyre-road contact state is introduced and validated with experimental data.

15:20-17:00, MoPoPT1.7
Juergen Wiest, Karg Matthias Karg, Felix Kunz, Stephan Reuter, Klaus Dietmayer (University of Ulm), Ulrich Kressel (Daimler AG)

This contribution proposes a novel algorithm for predicting maneuvers at intersections. With applicability to driver assistance systems and autonomous driving, the presented methodology estimates a maneuver probability for every possible direction at an intersection. For this purpose, a generic intersection-feature, space-based representation is defined which combines static and dynamic intersection information with the dynamic properties of the observed vehicle, provided by a tracking module. A statistical behavior model is learned from previously recorded patterns by approximating the resulting feature space. Because the feature space consists of different types of features (mixed-feature space), a Bernoulli-Gaussian Mixture Model is applied as approximating function. Further, an online learning extension is proposed to adapt the model to the characteristics of different intersections.

15:20-17:00, MoPoPT1.8
8. Multiview Random Forest of Local Experts Combining RGB and LIDAR Data for Pedestrian Detection
Alejandro González, Gabriel Villalonga, David Vázquez, Antonio M. López (Autonomous University of Barcelona), Jiaolong Xu, Jaume Amores (Computer Vision Center)

Despite recent significant advances, pedestrian detection continues to be an extremely challenging problem in real scenarios. In order to develop a detector that successfully operates under these conditions, it becomes critical to leverage upon multiple cues, multiple imaging modalities and a strong multi-view classifier that accounts for different pedestrian views and poses. In this paper we provide an extensive evaluation that gives insight into how each of these aspects (multi-cue, multi-modality and strong multi-view classifier) affect performance both individually and when integrated together. In the multi-modality component we explore the fusion of RGB and depth maps obtained by high-definition LIDAR, a type of modality that is only recently starting to receive attention. As our analysis reveals, although all the aforementioned aspects significantly help in improving the performance, the fusion of visible spectrum and depth information allows to boost the accuracy by a much larger margin. The resulting detector not only ranks among the top best performers in the challenging KITTI benchmark, but it is built upon very simple blocks that are easy to implement and computationally efficient. These simple blocks can be easily replaced with more sophisticated ones recently proposed, such as the use of convolutional neural networks for feature representation, to further improve the accuracy.

15:20-17:00, MoPoPT1.9
Carsten Slaatschmidt, Sebastian von Camen, Alexandros Gavriilidis, Anton Kummert (University of Wuppertal)

This paper proposes a method to analyse human-made environments regarding the existence of descending stairs and steps to assists visually impaired and furthermore disabled people, that are not able to use traditional supports like blind canes. Those people are heavily limited in their daily lives, since wrong decisions caused by the lack of information can easily lead to accidents. We use depth data acquired with a low resolution Time-of-Flight (ToF) camera to perceive the scene in front a mobile vehicle (rollator) to provide the user with detailed information about potentially hazardous situations. Experiments with affected persons have shown the ability of the system to help them understand
the environment and, in particular, avoid falls from descending stairs. 

15:20-17:00, MoPoPT1.10 
10. Stochastic Driver Speed Control Behavior Modeling in Urban Inter-Sections Using Risk Potential-Based Motion Planning Framework

Yasuhiro Akagi, Pongsathorn Raksincharoensak (Tokyo University of Agriculture and Tech)

In unsignalized intersections with poor visibility, proactive driving with hazard anticipation is required in order to avoid collisions with other traffic participants from a blind corner. However, for elderly drivers and novice drivers, it is difficult to recognize potential hazardous area and difficult to select an appropriate speed to pass the intersections safely. To assist such drivers, a driver model which can recommend the appropriate speed by learning driving data of expert drivers based on a statistical approach is useful for a driver assistance system. The proposed method automatically estimates parameters of the driver model from the actual driving data by defining risk potential functions for representing braking behaviors while passing through intersections, oncoming vehicles and pedestrians. To evaluate the proposed method, the driving data of instructors of a driving school are collected. The results show that the accuracy (RMSE) of the estimated braking behavior model is 2.5 km/h against the actual data.

15:20-17:00, MoPoPT1.11 
11. Urban Platooning Using a Flatbed Tow Truck Model

Alan Ali (IRCCYN), Gaetan Garcia, Philippe Martinet (Éc. Centrale De Nantes)

Finding solutions to traffic congestion is an active area of research. Many ideas have been proposed to reduce this problem, among of this ideas is moving in platoon. The constant time headway policy (CTH) is a very important platoon control policy, but it is too conservative and induces large inter-vehicle distances. Recently, we have proposed a modification of CTH [1,2]. This modification reduces inter-vehicle distances and makes CTH practical. This paper focuses on the control of platoons in urban areas. To control the vehicles we assume that the longitudinal and the lateral dynamics are decoupled. We take into account a simplified engine model. We linearize the two dynamics using exact linearisation technique. Then we use the modified CTH control law, adapted to urban platoons, for the longitudinal control and the robust sliding mode control for lateral control. The stability and the safety of the platoon are also studied. The conditions of stability of homogeneous and nonhomogeneous platoons are founded. The conditions to verify the safety of the platoon for the longitudinal control (assuming stable and accurate lateral control) are exhibited. The weakness (large inter-vehicle distance, weak stability near low frequencies) of the CTH are solved. The improved performance and the safety of the platoon are verified by simulation using TORCS (The Open Racing Car Simulator). A platoon consisting of ten vehicles is created and tested on a curved track, keeping a small desired intervehicle distance. The stability and safety of the longitudinal and lateral controls were tested in many scenarios. These scenarios include platoon creation, changing the speed and emergency stop on straight and curved tracks. The results demonstrate the effectiveness of the proposed approach.

15:20-17:00, MoPoPT1.12 
12. Correspondence between Variational Methods and Hidden Markov Models

Jens Ziehn, Miriam Ruf, Dieter Willersinn, Jürgen Beyerer (Fraunhofer IOSB), Bodo Rosenhahn (Leibniz University Hannover), Heinrich Gotzig ( Valeo Schalter Und Sensoren GmbH)

This paper establishes a duality between the calculus of variations, an increasingly common method for trajectory planning, and Hidden Markov Models (HMMs), a common probabilistic graphical model with applications in artificial intelligence and machine learning. This duality allows findings from each field to be applied to the other, namely providing an efficient and robust global optimization tool and machine learning algorithms for variational problems, and fast local solution methods for large state-space HMMs.

15:20-17:00, MoPoPT1.13 
13. Autonomous Lane-Change Controller

Yaoqiong Du, Yizhou Wang, Ching-Yao Chan (University of California Berkeley)

This paper focuses on the design of a model that can be used for high-level decision making and low-level maneuver control, to achieve safe, optimal and stable lane change maneuvers of autonomous vehicles. The objective of the controller optimized for lane change maneuvers is to minimize the travel time, maintain safety distances between the target vehicle and neighboring ones, satisfy the operational constraints of the target vehicle, and comply with the speed limit. In particular, the overall control problem is formulated with three sub-controllers. The high-level decision making algorithm is constructed as a mixed logic dynamic system and solved by Cplex. Secondly, the lane tracking problem is handled by a PD controller. Lastly, the dynamic game theory approach is adopted to deal with safety design. After the modeling of the overall system is established at the three levels, the effectiveness of the proposed methodology is demonstrated by simulated scenarios.

15:20-17:00, MoPoPT1.14 

Yongbon Koo, JINWOO KIM, Wooyong Han (ETRI)

Many researchers have reported that a decline in driving concentration caused by drowsiness or inattentiveness is one of the primary sources of serious car accidents. One of the most well-known methods to measure a driver’s concentration is called driver state monitoring, where the driver is warned when he or she is falling asleep based on visual information of the face. On the other hand, autonomous driving systems have garnered attention in recent years as an alternative plan to reduce human-caused accidents. This system shows the possibility of realizing a vehicle with no steering wheel or pedals. However, lack of technical maturity, human acceptance problems, and individual desire to drive highlight the demand to keep human drivers in the loop. For these reasons, it is necessary to decide who will be responsible for driving the vehicle and adjusting the vehicle control system. This is known as the driving control authority. In this paper, we present a system that can suggest transitions in various driving control authority modes by sensing a decline of the human driver’s performance caused by drowsiness or inattentiveness. In more detail, we identify the problems of the legacy driving control authority transition made only with vision-based driver state recognition. To address the shortcomings of this method, we propose a new recommendation method that combines the vision-based driver state recognition results
and path suggestion of an autonomous system. Experiment results of simulated drowsy and inattentive drivers on an actual autonomous vehicle prototype show that our method has better transition accuracy with fewer false-positive errors compared with the legacy transition method that only uses vision-based driver state recognition.

15:20-17:00, MoPoPT1.15
15. State-Statistical Model Based Trajectory-Band Planning in Urban Environment
Chao Ma, Jing Yang, Jianru Xue, Yuehu Liu, Liang Ma (Xi'an Jiaotong University)

In the traditional trajectory planning methods, a feasible, collision-free trajectory is generated to guide the vehicle. But generally the vehicle cannot follow the trajectory without tracking deviation because of the vehicle kinematical constraints and the performance of control algorithm. In this paper, State-Statistical Model (SSM) based trajectory-band planning method is proposed to predict the vehicle motion during the vehicle tracks the trajectory. In this method, the statistics of historical states are used to build the SSM which is a normal distribution model of tracking deviation in different segments of curvature radius and velocity. According to the SSM, the inaccessible states of vehicle can be obtained to search the best trajectory and the tracking deviation boundary can be calculated on the trajectory. Then the best trajectory is used as the base line to generate the trajectory-band of which the half-band width is the deviation boundary value. As a result, the trajectory-band can represent the maximum range of vehicle motion accurately.

15:20-17:00, MoPoPT1.16
16. Curve Modeled Lane and Stop Line Detection Based GPS Error Estimation Filter
Byung-Hyun Lee, Gyu-In Jee (Konkuk University), Sung-Hyuck Im, Moon-Beom Heo (KARI)

Street and angle information can be obtained from vision sensor and center of lane. Lane following system can be easily implemented through the use of controller making these two estimates 0. However, this cannot be applied into intersection without lane. Therefore, this paper proposes a method of estimating GPS error through filter for enhanced performance of waypoint following Guidance methods. In a curved section, straight line detection method is not desirable. In this method, errors occur in lateral distance estimation due to model mismatch. Therefore, this paper evaluates performance of proposed GPS error estimation filter based on lane and stop line detection of curved lane models in order to enhance performance of waypoint following and applying it to autonomous vehicles in experimental regions.

15:20-17:00, MoPoPT1.17
17. Detection and Motion Planning for Roadside Parked Vehicles at Long Distance
Xue Mei, Naoki Nagasaka, Bunyo Okumura, Danil Prokhorov (Toyota Research Institute North America)

Reliable long distance obstacle detection and motion planning is a key issue for modern intelligent vehicles, since it can help to make the decision early and design proper driving trajectory to avoid discomfort for the passengers caused by hard brake or sudden large lateral movement. Specifically, when there is vehicle parked on the roadside, we need to detect its position and pass it safely with proper distance without causing much disruption during driving. In this paper, we propose a method to detect roadside parked vehicles robustly and design a trajectory with proper lateral offset from the lane center for the host vehicle to safely pass by it. To successfully detect the roadside parked vehicles, we fuse the output from a long range lidar and radar. We pre-compute multiple path candidates with different lateral offset, and the path planner selects the most proper one based on the distance of the parked vehicle to the lane center. To deal with false alarms and missing detections, we apply temporal filtering to the detection output and history of the decision making. The speed control is carefully designed to ensure that the host vehicle passes the parked vehicle with a safe and comfortable speed. The implemented system was evaluated in numerous scenarios with vehicles parked on the roadside. The results show that the system effectively commands the host vehicle to pass by the parked vehicle safely and comfortably with proper distance and smooth trajectory.

15:20-17:00, MoPoPT1.18
Zhongshi Zhang (University of Chinese Academy of Sciences), Junzhi Zhang, Dongsheng Sun, Chen Lv (Tsinghua University)

Equipped with the regenerative braking system, electric vehicle coordinates friction braking and regenerative braking appropriately in normal braking conditions and activates anti-lock braking system (ABS) in emergency braking conditions. This paper mainly focuses on the control strategy of electric-hydraulic blended brake for ABS control of an electric passenger car. According to the variation of the adhesion coefficient under different roads, the maximum adhesion force and the optimal slip ratio are calculated in real-time. Then, the control strategy of electric-hydraulic hybrid ABS, in which regenerative braking and hydraulic braking are coordinated in order to obtain the maximum available road adhesion and guarantee vehicle’s braking stability, is proposed. Based on the control strategy developed, simulations and test-bench experiments are carried out. Simulation and test results indicate that braking stability and control performance of vehicle on different roads are guaranteed by the proposed hybrid ABS control, validating the feasibility and the effectiveness of the algorithms. Compared with conventional hydraulic ABS, the electric-hydraulic hybrid ABS, ensuring better braking performance on various road surfaces, provides a good solution to active safety control of EVs.

15:20-17:00, MoPoPT1.19
19. Evolutionary Algorithm Based On-Line PHEV Energy Management System with Self-Adaptive SOC Control
Xuewei Qi, Guoyuan Wu, Kanok Boriboonsomsin, Matthew Barth (University of California, Riverside)

The energy management system (EMS) is crucial to a plug-in hybrid electric vehicle (PHEV) in reducing its fuel consumption and pollutant emissions. The EMS determines how energy flows in a hybrid powertrain should be managed in response to a variety of driving conditions. In the development of an EMS, the battery state-of-charge (SOC) control strategy plays a critical role. This paper proposes a novel evolutionary algorithm (EA)-based EMS with self-adaptive SOC control strategy for PHEVs, which can achieve the optimal fuel efficiency without trip length (by time) information. Numerical studies show that this proposed system can save up to 13% fuel, compared to other on-line EMS with different SOC control strategies. Further analysis indicates that the proposed system is less sensitive to the errors in predicting propulsion power in real-time, which is favorable for on-line implementation.
In this paper, an optimization method of gear shift schedule for electric buses equipped with 4-AMT is proposed based on Dynamic Programming (DP) to improve the energy economy of the vehicle. A gear shift schedule that can be used in real-vehicle is extracted based on analysis of the obtained optimal gear shift points by DP approach in Chinese typical urban driving-cycles. Compared to the traditional two-parameter gear shift schedule in both simulation and real vehicle platform, the extracted gear shift schedule is proved to improve the energy economy of the electric vehicles (EVs) obviously.

LIDAR scanners are essential components of intelligent vehicles capable of autonomous travel. Mutual interference between LIDAR scanners has not been regarded as a problem yet. Mutual interference is identified as a problem of increased importance because of the appearance of safety functions and the increasing rate of vehicles equipped with LIDAR scanner. This paper will show the probability that any LIDAR scanner is probably interfered mutually by considering spatial and temporal overlaps. It will present three types of experiments and their results are showed, according to the arrangement of two LIDAR scanners.

Traffic sign recognition, including sign detection and classification, is essential for advanced driver assistance systems and autonomous vehicles. This paper introduces a novel machine learning-based sign recognition scheme. In the proposed scheme, detection and classification are realized through learning in a coarse-to-fine manner. Based on the observation that signs in the same category share some common attributes in appearance, the proposed scheme first distinguishes each individual sign category from the background in the coarse learning stage (i.e. sign detection) followed by distinguishing different sign classes within each category in the fine learning stage (i.e. sign classification). Both stages are realized through machine learning techniques. A complete recognition scheme is developed that is effective for simultaneously recognizing multiple categories of traffic signs. In addition, a novel saliency-based feature extraction method is proposed for sign classification. The method segments salient sign regions by leveraging the geodesic energy propagation. Compared with the conventional feature extraction, our method provides more reliable feature extraction from salient sign regions. The proposed scheme is tested and validated on two categories of Chinese traffic signs from Tencent street view. Evaluations on the test dataset show reasonably good performance, with an average of 97.5% true positive and 0.3% false positive on two categories of traffic signs.

As free space boundary defined as the boundary between the closest obstacles and a road surface provides information about drivable space and obstacles, it has been one of the most important research topics in the automotive field. This paper proposes a method enhancing the accuracy of u-disparity-based free space boundary estimation to the subpixel level. The conventional method detects peak series by exploiting dynamic programming in u-disparity made by accumulating disparity maps depending on the u coordinate. It assumes that the bigger accumulation value of the u-disparity of a position and the smaller vertical coordinate change between the position and its previous column, the higher is the possibility that the position belongs to peak series. However, as the conventional method considers only vertical coordinate change with respect to the previous column, it has a problem that even a straight line will be penalized if it is not seen to be horizontal. To address this problem, this paper proposes preview dynamic programming, which is modified to consider the slope change with the previous and next column. Additionally, to solve the problem that a slope smaller than 45˚ cannot be represented by integer coordinates, this paper proposes modified u-disparity, which uses average coordinates weighted by u-disparity values within a fixed size window. Through qualitative evaluations with an open dataset, it is confirmed that the proposed method significantly mitigates the quantization noise of free space boundary estimated by the conventional method.
25. Implementation of a Multi-Criteria Tracking Based on the Dempster-Shafer Theory
Valentin Magnier, Jérôme Godelle (RENAULT), Dominique Gruyer (IFSTTAR)

This paper aims to present how the Belief Theory (also known as the Dempster-Shafer theory) can be relevant to implement powerful tracking systems. As the Belief theory belongs to the group of information-theories, it is very suitable for solving the track-to-target association problem which is one of the main issue of tracking systems. The data association problem is about associating the measurement at a given timestamp with the objects that are being tracked along the time. In this paper, we present two methods based on the belief theory that can be used to improve the data association reliability. After that we propose as an example of tracking implementation and discuss the effect of using a multi-criteria track-to-target association algorithm.

26. Disparity Refinement with Stability-Based Tree for Stereo Matching
Yuhang Ji, Qieshi Zhang, Kenjiro Sugimoto, Sei-ichiro Kamata (Waseda University)

This paper proposes a disparity refinement method with stability-based tree. By developing stability-based tree to evaluate and reconstruct support regions for error parts, the proposed method achieves effective performance in removing outliers. This approach further improves the quality of raw disparity map in stereo matching, which makes the local methods results comparable to the global ones. Experiments exhibit that the proposed method reduces more than 70% aggregation time compared with traditional tree method without loss of accuracy. It also outperforms existing disparity refinement methods in removing large error parts.

27. Robust Scale Estimation for Monocular Visual Odometry Using Structure from Motion and Vanishing Points
Johannes Gräter, Tobias Schwarze, Martin Lauer (Karlsruher Institut für Technologie)

While monocular visual odometry has been widely investigated, one of its key issues restrains its broad appliance: the scale drift. To tackle it, we leverage scene inherent information about the ground plane to estimate the scale for usage on Advanced Driver Assistance Systems. The algorithm is conceived so that it is independent of the unscaled ego-motion estimation, augmenting its adaptability to other frameworks. A ground plane estimation using Structure From Motion techniques is complemented by a vanishing point estimation to render our algorithm robust in urban scenarios. The method is evaluated on the KITTI dataset, outperforming state of the art algorithms in areas where urban scenery is dominant.

28. Estimation of Automotive Pitch, Yaw, and Roll Using Enhanced Phase Correlation on Multiple Far-Field Windows
Marc Barnada, Rudolf Mester, Matthias Ochs, Christian Conrad (Goethe University Frankfurt)

The online-estimation of yaw, pitch, and roll of a moving vehicle is an important ingredient for systems which estimate egomotion, and 3D structure of the environment in a moving vehicle from video information. We present an approach to estimate these angular changes from monocular visual data, based on the fact that the motion of far distant points is not dependent on translation, but only on the current rotation of the camera. The presented approach does not require features (corners, edges, ...) to be extracted. It allows to estimate in parallel also the illumination changes from frame to frame, and thus allows to largely stabilize the estimation of image correspondences and motion vectors, which are most often central entities needed for computing scene structure, distances, etc. The method is significantly less complex and much faster than a full egomotion computation from features, such as PTAM but it can be used for providing motion priors and reduce search spaces for more complex methods which perform a complete analysis of egomotion and dynamic 3D structure of the scene in which a vehicle moves.

29. Pedestrian Detection from Non-Smooth Motion
Mehmet Kilicarslan, Jiang Yu Zheng, Aied Algarni (IUPUI)

Pedestrian detection has been intensively studied based on appearances for driving safety. Only a few works have explored between-frame optical flow as one of features for human classification. In this paper, however, a new point of view is taken to watch a longer period for non-smooth movement. We explore the pedestrian detection purely based on motion, which is common and intrinsic for all pedestrians regardless of their shape, color, background, etc. We found unique motion characteristics of humans different from rigid objects in motion profiles. Based on the explicit analysis of spatial-temporal behaviors of pedestrians, non-smooth motion points are detected at the motion trajectories of limbs and body. This method works for driving video where both pedestrians and background are moving, and it yields good results as it is less influenced from pedestrian variations in shape and environment. The method also has low computational cost and it can be combined with a shape-based method as pre-screening tool for accuracy and speed.

30. Improved Path Tracking Approach for Unmanned Vehicles Based on Clothoid Curve
Bijun Li, Yunxiao Shan, Cheng Chen, Wei Yang (Wuhan University)

For its high efficiency and simplicity, Pure-Pursuit has been widely used in fields of automatic drive. This paper presents a modified robust controller based on Pure-Pursuit. The highlight of the method is that it replaces the circle in Pure-Pursuit with a clothoid C1 curve. Meantime, it applies the curvature information from the clothoid curve to tune the look-ahead distance. We compare the controller with improved Pure-Pursuit through experiments on the platform of autonomous vehicle, TuZhi, developed by Wuhan University. The results demonstrate that the proposed controller is more effective.
particles can be covered by the field-of-view of the UAV sensor at all times. To improve target prediction/estimation accuracy, the road information is incorporated into the constrained particle filter where the road boundaries are modelled as nonlinear inequality constraints. Both Lyapunov vector field guidance and nonlinear model predictive control methods are applied for the standoff tracking and phase angle control, and the advantages and disadvantages of them are compared using numerical simulation results.

15:20-17:00, MoPoPT1.32
32. An Experiment on Ambient Light Patterns to Support Lane Change Decisions
Andreas Löckcn, Susanne Boll (University of Oldenburg), Heiko Müller, Wilko Heuten (Institute for Information Technology)

In the recent years, several automotive manufacturers started to integrate ambient light displays into cars to increase drivers' comfort. Expanding their possible application areas, we propose a display that continuously informs the driver of the vehicle's as well as the environment's state. We studied this display in a lane change maneuver, in which a driver has to decide if he or she can change lane in front of a faster closing car or brake to keep a safe distance to a slower car in front. We present results of an experiment for light patterns that are based on results of a design workshop and definitions for lane change decision aid systems (LCDAS) of ISO 17387. Though we used ISO’s definitions for the timings, our participants felt that status updates on the display came too late. In addition, the abrupt warnings, implemented in one of the tested patterns, led to worse performance of the participants. On the other hand, we observed that participants liked a continuous encoding of the time-to-collision (TTC) and observed a decrease in missed opportunities to overtake. Therefore, we argue that the defined limits for the warning levels are not well suited to support drivers during decision making in our scenario. Our contribution lies in a novel way of supporting drivers during lane change using an ambient in-vehicle light display. We showed that a continuous light pattern might help drivers in decision making, while more research has to be done to validate this.

15:20-17:00, MoPoPT1.33
33. Understanding Surrounding Vehicles in Urban Traffic Scenarios Based on a Low-Cost Lane Graph
Chunzhao Guo, Kiyosumi Kidono, Yoshiko Kojima (Toyota Central R&D Labs., Inc)

Understanding the surrounding vehicles with respect to the road lane context and the host vehicle is crucial for the success of autonomous driving and advanced driver assistance systems (ADAS) used in daily urban traffic. This paper proposed a vision-based approach to locate the surrounding vehicles into the corresponding driving lanes as well as classify them with respect to the host vehicle's driving. In particular, the driving corridor of the host vehicle is generated by fusing multiple sources of data and the leader vehicle is determined, if available, to provide the real-time and validated information, such as trajectory and velocity, for the control purposes of the host vehicle. The potential applications of such information range from extending the functionality of the existing ADAS systems, e.g., vision-based platooning, stop-and-go traffic jam assist, etc., to autonomous driving in terms of high-level decision making and path planning. Furthermore, instead of the expensive high-precision detailed map, only a simple lane graph, constructed automatically by using conventional low-cost sensors, is used in this work to provide the driving lane information. Experimental results in various typical but challenging urban traffic scenes have substantiated the effectiveness of the proposed system.

15:20-17:00, MoPoPT1.34
34. Fast Pixelwise Road Inference Based on Uniformly Reweighted Belief Propagation
Mario Passani, José Javier Yebes Torres, Luis M. Bergasa (University of Alcala)

The future of autonomous vehicles and driver assistance systems is underpinned by the need of fast and efficient approaches for road scene understanding. Despite the large explored paths for road detection, there is still a research gap for incorporating image understanding capabilities in intelligent vehicles. This paper presents a pixelwise segmentation of roads from monocular images. The proposal is based on a probabilistic graphical model and a set of algorithms and configurations chosen to speed up the inference of the road pixels. In brief, the proposed method employs Conditional Random Fields and Uniformly Reweighted Belief Propagation. Besides, the approach is ranked on the KITTI ROAD dataset yielding state-of-the-art results with the lowest runtime per image using a standard PC.

15:20-17:00, MoPoPT1.35
35. Urban Road Localization by Using Multiple Layer Map Matching and Line Segment Matching
Keisuke Yoneda, Chenxi Yang, Seiichi Mita (Toyota Technological Institute), Tsubasa Okuya, Kenji Muto (DENSO Corp)

In recent years, automated vehicle researches move on to the next stage, that is, auto-driving experiments on public roads. This study focuses on how to realize accurate localization based on the use of Lidar data and precise map. On different roads such as urban roads and expressways, the observed information of surrounding is significantly different. For example, on the urban roads, many buildings can be observed around the upper part of the vehicle. Such observation realizes accurate map matching. On the other hand, the upper part has no specific observation on the expressway. Therefore, it is necessary to observe the lower part for the map matching. To adapt the situation changes, we propose a localization method based on self-adaptive multi-layered scan matching and road lane segment matching. The main idea is to effectively match the features observed from different heights and to improve the results by applying the line segment matching in certain scenes. Localization experiments show the ability to estimate accurate vehicle pose in urban driving.

15:20-17:00, MoPoPT1.36
36. Obstacle Localization and Recognition for Autonomous Forklifts Using Omnidirectional Stereovision
Arthur Daniel Costea, Andrei Vatavu, Sergiu Nedevschi (Technical University of Cluj-Napoca)

In this paper we propose an approach for obstacle localization and recognition using omnidirectional stereovision applied to autonomous forklifts in industrial environments. We use omnidirectional stereovision with two fisheye cameras for the 3D perception of the surrounding environment. Using the reconstructed 3D points, a Digital Elevation Map (DEM) is constructed consisting of a 2.5D grid of elevation cells. Each cell is then classified as ground or obstacle. Further, we use the classified DEM to generate obstacle hypotheses. To ensure a higher detection rate we also propose a fast sliding window based approach relying on the monocular fisheye intensity image. The detections
from both approaches are merged and are subjected to a tracking mechanism. Finally each obstacle is classified using boosting over Visual Codebook type features. The classification is refined using the classification history available from tracking. The presented approaches are integrated into a 3D visual perception system for AGVs and are of real time performance.

15:20-17:00, MoPoPT1.37

37. Unsupervised Image Transformation for Outdoor Semantic Labelling
German Ros (Computer Vision Center), José M. Alvarez (NICTA)

Semantic labelling of urban images is a crucial component towards autonomous driving. The accuracy of current methods is highly dependent on the training set being used and drops drastically when the distribution in the test image does not match the expected distribution of the training set. This situation will inevitably occur, as for instance, when the illumination changes from daytime to dusk. To address this problem we propose a fast unsupervised image transformation approach following a global color transfer strategy. Our proposal generalizes classical one-to-one color transfer schemes to the more suitable one-to-many scheme. In addition, our approach can naturally deal with the temporal consistency of video streams to perform a coherent transformation. We demonstrate the benefits of our proposal in two publicly available datasets using different state-of-the-art semantic labelling frameworks.

15:20-17:00, MoPoPT1.38

38. Accurate Ego-Lane Recognition Utilizing Multiple Road Characteristics in a Bayesian Network Framework
Soomok Lee, Seung-Woo Seo (Seoul National University), Seong-Woo Kim (Singapore-MIT Alliance for Res. and Tech)

Accurate lateral localization of an ego-vehicle is one of the core technologies for autonomous driving. Conventional approaches have utilized GPS data, pre-built map information, and lane detection results to estimate the lateral location of an ego-vehicle. However, these approaches demonstrate several performance limitations due to inaccurate data from GPS, high costs for building and maintaining maps, and insufficient visual cues for handling various tasks in diverse driving environments. In this paper, we propose an accurate ego-lane recognition framework that utilizes multiple evidence from visual processing upon the theory of the Bayesian Network to overcome these limitations. We show that more accurate and reliable lateral localization results can be achieved by combining several visual cues, which increases confidence and reliability of the results. We also show that our approach can be applicable to various driving environments without maps because the framework analyzes multiple context information of driving environments simultaneously. We verify the robustness of our algorithm in various driving scenarios such as highways and wide/narrow urban roadways.

15:20-17:00, MoPoPT1.39

39. Effective Height-Grid Map Building Using Inverse Perspective Image
Seung-Jun Han, Juwan Kim, JeongDan Choi (ETRI)

This paper discusses an efficient method for generating height-grids maps, which are widely utilized in developing mobile robots and autonomous vehicles. The proposed method consists of four steps. First, inverse perspective images (IPI) are obtained from wide-angle cameras equipped with a fish-eye lens. Second, dense motion stereo is performed using IPI. Next, depth information is calculated and mapped onto the grid map. Lastly, a fusion of the grid maps is executed to enhance the quality of the map using a modified temporal median filter. The method can efficiently collect height and position information about objects relative to the road surface. The reason is that wide-angle images are converted to IPI to remove the perspective distortion of the road surface, and the depth is calculated using dense motion stereo from IPI. Moreover, the efficiency of the proposed fusion method is significantly higher than that of previous methods. The proposed method is very simple, but the quality that could be obtained is similar to the quality produced by the conventional technique, and the building speed showed dramatically fast performance of up to 200 fps in a single core CPU. In addition, we used a variety of test data and showed that the result verifies the validity of the proposed algorithm.

15:20-17:00, MoPoPT1.40

40. Time Delay Compensation for Environmental Sensors of High-Level Automated Driving Systems
Sungyoul Park, Beomjin Kim, Kyuwon Kim, Kyongsu Yi (Seoul National University), YoungSeop Son (Mando)

This paper presents a time delay compensation algorithm for environmental sensors of automated driving systems. The time delay involved with the transmission of the measurements from the sensors to the processor cannot be negligible because it is responsible for estimation and control of the system. As the automotive environmental sensors such as laser scanner or radar perform measurements at a constant frequency, the measurement time latencies can be assumed to be constant. From this aspect, the constant time delay characteristics is analyzed via vehicle tests and compensated by forward estimation based coordinate transformation. The proposed compensation algorithm has been verified via test data based open loop simulation of Automated Driving Systems (ADS). It is shown that the proposed compensation enhances environment perception performance and driver’s safety.

Monday, June 29, 2015

17:00-18:20 MoOrPT1: Vehicle Environment Perception

Chair: Miguel A. Sotelo (University of Alcala)
Co-Chair: Seung-Woo Seo (Seoul National University)

17:00-17:20, MoOrPT1.1

1. Simultaneous Localization and Mapping Based on the Local Volumetric Hybrid Map
Jaebum Choi, Markus Maurer (TU Braunschweig)

Simultaneous localization and mapping (SLAM) plays a significant role in autonomous vehicles when a global navigation satellite system (GNSS) is not available. Environment models and underlying estimation techniques are key factors of this algorithm. In this paper, we present a hybrid map-based SLAM approach using Rao-Blackwellized particle filters (RBPFs). We represent the environment in the hybrid map which consists of feature and grid maps. The joint posterior between the vehicle positions and both maps are maintained using RBPFs. This approach allows a vehicle to update its states in a more robust and efficient way. We derived a novel sampling formula by combining a feature measurement likelihood to the traditional grid-based SLAM framework and can decrease the uncertainty of the predicted vehicle position significantly. Moreover, we represent the grid maps with 3D models because 2D models could be insufficient and less reliable to achieve tasks such as navigation and obstacle avoidance in complex 3D environments.
environment. We are also able to show that the 3D grid measurement likelihood has a lower variance and with that we can improve the overall performance of the algorithm.

17:20-17:40, MoOrPT1.2

2. Predicting Driving Behavior Using Inverse Reinforcement Learning with Multiple Reward Functions towards Environmental Diversity
Masamichi Shimosaka, Kentaro Nishi, Junichi Sato (The University of Tokyo), Hirokatsu Kataoka (Keio University)

Predicting defensive driving is a promising technology for novel advanced driver assistance systems. In recent years, modeling driving behavior in residential roads through inverse reinforcement learning (IRL) has been attracting attention in intelligent vehicle community thanks to the superiority of this approach providing long-term prediction of fine-grained driving behavior. However, it suffers from poor performance in diverse environment due to the fact that the single reward function could not handle all the environment with large diversity. Towards this issue, a novel IRL framework with multiple reward functions to deal with environmental diversity is proposed in the paper. Specifically, the model employs Dirichlet process mixtures as a flexible and powerful Bayesian model to divide the environment into clusters and learns the parameters in each cluster simultaneously. Experimental result with expert driver behavior data shows that our model with multiple reward functions provides superior performance over the IRL model with single reward function. It also suggests that the clustering of environments based on the driving behavior of professional drivers could be useful on evaluating driving environments.

17:20-17:40, MoOrPT1.3

3. Exploiting 3D Semantic Scene Priors for Online Traffic Light Interpretation
Dan Barnes, William Paul Maddern, Ingmar Posner (The Univ. of Oxford)

In this paper, we present a probabilistic framework for increasing object detection performance when given a semantic 3D scene prior, which we apply to the task of traffic light detection for autonomous vehicles. Previous approaches to traffic light detection on autonomous vehicles have involved either precise knowledge of the relative 3D positions of the vehicle and the traffic light (requiring accurate and expensive mapping and localisation systems), or a classifier-based approach that searches for traffic lights in images (increasing the chance of false detections by searching all possible locations for traffic lights). We combine both approaches by explicitly incorporating both prior map and localisation uncertainty into a classifier-based object detection framework, generating a scale-space search region that only evaluates parts of the image likely to contain traffic lights, and weighting object detection scores by both the classifier score and the 3D occurrence prior distribution. We present results comparing a range of low- and high-cost localisation systems using over 30km of data collected on an autonomous vehicle platform, demonstrating up to a 40% improvement in detection precision over no prior information and 15% improvement on unweighted detection scores. We demonstrate a 10x reduction in computation time compared to a naive whole-image classification approach by considering only locations and scales in the image within a confidence bound of the predicted traffic light location. In addition to improvements in detection accuracy, our approach reduces computation time and enables the use of lower-cost localisation sensors for reliable and cost-effective object detection.

17:20-17:40, MoOrPT1.4

4. Curvature-Based Curb Detection Method in Urban Environments Using Stereo and Laser
Carlos Fernandez Lopez, David Fernandez Llorca, Miguel A. Sotelo (Univ. of Alcala), Christoph Stiller (Karlsruhe Institute of Technology)

This paper addresses the problem of curb detection for ADAS or autonomous navigation in urban scenarios. The algorithm is based on clouds of 3D points. It is evaluated using 3D information from a pair of stereo cameras and a LIDAR. Curbs are detected based on road surface curvature. The curvature estimation requires a dense point cloud, therefore the density of the LIDAR cloud has been augmented using Iterative Closest Point (ICP) based on the previous scans. The proposed algorithm can deal with curbs of different curvature and heights, from as low as 3 cm, in a range up to 20 m (whenever that curbs are connected in the curvature image). The curb parameters are modeled using straight lines and compared to the ground-truth using the lateral error as the key parameter indicator. The ground-truth sequences were manually labeled on urban images from the KITTI dataset and made publicly available for the scientific community.
Block-Matching stereo is commonly used in applications with low computational resources in order to get some rough depth estimates. However, research on this simple stereo estimation technique has been very scarce since the advent of energy-based methods which promise a higher quality and a larger potential for further improvement. In the domain of intelligent vehicles, especially semi-global-matching (SGM) is widely spread due to its good performance and simple implementation. Unfortunately, the big downside of SGM is its large memory footprint because it is working on the full disparity space image (DSI). In contrast to this, local block-matching stereo is much more lean. In this paper, we will introduce a novel multi-block-matching scheme which tremendously improves the result of standard block-matching stereo while preserving the low memory-footprint and the low computational complexity. We tested our new multi-block-matching scheme on the KITTI stereo benchmark as well as on the new Middlebury stereo benchmark. For the KITTI benchmark we achieve results that even surpass the results of the best SGM implementations. For the new Middlebury benchmark we get results that are only slightly worse than state-of-the-art SGM implementations.

1. A Multi-Block-Matching Approach for Stereo

Nilz Einecke, Julian Eggert (Honda Research Institute Europe GmbH)

10:30-10:50, TuOrAT1.4

4. Vehicle Localization Using Mono-Camera and Geo-Referenced Traffic Signs

XiaoZhi Qu, Bahman Soheilian, Nicolas Paparoditis (Univ. Paris-Est)

Vision based localization is a cost effective method for indoor and outdoor application. However, it has drift problem if none global optimization is used. We proposed a geo-referenced traffic sign based localization method, which integrated the constraints of 3D traffic signs with local bundle adjustment to reduce the drift. Comparing to global bundle adjustment, Local Bundle Adjustment (LBA) has low computational cost but suffers the drift problem for large scale localization because of the random error accumulation. We reduced the drift by means of the constraints from geo-referenced traffic signs for bundle adjustment process. The original LBA model was extended for the constraints and the traffic signs were detected in images and matched with 3D landmark database automatically. From the experiments of simulated and real images, our approach can reduce the drift and have better locating results than none-constraint LBA based localization method.

Tuesday, June 30, 2015

TuPoAT1: Poster Session 3

10:50-12:30

Chair: Fawzi Nashashibi (INRIA)
Co-Chair: Kangwon Lee (Korea Polytechnic University)

1. Scenario Model Predictive Control for Lane Change Assistance on Highways

Georg Schildbach, Francesco Borrelli (University of California at Berkeley)

This paper presents a new algorithm for detecting the safety of lane changes on highways and for computing safe lane change trajectories. This task is considered as a building block for driver assistance systems and autonomous cars. The presented algorithm is based on recent results in Scenario Model Predictive Control (SCMPC). It accounts for the uncertainty in the traffic environment via a small number of future scenarios, which can be generated by any model-based or data-based approach. The paper describes the SCMPC design as well as the integration with scenario-based traffic predictions. The design procedure is simple and can be generalized to other control situations. An extensive case study demonstrates the effectiveness of the proposed SCMPC algorithm and its performance in lane change situations.
10:50-12:30, TuPoAT1.2

2. Road Marking Detection and Classification Using Machine Learning Algorithms
TaiRui Chen, Zhilu Chen, Xinming Huang (WPI), Quan Shi (Nantong University)

This paper presents a novel approach for road marking detection and classification based on machine learning algorithms. Road marking recognition is an important feature of an intelligent transportation system (ITS). Previous works are mostly developed using image processing and decisions are often made using empirical functions, which makes it difficult to be generalized. Hereby, we propose a general framework for object detection and classification, aimed at video-based intelligent transportation applications. It is a two-step approach. The detection is carried out using binarized HOG features (BING) method. PCA network (PCANet) is employed for object classification. Both BING and PCANet are among the latest algorithms in the field of machine learning. Practically the proposed method is applied to a road marking dataset with 1,443 road images. We randomly choose 60% images for training and use the remaining 40% images for testing. Upon training, the system can detect 9 classes of road markings with an accuracy better than 96.8%. The proposed approach is readily applicable to other ITS applications.

10:50-12:30, TuPoAT1.3

Andreas Schulz (Robert Bosch GmbH), Rainer Stiefelhagen (Karlsruhe Institute of Technology)

We present a novel approach for pedestrian intention recognition for advanced video-based driver assistance systems using a Latent-dynamic Conditional Random Field model. The model integrates pedestrian dynamics and situational awareness using observations from a stereo-video system for pedestrian detection and human head pose estimation. The model is able to capture both intrinsic and extrinsic class dynamics. Evaluation of our method is performed on a public available dataset addressing scenarios of lateral approaching pedestrians that might cross the road, turn into the road or stop at the curbside. During experiments, we demonstrate the higher stability and separation efficiency of our model compared to other machine learning approaches.

10:50-12:30, TuPoAT1.4

4. Application of In-Vehicle Traffic Lights for Improvement of Driving Safety at Unsignalized Intersections
Bo Yang, Rencheng Zheng, Kimihiko Nakano (The University of Tokyo)

Most of intersections are without traffic signals to help drivers safely pass through intersections. Nowadays, it becomes possible to transfer traffic information of unsignalized intersections to drivers by application of communication technologies. Therefore, this study concentrated on in-vehicle traffic lights for assisting drivers to cross unsignalized intersections. Dependent on different traffic situations, unsignalized intersections can be classified as priority-controlled and non-priority-controlled intersections. Consistently, in-vehicle traffic lights were elaborated and provided to drivers in different unsignalized intersections, considering gap acceptance to ensure driving safety. A driving simulator experiment involving nine participants was performed to evaluate the effectiveness of the proposed system. The experimental results indicated that post-encroachment time was significantly improved when in-vehicle traffic lights were applied for crossing unsignalized intersections.

10:50-12:30, TuPoAT1.5

5. A Stereovision Based Approach for Detecting and Tracking Lane and Forward Obstacles on Mobile Devices
Andra Petrovai, Radu Gabriel Danesucu, Sergiu Nedevschi (Technical University of Cluj-Napoca)

This paper presents SmartCoDrive, an Android application which performs driving assistance functions: 3D lane detection and tracking, forward obstacle detection, obstacle tracking. With this mobile application we wish to increase the adoption rate of driving assistance systems and to provide a viable and cheap solution for every driver, that will be able to use his own tablet or smartphone as a personal driving assistant. The mobile application is deployed on a tablet equipped with dual back-facing cameras. The visual information from the two cameras, along with the data received from the Controller Area Network bus of the vehicle enable a thorough understanding of the 3D environment. First, we develop the sparse 3D reconstruction algorithm. Then, using monocular vision we perform lane markings detection. Obstacle detection is done by combining the superpixel segmentation with 3D information and the tracking algorithm is based on the Kalman Filter. Since the processing capabilities of the mobile platforms are limited, different optimizations are carried out in order to obtain a real-time implementation. The Android application may be used in urban traffic that is characterized by low-speed and short-medium distances to obstacles.

10:50-12:30, TuPoAT1.6

Beomjun Kim, Kyongsu Yi (Seoul National University), YoungSeop Son (Mando)

The objective of this paper is to propose an original probabilistic threat assessment method to completely predict and avoid all possible kinds of collision in multi-vehicle traffic. The main concerns in risk assessment can be summarized as three requirements: 1) a description of a traffic situation containing the geometric description of the road, dynamic and static obstacle tracking, 2) a prediction of multiple traffic’s reachable set under the reasonable behavior restriction, and 3) an assessment of collision risk which corresponds with driver sensitivity and can be applied to many complex situations without loss of generality. To fulfill these three requirements, the proposed algorithm for estimating the probability of collision occurrence of the ego vehicle follows the basic idea of the particle filtering and the collision probability can be numerically implemented and calculated. The overall performance of the proposed threat assessment algorithm is verified via vehicle tests in real road. It has been shown that the threat assessment performance for the given driving situations can be significantly enhanced by the proposed algorithm. And this enhancement of risk assessment performance led to capabilities improvement of driver assistance functions of ADASs.

10:50-12:30, TuPoAT1.7

7. Identifying a Gap in Existing Validation Methodologies for Intelligent Automotive Systems: Introducing the 3xD Simulator
Siddartha Khaustgir, Stewart Birrell, Gunwant Dhadyalla, Paul Jennings (University of Warwick)

Recently there has been a growth in the incorporation of autonomous features within vehicles. From being perceived
as a comfort feature, autonomous features in vehicles have now become a safety feature which are foreseen to reduce accidents. This has led to a new trend within the automotive industry of focusing on autonomous features for driver safety, which might ultimately lead to fully autonomous vehicles. Considering the fact that most of the accidents on UK roads occur due to driver error, driver-less vehicles would prove to be a benefit. However with automation, an even greater challenge of system validation in all scenarios needs to be addressed. For this, various methods of validation have been developed by different research organizations and manufacturers, but a standardized process still evades the industry. Some of the existing methods have been discussed in this paper to critically compare their quality of results and ease of execution. Subsequently, a new test platform has been proposed using the 3xD driving simulator which encompasses most requirements of a general testing method. A standardized process which would benefit the industry both in terms of reducing costs of having varied processes, and by increasing customer confidence can be developed using a non-invasive platform like the 3xD driving simulator. The novelty of the 3xD simulator is the ability to drive-in any vehicle (production/prototype) and develop testing methodologies in an immersive wireless environment.

10:50-12:30, TuPoAT1.8
8. Drive Quality Analysis of Lane Change Manoeuvres for Naturalistic Driving Studies
Ravi Kumar Satzoda, Mohan M. Trivedi (University of California at San Diego), Pujitha Gunaratne (Toyota Research Institute North America)

Analysis of naturalistic driving data provides a rich set of semantics which can be used to determine the driving characteristics that could lead to crashes and near-crashes. In this paper, we introduce “drive quality” analysis as part of the drive analysis process of naturalistic driving studies (NDSs) that we have previously introduced in [1]. In this first work on drive quality analysis for NDS data reduction, lane change maneuvers that are reduced from naturalistic driving data are further analyzed in a detailed manner in order to characterize them. Visual data from multiple perspectives and the data from in-vehicle sensors are used to characterize lane changes based on both the ego-vehicle kinematics and ego-vehicle surround dynamics. According to available literature on NDS and data reduction, this is the first work that presents an analysis of visual data from multiple perspectives to characterize and extract semantics related to ego-vehicle maneuvers in NDSs such as SHRFP.

10:50-12:30, TuPoAT1.9
9. Snap-DAS: A Vision-Based Driver Assistance System on a Snapdragon Embedded Platform
Ravi Kumar Satzoda, Sean Lee, Frankie Lu, Mohan M. Trivedi (University of California at San Diego)

In the recent years, mobile computing platforms are becoming increasingly cheaper and yet more powerful in terms of computational resources. Automobiles provide a suitable environment to deploy such mobile platforms in order to provide low cost driver assistance systems. In this paper, we propose Snap-DAS which is a vision-based driver assistance system that is implemented on a Snapdragon embedded platform. A forward facing camera combined with the Snapdragon platform constitute Snap-DAS. The compute efficient implementation of the LASER lane estimation algorithm in [1] is exploited to implement a set of lane related functions on Snap-DAS, which include lane drift warning and lane change event detection. A detailed evaluation is performed on live data and Snap-DAS is also field tested on freeways. Furthermore, we explore the possibility of using Snap-DAS for analyzing drives for online naturalistic driving studies.

10:50-12:30, TuPoAT1.10
10. Autonomous Driving at Ulm University: A Modular, Robust, and Sensor-Independent Fusion Approach
Felix Kunz, Dominik Nuss, Juergen Wiest, Hendrik Deusch, Stephan Reuter, Alexander Scheel, Manuel Stuebler, Cornelius Wild, Klaus Dietmayer (University of Ulm), Franz Gritschneder, Martin Bach, Patrick Hatzelmann (Inst. of Measurement, Control and Microtechnology)

The project “Autonomous Driving” at Ulm University aims at advancing highly-automated driving with close-to-market sensors while ensuring easy exchangeability of the particular components. In this contribution, the experimental vehicle that was realized during the project is presented along with its software modules. To achieve the mentioned goals, a sophisticated fusion approach for robust environment perception is essential. Apart from the necessary motion planning algorithms, this paper thus focuses on the sensor-independent fusion scheme. It allows for an efficient sensor replacement and realizes redundancy by using probabilistic and generic interfaces. Redundancy is ensured by utilizing multiple sensors of different types in crucial modules like grid mapping, localization and tracking. Furthermore, the combination of the module outputs to a consistent environment model is achieved by employing their probabilistic representation. The performance of the vehicle is discussed using the experience from numerous autonomous driving tests on public roads.

10:50-12:30, TuPoAT1.11
11. Local Trajectory Planning and Tracking for Autonomous Vehicle Navigation Using Clothoid Tentacles Method
Alia Chebli, Gilles Tagne, Reine Tajj, Ali Charara (Université de Technologie de Compiègne)

In general, autonomous navigation requires three key steps, the perception of the environment surrounding the vehicle, the trajectory planning and the actuators control. Numerous works on the localization, perception, generation of occupancy grids and control of vehicles were developed within the ASER team at Heudiasyc laboratory. The work presented in this paper covers, essentially, trajectory planning and is based on the results of these works. The challenge is to avoid static and dynamic obstacles at high speed, using real time algorithms. The planning method developed in this work uses an empirical approach for local path planning. This approach consists on drawing clothoid tentacles in the egocentered reference frame related to the vehicle. An occupancy grid represents the environment surrounding the vehicle and is considered to be ego-centered around it. Using the information of the occupancy grid, each tentacle is classified as navigable or not navigable. Among the navigable tentacles, only one tentacle is chosen as the vehicle reference trajectory using several criteria. The chosen tentacle is then applied to the vehicle using a lateral controller based on Immersion and Invariance principle (I&I).

10:50-12:30, TuPoAT1.12
12. Lane Map Building and Localization for Automated Driving Using 2D Laser Rangefinder
Dongwook Kim, Kyongsu Yi (Seoul National University), Taeyoung Jung (Hyundai Mobis)

This paper describes a method of lane map building and localization for automated driving using 2d laser rangefinder. Today’s on-board sensors such as radar or camera do not reach a satisfying level of development from the point of view
of robustness and availability. Thus, map data is often used as an additional data input to support these systems. An digital map is used as a powerful additional sensor. So we propose a lane map-based localization using a 2D Laser RangeFinder. The maps are created beforehand using a 2D LiDAR and RTK GPS. A pose estimation of vehicle was derived from a low-cost GPS and an iterative closest point (ICP) match of real-time sensor data to lane map. And the estimated pose was used as an observation inside a Kalman filter framework. The performance of the proposed localization algorithm is verified via vehicle tests in ITS proving ground. It has been shown through vehicle tests that good localization performance can be obtained. The proposed algorithm will be useful in the implementation of automated driving.

10:50-12:30, TuPoAT1.13
13. Robust Stereo Visual Odometry from Monocular Techniques
Mikael Persson, Tommaso Piccini, Michael Felsberg (Linköping University), Rudolf Mester (University Frankfurt)

Visual odometry is one of the most active topics in computer vision. The automotive industry is particularly interested in this field due to the appeal of achieving a high degree of accuracy with inexpensive sensors such as cameras. The best results on this task are currently achieved by systems based on a calibrated stereo camera rig, whereas monocular systems are generally lagging behind in terms of performance. We hypothesize that this is due to stereo visual odometry being an inherently easier problem, rather than than due to higher quality of the state of the art stereo based algorithms. Under this hypothesis, techniques developed for monocular visual odometry systems would be, in general, more refined and robust since they have to deal with an intrinsically more difficult problem. In this work we present a novel stereo visual odometry system for automotive applications based on advanced monocular techniques. We show that the generalization of these techniques to the stereo case result in a significant improvement of the robustness and accuracy of stereo based visual odometry.

We support our claims by the system results on the well known KITTI benchmark, achieving the top rank for visual only systems.

10:50-12:30, TuPoAT1.14
14. The Deeva Autonomous Vehicle Platform
Alberto Broggi, Stefano Debattisti, Paolo Grisleri, Matteo Pancirolli (University of Parma)

This paper presents the design, the setup, and the architecture of a new class of autonomous vehicles prototype. The car is equipped with 26 cameras, divided into 13 stereo pairs. Four stereo systems are dedicated to the reconstruction of the near area surrounding the vehicle, other nine are dedicated to the 3D reconstruction of the far driving area. Additionally four lasercanners, and a high performance GPS/IMU unit provide more information on the ground truth to measure the validity of the data obtained with vision. The autonomous driving system, the perception system, and the processing system have been installed in the vehicle taking extra care for an as-clean-as-possible integration with te aim of setting a new state of the art level for this kind of setup. A Human Machine Interface, allows the driver to control all the functions of the systems using a touch screen. A high precision synchronization system coupled with a custom software architecture allows to obtain recordings from all sensors installed.

10:50-12:30, TuPoAT1.15
15. A Constrained VFH Algorithm for Motion Planning of Autonomous Vehicles
Panrang Qui, Jianru Xue, Liang Ma, Chao Ma (Xi'an Jiaotong Univ)

The Vector Field Histogram (VFH) is a classical motion planning algorithm which is widely used to handle the trajectory planning problem of mobile robots. However, the traditional VFH algorithm is rarely applied to autonomous vehicles due to the vehicle's well-known non-holonomic constraints, especially in urban environments. To address this problem, we propose a constrained VFH algorithm which takes both kinematic and dynamic constraints of the vehicle into consideration. The goal is achieved via two contributions that concern both kinematic and dynamic constraints of the vehicle. First, we develop a new active region for VFH to guarantee that all states within the region are reachable for the vehicle. Second, we improve the cost function to guide the search to favor feasible motion direction for the vehicle. The proposed algorithm is extensively tested in various simulated urban environments, and experimental results validate its efficiency.

10:50-12:30, TuPoAT1.16
16. Map Free Lane Following Based on Low-Cost Laser Scanner for Near Future Autonomous Service Vehicle
Zhwei Song, Weiwei Huang, Ning Wu, Xiaojun Wu, Chern Yuen Anthony Wong, Vincensius Billy Saputra, Benjamin Chia, Jian Simon Chen, Qun Zhang, Susu Yao, Boon Siew Han (Agency for Science, Technology and Research)

This paper proposes a map free lane following solution based on low-cost 2D laser scanners for Autonomous Service Vehicle to fill the gap between future driverless car and the lane keeping assistant. The applications of autonomous service vehicle include feeder bus in a local residential area, shuttle bus in a park or playground, sprinkler car, sweeper car, and transporter in airport or container terminal. As autonomous service vehicle is running only in a limited area and its speed is slow compared to normal vehicles, we can further simplify the problem regardless of the issues of road infrastructure detection/communication and V2I maps which prevent the popularization of driverless car, and to propose a unique map free solution. The features of our approach include: 1) an innovative configuration for two 2D laser scanners to detect the lane with sharp curve; 2) a fast and accurate lane detection algorithm based on 2D laser's raw data directly; 3) a reliable and smooth path planning based on local lane fitting and prediction; and 4) a self-built unique drive-by-wire system for electronic car. We successfully tested our vehicle with autonomous driving in the testing field. The experiments show that the vehicle's trajectory matched the planned path accurately.

10:50-12:30, TuPoAT1.17
17. Evidential Occupancy Grid Mapping with Stereo-Vision
Chunlei Yu, Véronique Cherfaoui, Philippe Bonnifait (Universite de Technologie de Compiene)

Occupancy grids have shown interesting properties to model the environment for intelligent vehicles perception. In this paper, we present a novel approach to build 2D occupancy grid maps with stereo-vision. Our approach proposes a fitted sensor model based on the disparity space to interpret the stereo-vision information onto an occupancy grid map. The evidential model deals with sensor uncertainties by using Dempster-Shafer theory. Our approach exploits the U-disparity space to model the obstacle information and the V-disparity space to model the road space information. The
fusion of these two sources of complementary information results to an enhanced environmental model. In a first data set, experimental results based on real road data and comparisons with Lidar grids show that the proposed evidential sensor model can model efficiently the environment. In a second one, the mapping of a road environment is reported to show the performance of the proposed model with another stereo-vision system.

10:50-12:30, TuPoAT1.18
18. Optimizing Fuel Economy of Hybrid Electric Vehicles Using a Markov Decision Process Model
Xue Lin, Yanzhi Wang, Paul Bogdan, Massoud Pedram (University of Southern California), Naehyuck Chang (KAIST)

In contrast to conventional internal combustion engine (ICE) propelled vehicles, hybrid electric vehicles (HEVs) can achieve both higher fuel economy and lower pollutant emissions. The HEV features a hybrid propulsion system consisting of one ICE and one or more electric motors (EMs). The use of both ICE and EM increases the complexity of HEV power management, and so advanced power management policy is required for achieving higher performance and lower fuel consumption. This work aims at minimizing the HEV fuel consumption over any driving cycles, about which no complete information is available to the HEV controller in advance. Therefore, this work proposes to model the HEV power management problem as a Markov decision process (MDP) and derives the optimal power management policy using the policy iteration technique. Simulation results over real-world and testing driving cycles demonstrate that the proposed optimal power management policy improves HEV fuel economy by 23.9% on average compared to the rule-based policy.

10:50-12:30, TuPoAT1.19
19. Energy Optimal Adaptive Cruise Control During Following of Other Vehicles
Folko Flehmig, Amir Sardari, Uta Fischer, Andreas Wagner (Robert Bosch GmbH)

Adaptive Cruise Control (ACC) automates longitudinal guidance of the vehicle. This paper presents a method to calculate energy optimal drive strategies when the longitudinal movement of the vehicle is constrained by another vehicle, i.e., when the ACC vehicle follows another slower vehicle. The A*-Algorithm is employed for optimization and is shown to yield the optimal solution due to a suitable heuristics. Energy optimal drive strategies are calculated for some ACC use cases and their benefit is illustrated with measurements from test tracks, on public roads as well as with simulation of traffic scenarios as encountered on public roads.

10:50-12:30, TuPoAT1.20
20. Optimal Energy Consumption Algorithm Based on Speed Reference Generation for Urban Electric Vehicles
Carlos Flores, Vicente Milanés, Joshua Pérez Rastelli, David González Bautista, Fawzi Nashashibi (INRIA)

Power consumption and battery life are two of the key aspect when it comes to improve electric transportation systems autonomy. This paper describes the design, development and implementation of a speed profile generation based on the calculation of the optimal energy consumption for electric Cybervcar vehicles for each of the stretches that are covering. The proposed system considers a commuter daily route that is already known. It divides the pre-defined route into segments according to the road slope and stretch length, generating the proper speed reference. The developed system was tested on an experimental electric platform at Inria's facilities, showing a significant improvement in terms of energy consumption for a pre-defined route.

10:50-12:30, TuPoAT1.21
Md. Abdus Samad Kamal, Takayoshi Yoshimura, Shun Taguchi (Toyota Central R&D Labs., Inc)

Anticipative control of vehicles is a potential approach for improving travel efficiency of individual vehicles, smoothing traffic flows on urban roads, alleviating impacts on the environment and elevating comforts of the users in various respects. This paper presents such a vehicle driving system in a model predictive control (MPC) framework to efficiently drive a vehicle on multi-lane roads. Anticipation enhances the driving intelligence and strengthens the vehicle’s ability in taking advance action, e.g., lane change, speed adjustment, in a dynamically varying traffic environment. More elaborately, presuming a connected vehicle environment, the system receives the state information of the surrounding vehicles and infrastructure instantly through V2X communication systems and, using dynamical models, predicts the future road-traffic states. Considering relevant constraints and a performance index, the system generates the optimal acceleration and executes lane change maneuver optimally if long term advantages are anticipated. Numerical simulation in realistic traffic flow conditions reveals that the vehicles with the proposed driving system improve their travel efficiency significantly.

10:50-12:30, TuPoAT1.22
22. Optimal Parameter Selection of a Model Predictive Control Algorithm for Energy Efficient Driving of Heavy Duty Vehicles
Michael Henzler (Daimler AG), Michael Buchholz, Klaus Dietmayer (University of Ulm)

This paper presents an improved approach to the problem of energy efficient driving of heavy duty vehicles. The proposed model for a map-based Model Predictive Control (MPC) leads to an underlying Quadratic Programming (QP) optimization problem, allowing computationally efficient and robust solutions. A parameter estimation procedure is developed for a vehicle- and optimization-independent parametrization of the tradeoff between saving energy and keeping a desired vehicle velocity. Extensive simulations on a highway scenario for different optimization parameters give further insight to optimization properties, which can be utilized to enhance control performance. Compared to previous literature, we demonstrate a significant improvement of the computation time to under one-fifth of a millisecond, while maintaining (or even increasing) the fuel consumption reduction, which is 8.1 percent with the proposed approach compared to a standard cruise controller, without a decrease in the average cruising speed.

10:50-12:30, TuPoAT1.23
23. Improved Energy Efficiency and Vehicle Dynamics for Battery Electric Vehicles through Torque Vectoring Control
Stefan Köhler, Alexander Viehl (Forschungszentrum Informatik Karlsruhe), Oliver Bringmann, Wolfgang Rosenstiel (Eberhard Karls Univ. Tübingen)

We propose a novel torque vectoring concept for battery electric vehicles propelled by wheel-individual electric machines. Besides vehicle dynamic aspects, mainly addressed in other works, we especially focus on energy efficiency improvements. Our approach is based on a
comprehensive four-wheel model taking the tires’ nonlinear characteristics into account. A yaw torque optimized for vehicle dynamics and energy efficiency is calculated by a controller and allocated to the wheel hubs by a torque distribution block considering the efficiency characteristics of the electric machines. The resulting torque vectoring control system leads to an energy consumption reduction of around 10% for many driving situations, containing both high and low lateral acceleration scenarios.

10:50-12:30, TuPoAT1.24
Abdel-Djaili Ourabah, Benjamin Quost, Thierry Denoeux (Université de Technologie de Compiègne), Atef Gayed (Renault S.A.S.)

This paper presents a novel approach for predicting the energy consumption of a plug-in hybrid electric vehicle (PHEV). We propose to estimate energy consumption strategy from data via regression applied to trip recordings. Descriptors of the trip elements are obtained from both recordings and statistics provided by a GPS navigation system. Trips are then split into elementary units corresponding to an homogeneous driving context. For each trip element, the optimal energy consumption strategy is computed via (expensive) dynamic programming simulations. Here, data analysis is used so as to identify descriptors of this trip element that are relevant to predict the energy consumption. Then, a polynomial model is fit to the data so as to estimate, for each new trip element, the optimal energy consumption strategy from the expected driving condition, rather than using dynamic programming. Our approach distinguishes itself by the fact that road context, driver style, road slope and auxiliary electrical power are taken into account to estimate the energy consumption of a PHEV. The accuracy of the prediction process is evaluated over test data, and demonstrates the interest of our approach in predicting energy consumption.

10:50-12:30, TuPoAT1.25
25. The Development of Optimum Control Strategy for Hybrid EPS System Using Taguchi Method
Ji In Park, Kwangki Jeon (Korea Automotive Technology Institute), Kyongsu Yi (Seoul National University)

Recently hydraulic power steering systems are commonly used for heavy duty vehicles. The hydraulic pump is driven by belt connected to engine crank shaft. The main disadvantage of this steering system is that energy loss occurs in the case of straight-line driving situation (few or no steering situation). This fact is directly connected to reducing fuel efficiency of heavy duty vehicle equipped the hydraulic power steering systems. To improve the fuel efficiency, it is necessary to consider application of EHPS (Electro Hydraulic Power Steering system) or MDPS (Motor Driven Power Steering system) which have been developed for passenger cars. This paper introduces the research about Hybrid Electro Power Steering (Hybrid EPS) system which combines EHPS and MDPS for heavy duty vehicles. Also the dynamic model and control strategy for the Hybrid EPS are proposed to improve the fuel efficiency by minimizing the energy consumption in steering system using robust design method called “Taguchi Method”.

10:50-12:30, TuPoAT1.26
Heiko Feichtner, Benedikt Schmulling (University of Wuppertal), Thomas Teschner (Thomas Teschner Consulting)

E-Mobility is facing a lot of obstacles nowadays, as for example the limits in the operating distance or the price difference between electric vehicles and vehicles with an internal combustion engine. This prevents many people from buying electric cars. Therefore, this paper presents a system to determine the payload of electric vehicles by measuring the tire pressure respectively the change of the tire pressure. The result of the measurement allows in combination with a range calculator a more detailed range prediction for automobiles (particularly for electric vehicles). The goal of this study is among others the reduction of the range anxiety of electric vehicle drivers.

10:50-12:30, TuPoAT1.27
27. State-Based Power Optimization Using Mixed-Criticality Filter for Automotive Networks
Wei Hong, Otto Huckle, Andreas Burger (FZI Research Center for Information Technology), Alexander Viehl (Forschungszentrum Informatik Karlsruhe), Oliver Bringmann, Wolfgang Rosenstiel (Eberhard Karls University Tübingen)

In this paper we propose an approach on energy management for optimizing the energy consumption of both electrical and conventional vehicle's board electronic. The pursued idea exploits degrees of freedom resulting from vehicle functions which are not permanently used during operation. The elaborated framework achieves this by a state-based power optimization approach using partial networking. It selectively shuts down Electronic Control Units (ECUs) based on requirement and criticality. Experimental results show up to 29.6% saving of the ECUs energy consumption on several driving cycles, which were created from real measured data provided by an automotive OEM.

10:50-12:30, TuPoAT1.28
28. Eco-Driven Signal Control and Eco-Driving of Hybrid City Buses
Michael Haberl, Martin Fellendorf (Graz University of Technology)

Several European cities need to reduce traffic related emissions in order to meet the European Directive 2008/50 on ambient air quality. In order to achieve these reductions diverse concepts to reduce traffic-related pollution do exist. The introduction of single measures in an urban region is often not sufficient. Hence, multiple concepts must be combined. The main focus of this work is to integrate emissions caused by individual and public traffic as a direct and explicit objective for a local adaptive signal-control optimization to guarantee emission-minimizing signalization. The second aim is the introduction of tactical driving for public transport using V2I communication to increase efficiency of traffic flow resulting from additional information for the drivers. The third goal is to quantify the Influence of the driving style on fuel consumption and battery wear of a parallel hybrid city bus, leading to Eco-driving. According to present simulation results the integration of an emission-minimizing extension in EPICS can help to reduce fuel consumption, air pollution and PM. Further results confirm the potential reduction of fuel consumption of public transport vehicles using tactical driving. Moreover present results confirm the potential for reducing fuel consumption of hybrid buses with eco-driving and quantifies it at around 20%. In terms of battery wear it has been calculated that the battery
life is 11% longer for passive driving compared to the average driving habit.

10:50-12:30, TuPoAT1.29
29. Intelligent Navigation System-Based Optimization of the Energy Consumption
Adnane Cabani, Khemmar Radouane Khemmar, Jean-Yves Ertaud, Joseph Mouzna (ESIGELEC-IRSEEM)

The aim of this work is to design and build by 2015 an electric four-seater equipped with an autonomous extension device. The project was born from two observations: in a context of necessary diversification of energy sources and the development of electric vehicles, the main problem remains the battery life and availability of charging stations. The issue of our work lies both in the optimization of energy consumption and improving the electric vehicle. Our team was tasked to develop and implement an Energy Management System of Electric Vehicle. The objective of the mission is to create a program that calculates the set speed to minimize the cost of energy consumption and maximize battery life. This calculation is done by taking into account prevention parameters are: vehicle speed, real-time parameters from Maps (elevations in the path, wind speed, etc.), the forces applied to the vehicle.

10:50-12:30, TuPoAT1.30
30. Ecodriving Performances of Human Drivers in a Virtual and Realistic World
Olivier Orfila, Dominique Gruyer, Vincent Judalet, Marc Revilloud (IFSTTAR)

In this study, results of an ecodriving challenge that took place during the Paris Motor Show in 2014 are presented. The principle of this challenge was to drive a passenger car as far as possible with a limited quantity of energy (15 cL). The experimental setup, constituted of a the SiVIC software, an Oculus Rift Helmet and a fuel consumption model, is also detailed. 1211 trips of visitors were validated during the 17 days of the event. Results showed that high acceleration without kickdown is desirable and that constant speed can lead to significant reduction in energy consumption. Next work will concentrate on improving the simulation and the scenario to increase the immersion realism and the ecodriving behavior sensitivity.

10:50-12:30, TuPoAT1.31
31. Developing a Framework of Eco-Approach and Departure Application for Actuated Signal Control
Peng Hao, Guoyuan Wu, Kanok Boriboonsomsin, Matthew Barth (University of California-Riverside)

The Eco-Approach and Departure application for fixed-time traffic signals, which uses the signal phase and timing information from the upcoming traffic signal to better guide a driver through the intersection in an environmentally-friendly way, has shown promising results in terms of fuel savings and carbon emissions reduction. However, there is very limited research on the development and evaluation of such application for actuated traffic signals. This paper proposes a framework for the Eco-Approach and Departure application for actuated signals which takes into account uncertainties in count-down information, preceding vehicle’s state, and potential driver’s distraction issues. The framework has been evaluated with numerical experiments. The results indicated that the proposed framework is effective at reducing energy consumption and emissions of the equipped vehicle, especially when the initial entry speed is relatively low.

10:50-12:30, TuPoAT1.32
32. Fast PatchMatch Stereo Matching Using Multi-Scale Cost Fusion for Automotive Applications
Ji-Ho Cho (Vienna University of Technology), Martin Humenberger (AIT Austrian Institute of Technology)

Due to recent developments of low-cost image sensors and high-performance embedded processing hardware, future cars and automotive systems will increasingly use binocular stereo vision for environmental perception. However, research and development in stereo vision is still ongoing since there are many challenges unsolved. In this paper, we propose a fast and accurate stereo matching algorithm, designed for automotive applications. It convincingly handles real-world scenes containing complex, textureless, and slanted surfaces. To achieve that, we propose an improved PatchMatch stereo algorithm that combines a census-based cost function with Semi-Global Matching optimization integrated in a cross-scale fusion processing scheme. To further accelerate the algorithm, we propose a novel enhancement approach for PatchMatch-based approximation which allows us to skip the random search or at least significantly reduce the number of iterations. Our method is ranked in the upper third of the KITTI benchmark and among the top performers in terms of processing time.

10:50-12:30, TuPoAT1.33
33. Can Appearance Patterns Improve Pedestrian Detection?
Eshed Ohn-Bar, Mohan M. Trivedi (University of California at San Diego)

This paper studies the usefulness of appearance patterns for the challenging task of pedestrian detection. Despite appearance specific models being common in rigid object detection, the technique is still little understood for pedestrians. Three main approaches for reasoning over orientation, occlusion, and visual cues in obtaining the appearance patterns are compared. This work demonstrates that large gains in detection performance (up to 17 AP points on the challenging KITTI dataset) can be made using a state-of-the-art pedestrian detector.

10:50-12:30, TuPoAT1.34
34. On Line Mapping and Global Positioning for Autonomous Driving in Urban Environment Based on Evidential SLAM
Guillaume Trehard, Evangeline Pollard, Fawzi Nashashibi (INRIA), Benazouz Bradai (Valeo Lighting Systems)

Locate a vehicle in an urban environment still remains a challenge for the autonomous driving community. By fusing information from a LIDAR, a Global Navigation by Satellite System (GNSS) and the vehicle odometry, this article proposes a solution based on evidential grids and a particle filter to map the static environment and simultaneously estimate the position in a global reference at a high rate and without any prior knowledges.

10:50-12:30, TuPoAT1.35
35. Efficient Scene Parsing by Sampling Unary Potentials in a Fully-Connected CRF
Lachlan Horne, José M. Alvarez, Mathieu Salzmann, Nick Barnes (NICTA)

Efficient, fully-connected CRF inference enables fast semantic labelling of images. However, this requires high-quality unary potentials to be computed, which is currently time-consuming. While some recent work attempts to address this issue by only computing a subset of unary potentials, a need remains for a simple, fast way to decide
which unary potentials should be computed, without sacrificing accuracy. In particular, for embedded applications, a method which avoids time or memory-intensive operations is desired. In this paper, we introduce an approach to selecting good locations to compute unary potentials. We implement an efficient morphological approach to select a small proportion of pixel locations where unary potentials will be calculated. The speed of our labelling method allows us to directly search a large parameter space to optimize our method for a given task. We show that our method can achieve comparable accuracy to what can be achieved when all unary potentials are calculated, with significant time saving. Furthermore, we show that it is possible to tune our method to yield improved accuracy for certain classes of interest. We demonstrate this over multiple datasets representing challenging applications for our approach.

10:50-12:30, TuPoAT1.36
36. Robust Profile Face Detection and Rotation Angle Estimation of the Driver’s Head in a Novel Dazzling Avoidance System
Xiangpeng Liu, Qianrui Wang, Jie Zhao, Axel Graeser (University of Bremen)

This paper presents robust methods of detecting the profile face and estimating the rotation angle of the driver’s head in the ShadeVision system [1], which is a novel vision-based driving assistance system aiming to avoid the dazzling effect caused by strong external light. As the detection rate of dazzling effect highly relies on the brightness of the profile face [2], new algorithms need to be developed to realize the robust profile face detection in driving scenario. When there are multiple strong external light sources, the system needs to know where the driver’s sight is focusing in order to determine the light source that is dangerous to the driver [1]. To this end the precise rotation angle of the driver’s head is of great importance. The effectiveness of the developed algorithms is verified by the laboratory and field tests.

10:50-12:30, TuPoAT1.37
37. Fast Accurate Contours for 3D Shape Recognition
Muhammad Usman Butt, John Morris, Nitish Patel, Morteza Biglari-Abhari (The University of Auckland)

We describe an efficient GPU algorithm which extracts multiple contours from an image. The algorithm uses crack codes to generate contours which sit logically between adjacent image values: it works scan line by scan line and it can generate multiple contours in parallel with an image streamed directly from a camera. Whilst specifically targeted at detecting object contours in stereo disparity maps, it can also be used for general segmentation with a trivial change to the code generating the crack code masks. Using a 480 ALU 1.4 GHz nVidia GPU, it can generate ~ 25000 contours from a real 2048 \times 768 resolution 128 level disparity map image in ~ 29 ms if the contours are further processed in the GPU (additional ~ 5 ms to calculate shape moments) or ~ 39 ms if contours are transferred to the host. This is ~ 40 times faster than an OpenCV CPU implementation.

10:50-12:30, TuPoAT1.38
38. Joint Spatial and Doppler-Based Ego-Motion Estimation for Automotive Radars
Michael Barjenbruch, Dominik Kellner, Klaus Dietmayer (Univ. of Ulm), Jens Klappstein (Daimler AG), Jürgen Dickmann (Mercedes-Benz AG)

An ego-motion estimation method based on the spatial and Doppler information obtained by an automotive radar is proposed. The estimation of the motion state vector is performed in a density-based framework. Compared to standard vehicle odometry the approach is capable to estimate the full two dimensional motion state with three degrees of freedom. The measurement of a Doppler radar sensor is represented as a mixture of Gaussians. This mixture is matched with the mixture of a previous measurement by applying the appropriate ego-motion transformation. The parameters of the transformation are found by the optimization of a suitable joint metric. Due to the Doppler information the method is very robust against disturbances by moving objects and clutter. It provides excellent results for highly nonlinear movements. Real world results of the proposed method are presented. The measurements are obtained by a 77 GHz radar sensor mounted on a test vehicle. A comparison using a high-precision inertial measurement unit with differential GPS support is made. The results show a high accuracy in velocity and yaw-rate estimation.

10:50-12:30, TuPoAT1.39
39. A Comparative Study of Color and Depth Features for Hand Gesture Recognition in Naturalistic Driving Settings
Eshed Ohn-Bar, Mohan M. Trivedi (University of California at San Diego)

We are concerned with investigating efficient video representations for the purpose of hand gesture recognition in settings of naturalistic driving. In order to provide a common experimental setup for previously proposed space-time features, we study a color and depth naturalistic hand gesture benchmark. The dataset allows for evaluation of descriptors under settings of common self-occlusion and large illumination variation. A collection of simple and quick to extract spatio-temporal cues requiring no codebook encoding are proposed. Their effectiveness is validated on our dataset, as well as on the Cambridge hand gesture dataset, improving state-of-the-art. Finally, fusion of the modalities and various cues is studied.

Tuesday, June 30, 2015
TuPoPT1: Poster Session 4
16:00-17:40

Chair: Kyoungchul Kong (Sogang University)
Co-Chair: Jianqiang Wang (Tsinghua University)

16:00-17:40, TuPoPT1.1
1. An Auto Exposure Control Algorithm Based on Lane Recognition for On-Board Camera
Tong Li, Yan Song, Tao Mei (Chinese Academy of Sciences)

In order to obtain the accurate exposure time in real-time for an on-board camera in different urban environments, the proposed algorithm divides captured image into 5x5 sub-areas, calculates each sub-area’s average brightness value to get a histogram, analyzes the peak value distribution in histogram to determine what environments the automobile is in. According to the environment the automobile works in, the algorithm includes two modes: normal lit condition and high-contrast lit condition. It executes the appropriate exposure adjustment mechanism for two modes by analyzing their brightness distribution in different environments. To avoid the interference of other factors like the sky, the algorithm marks the road surface be the region of interest in real time. Besides, the optimization goal is not mid-tone at all but the maximum difference between lane and background in the region of interest. The experimental results show that the algorithm can rapidly and stably switched exposure mode when the automobile is traveling in different road conditions, and it can get accurate exposure time in both modes fast and accurately.
This paper addresses the problem of future behavior evaluation and planning for ADAS in general traffic situations. Complex traffic situations require the estimation of future behavior alternatives in terms of predictive risks. Based on the predicted future dynamics of traffic scene entities, we present an approach where a continuous, probabilistic model for future risks is used to build so-called predictive risk maps. These maps indicate how risky a certain ego-car trajectory will be at different predicted times so that they can be used to directly plan the best possible future behavior. Since this optimization problem is highly non-convex we combine the risk maps with sampling-based planning algorithms of the RRT* type to obtain future trajectories which minimize risk and maximize utility. We apply our approach to multiple risk types and various different scenarios, including inner city and highway situations.

3. Lane Change Maneuver Recognition Via Vehicle State and Driver Operation Signals – Results from Naturalistic Driving Data
Guofa Li, Shengbo Li, Yuan Liao, Wenjun Wang, Bo Cheng (Tsinghua University), Fang Chen (Chalmers University of Technology)

Lane change maneuver recognition is critical in driver characteristics analysis and driver behavior modeling for active safety systems. This paper presents an enhanced classification method to recognize lane change maneuver by using optimized features exclusively extracted from vehicle state and driver operation signals. The sequential forward floating selection (SFFS) algorithm was adopted to select the optimized feature set to maximize the k-nearest-neighbor classifier performance. The hidden Markov models (HMMs), based on the optimized feature set, were developed to classify driver lane change and lane keeping maneuvers. Fifteen drivers participated in the road test for validation with an accumulation of 2,200 km naturalistic driving data, from which 372 lane changes were extracted. Results show that the recognition rate of lane change maneuver achieves 88.2%. The numbers are 87.6% and 88.8% for left and right lane change maneuvers, respectively, superior to the results from conventional classifiers.

4. Safety Benefits of Belt Pretensioning in Conjunction with Precrash Braking in a Frontal Crash
Xiao Luo, Wenjing Du, Jinhuan Zhang (Tsinghua University)

This paper estimates safety benefits of crash with precrash braking maneuvers under different pretensioning control factors. A sled test was conducted at 40 kmph with a lap-shoulder-belted Hybrid III 50th percentile male dummy to simulate a frontal crash. A multi-body model of the sled test was developed based on the actual situation and verified by test data including the seat belt loads, head and chest injury responses of the test dummy and motion postures of the dummy. An impact pulse with a 0.2-second-long constant deceleration of 0.8 g ahead of crash was loaded on the verification model to simulate the real deceleration and the crash process with precrash braking maneuvers. The protection performance of a 3-point seat belt, a seat belt with pyrotechnic pretensioner and a motorized seat belt was compared, and the motorized seat belt had the best protection effect. Different pretensioning control factors, such as pretensioning time and pretensioning force, had remarkable effects on injury responses of the dummy. This method could also be used to develop advanced occupant restraint systems coupled with precrash systems to integrate vehicle active safety and passive safety.

5. Quaternion-Based IMU and Stochastic Error Modeling for Intelligent Vehicles
Thomas Brunner, Sèbastien Changey (ISL), Jean-Philippe Lauffenburger, Michel Basset (Université de Haute Alsace)

This paper focuses on the development of an IMU measurement simulator for navigation estimation algorithms validation. Its aim is to generate the sensor measurements thanks to an input trajectory described by the position and orientation. The proposed models are derived from an inverse kinematic modeling of the sensors and an identification of their stochastic errors. These latter are composed of the biases instability, random walks and finally the sensors dynamics and bandwidth. The error model parameters of a low cost MEMS-IMU are determined using the Allan Variance method. In a second step, a Matlab simulator is built gathering the aforementioned models. Thanks to their completeness, this simulation tool is characterized by its wide range of application fields and dynamics that can be described. Its aim is to determine, from the time-dependent position and orientation data, the IMU measurements (3D accelerations and angular rates) without any object model. Finally, the simulator is validated using real experiments performed with an instrumented test car in normal driving as well as in obstacle avoidance situations.

6. Enhanced Maximum Tire-Road Friction Coefficient Estimation Based Advanced Emergency Braking Algorithm
Taewoo Kim, Kyongsu Yi (Seoul National University), Jaewan Lee (Korea Transportation Safety Authority)

This paper presents the maximum tire-road friction coefficient estimation algorithm which considers about the effect of states. Tire force information is an important factor for active safety system. However, it is difficult to estimate due to the dependency on many states such as vehicle speed, tire pressure, and tire wear. In this paper, several experimental researches about the effect of states on the maximum friction coefficient and previous maximum tire-road friction coefficient estimation algorithms are reviewed and summarized. The influential states and the estimation method which doesn’t require extra sensors were determined and combined. The proposed algorithm consists of two parts: an interacting multiple models (IMM) based maximum tire-road friction coefficient estimation and an updating sequence based on the effect of vehicle speed. To validate the algorithm, the closed-loop simulation with the advanced emergency braking system (AEBS) has been conducted. It has been shown that the proposed estimation algorithm could enhance the performance of AEBS algorithm.

7. Problem Formulation Improvement for Multi-Vehicle Collision Avoidance and Impact Mitigation
Ye Yuan, Jianqiang Wang (Tsinghua University), Xiao-Yun Lu (University of California, Berkeley)

Multi-vehicle longitudinal collision avoidance is a long-standing topic in vehicle control and Active Safety. In our previous work we formulated the multi-vehicle collision avoidance and impact mitigation problem assuming V2V (vehicle-to-vehicle communication) as a finite time horizon...
Model Predictive Control (MPC) problem. We intended to use the relative kinetic energy between the approaching vehicles as the measure of potential collision impact, which forms a quadratic objective function. However, the constraint representing vehicle approaching was not formulated appropriately, which caused a very stringent constraint to the feasible could set in the optimization at each time step of the sequential quadratic programming resulted from the MPC process. In this paper, we propose two improvements to the problem formulation: one is in the objective function and the other is in constraints. Performance comparisons between those algorithms are conducted to analyze the pros and cons of those two improvements through simulations.

16:00-17:40, TuPoPT1.8
Julian Timper, Johannes van Balen, Lars Wolf (TU Braunschweig), Stephan Friedrichs (Max Planck Institute for Informatics)

Automated valet parking not only improves driving comfort, but can have a considerable impact on the urban landscape by reducing the required parking space. We present the first study of parking space optimization for automated valet parking with an in-depth theoretical analysis of the parking lot properties under various aspects, including the worst-case extraction time, total shunting distance, and the number of shunting operations (each per car). Most importantly, the proposed model bounds all these values. We verify the theoretical properties of our model in four simulated scenarios, one of which is based on real-world data from a downtown parking garage. We show that very good pick-up times of about 1 min are possible with very little overhead in terms of shunting distance and time, while providing a significantly improved parking density as compared to conventional parking lots.

16:00-17:40, TuPoPT1.9
9. Multi Trajectory Pose Adjustment for Life-Long Mapping
Marc Sons, Christoph Stiller (Karlsruhe Institute of Technology), Henning Lategahn (Atlatec), Christoph Gustav Keller (Daimler AG)

Current highly automated and self-driving vehicles heavily depend on detailed maps since they free the system from many otherwise complex onboard processing tasks. However, depending on the environment and the fineness of the map, the validity span of maps is often short and a periodic remapping of large areas with sensor-packed mapping vehicles is beyond any feasibility. Crowd base mapping approaches using low cost sensors appear more practicable. Herein we propose a general method to align several survey trajectories of the same area which is fundamental for any life-long mapping. Our algorithm requires previously acquired pose differences as input. These differences induce a pose graph which is aligned yielding a minimum least-squares residual. Therefore, our method is independent from the underlying sensor technology. For evaluation purposes, we align pose graphs from simulated pose differences and compare it against the ground truth. Furthermore, stereo cameras are used to obtain pose difference estimates by common visual odometry methods. We present quantitative results of the robustness and accuracy of our method based on these pose differences. The results are compared against a high precision GPS receiver. Our approach clearly outperforms this costly reference sensor.

16:00-17:40, TuPoPT1.10
10. Collision-Free and Kinematically Feasible Path Planning Along a Reference Path for Autonomous Vehicle
Mengyin Fu, Kai Zhang, Yi Yang, Hao Zhu, Meiling Wang (Beijing Institute of Technology)

For the local path planning problem of autonomous vehicle in a complicated environment, a method combining cubic Hermite spline curves with the kinematic model of autonomous vehicle is developed. And a novel algorithm for obstacle avoidance, called navigation circle, is proposed to take the road structure into account, which is a practical method for real-time path planning. In the new method, one of the trajectory generated by cubic Hermite spline curves or navigation circle is optimized through the kinematic model of autonomous vehicle to get the kinematically feasible trajectory. The optimization is actually a numerical forward propagation and is easy to implement. The simulation experiment is conducted on the Robot Operating System (ROS) platform, which is based on replaying the data of the real world obtained from sensors or other modules on autonomous vehicle. Satisfactory simulation results verify the validity and the efficiency of the proposed method as well as the planner’s capability to navigate in a realistic scenario.

16:00-17:40, TuPoPT1.11
11. Please Take Over! An Analysis and Strategy for a Driver Take Over Request During Autonomous Driving
Mohammad Bahram, Michael Aebiherhard (BMW Group Research and Technology), Dirk Wollherr (Technische Universität München)

During autonomous driving, in particular conditional or highly automated driving, a critical part of the system is the driver take over request. Little focus has been given to this important aspect in an automated driving journey. A driver takes over the control of the vehicle before the automated driving system deactivates. This paper presents a detailed analysis of why a TOR can occur, how the automated driving system should react during the TOR phase and what should happen at the end of a TOR in order to realize a safe and comfortable TOR for the driver. Various driving strategies during a TOR are presented and evaluated for a single-lane highway scenario.

16:00-17:40, TuPoPT1.12
12. Autonomous Car Following: A Learning-Based Approach
Stéphanie Lefèvre, Ashwin Carvalho, Francesco Borrelli (University of California at Berkeley)

We propose a learning-based method for the longitudinal control of an autonomous vehicle on the highway. We use a driver model to generate acceleration inputs which are used as a reference by a model predictive controller. The driver model is trained using real driving data, so that it can reproduce the driver’s behavior. We show the system’s ability to reproduce different driving styles from different drivers. By solving a constrained optimization problem, the model predictive controller ensures that the control inputs applied to the vehicle satisfy certain safety criteria. This is demonstrated on a vehicle by artificially creating potentially dangerous situations with virtual obstacles.
16:00-17:40, TuPoPT1.13
Yonghwan Jeong, Kyuwon Kim, Bemjun Kim, Kyongsu Yi (Seoul National University), Jihyun Yoon, Hyok-jin Chong, Bongchul Ko (Hyundai Motor Company)

This paper presents a vehicle sensor and actuator fault detection algorithm for automated vehicles. The diagnostic system is designed to monitor steering wheel angle, yaw-rate, and wheel speed sensors and steering, throttle, and brake actuators used by the lateral and longitudinal controllers of the vehicle. Different combinations of the observer estimates, the sensor measurements, and the control commands are used to construct a bank of residuals. A fault in any of the vehicle sensors or actuators leads to the increase of the unique subset of residuals. The adaptive threshold is used to enable the exact identification of the abnormal increase of residual. The fault detection performance and its reliability of the proposed algorithm have been investigated via computer simulation studies and real-time vehicle tests. The enhancement of the fault detection allows for the realization of autonomous driving vehicles using actuation by embedded computer.

16:00-17:40, TuPoPT1.14
Andreas Reschka, Gerrit Bagschik, Simon Ulbrich, Marcus Noile, Markus Maurer (TU Braunschweig)

In this paper, the ability and skill graphs are introduced for modeling vehicle guidance systems in the concept phase of the development process (abilities), for online monitoring of system operation (skills), and to support driving decisions (skill levels) of automated road vehicles and advanced driver assistance systems. Both graphs rely on a decomposition of the human driving task. An ability is the entirety of conditions which are necessary to provide a certain part of the driving task. The ability graph can be developed in parallel to the item definition according to the ISO 26262 standard in the concept phase of the development process and can be used for supporting further development steps. A skill is defined as an abstract representation of a part of the driving task including information about the skills current performance. The skill graph is used to monitor the current system performance during operation and skill levels are input to driving decisions. Abilities and skills cover all aspects of the driving task including environment and self perception, data processing, decision making, and behavior execution. During operation of the developed item, the skill graph is instantiated as a distributed software component to process online information for assessing current skill levels. Each skill uses one or more performance metrics, which represent its current performance capability in relation to the maximum (inherent) ability level. The resulting information could replace the monitoring of the system by a human driver and can be used as an input to driving decisions of the vehicle to support appropriate and safe decisions.

16:00-17:40, TuPoPT1.15
15. Task Planning for Highly Automated Driving
Chao Chen, Andre K Gaschler, Markus Rickert, Alois Knoll (Technische Universitat Munchen)

A hybrid planning approach is presented in this paper with the focus of integrating task planning and motion planning for highly automated driving. In the context of task planning, the vehicle and environment states are transformed from the continuous configuration space to a discrete state space. A planning problem is solved by a search algorithm for an optimal task sequence to reach the goal conditions in the symbolic space, regarding constraints such as space topology, place occupation, and traffic rules. Each task can be mapped to a specific driving maneuver and solved with a dedicated motion planning method in the continuous configuration space. The task planning approach not only bridges the gap between high-level navigation and low-level motion planning, but also provides a modular domain description that can be developed and verified individually. Our task planner for automated driving is evaluated in several scenarios with prior knowledge about the road-map and sensing range of the vehicle. Behavior that is otherwise complex to achieve is planned according to traffic rules and replanned regarding the on-line perception.

16:00-17:40, TuPoPT1.16
16. The Impact of Driver Cognitive Distraction on Vehicle Performance at Stop-Controlled Intersections
Yuan Liao, Shengbo Li, Wenjun Wang, Guofa Li, Bo Cheng (Tsinghua University), Ying Wang (Beihang University)

Driver distraction has been identified as an important driving safety issue. However, existing studies focused on low-speed conditions, especially at intersections. This paper aims to find the impact of driver cognitive distraction on vehicle performance at stop-controlled intersections. Eight subjects (young adult: 4, older adult: 4) participated in this study and each of them drove through 40 stop-controlled intersections. The intersections were presented randomly at two levels of FOV (field of view). Driver cognitive distraction was induced by a one-back task and a clock task. Results showed that the cognitive tasks led to more abrupt steering in both age groups while significant influence on lane-keeping capability was only observed in the young group. Steering smoothness was mainly influenced by the cognitive tasks at brake-on-restart phase in the young group while at after-restart phase in the older group. Impaired longitudinal control (stop for watching) was observed in the older adult group. These findings can be applied to automatically recognize driver distraction at stop-controlled intersections in future.

16:00-17:40, TuPoPT1.17
17. Estimating Driver Awareness of Pedestrians in Crosswalk in the Path of Right or Left Turns at an Intersection from Vehicle Behavior
Kei Tateiwa, Keiich Ynamda (Meijo University)

This paper presents a method for estimating a driver's awareness of the presence of a pedestrian while crossing or trying to cross a crosswalk located in the path of a right or left turn when the driver is trying to turn right or left at an intersection based on the behavior of the vehicle operated by the driver. The method is based on the idea that different driving behaviors occur in similar situations depending on whether the driver notices a pedestrian. The results of an evaluation performed using actual driving behavior data of vehicles driven on public roads are also reported.

16:00-17:40, TuPoPT1.18
18. Face Orientation Estimation for Driver Monitoring with a Single Depth Camera
Zhengcheng Hu, Naoko Uchida (Kumamoto University), Yanning Wang, Yancho Dong (Tongji University)

Parking Assistance System (PAS) provides useful help to beginners or less experienced drivers in complicated urban parking scenarios. In recent years, ultrasonic sensor based PAS and rear-view camera based PAS have been proposed from different car manufacturers. However, ultrasonic sensors detection distance is less than 3 meters and results cannot be used to extract further information like obstacle
recognition. Rear-view camera based systems cannot provide assistance to the circumstances like parallel parking which need a wider view. In this paper, we proposed a surround view based parking lot detection algorithm. An efficient tracking algorithm was proposed to solve the tracking problem when detected parking slots were falling out of the surround view. Experimental results on simulation and real outdoor environment showed the effectiveness of the proposed algorithm.

16:00-17:40, TuPoPT1.19
19. Predicting the Driver’s Turn Intentions at Urban Intersections Using Context-Based Indicators
Olaas Rodemerk, Hermann Winner (Technical University of Darmstadt), Robert Kastner (Honda R&D Europe GmbH)

Many improvements have been made in the area of vehicle safety and pedestrian protection; however, urban intersections are still black spots for Advanced Driver Assistance Systems (ADAS). One of the main reasons is the uncertainty of the future driving direction at intersections. Due to that uncertainty, the early activation of an intersection ADAS will lead to high false positive rates, while, in contrast, a late activation of an intersection ADAS will lead to a low accident-reduction potential. This tradeoff is described as warning dilemma. In order to solve the warning dilemma, an approach to predicting the driver’s turn intention at urban intersections is introduced. The novelty of the approach is its context-based prediction of the future driving maneuver several seconds before the driving trajectory changes. To predict maneuvers, indicators are used to encode the context information together with vehicle data. A system setup including prediction results of the system is described.

16:00-17:40, TuPoPT1.20
20. Estimation of Driver Awareness of Pedestrian Based on Hidden Markov Model
Minh-Tien Phan, Vincent Fremont, Indira Thouvenin, Mohamed Sallak, Véronique Cherfaoui (Université de Technologie de Compiègne)

Understanding driver behaviors is an important need for the Advanced Driver Assistance Systems. In particular, the pedestrian detection systems become extremely distracting and annoying when they inform the driver with unnecessary warning messages. In this paper, we propose to study the driver behaviors whenever a pedestrian appears in front of the vehicle. A method based on the driving actions and the Hidden Markov Model (HMM) algorithm is developed to classify the driver awareness of pedestrian and the driver unawareness of pedestrian. The method is successfully validated using the collected data from the experiments that are conducted on a driving simulator. Furthermore, two simple methods based on the static parameters such as the Time-To-Collision and the Required Deceleration Parameter are also applied to our problem and are compared to the proposed method. The result shows a significant improvement of the HMM-based method compared to the simple ones.

16:00-17:40, TuPoPT1.21
21. Automatic Lane Change Extraction Based on Temporal Patterns of Symbolized Driving Behavioral Data
Masataka Mori, Kazuhito Takenaka, Takashi Bando (DENSO Corporation), Tatadhiro Taniguchi (Ritsumeikan University), Chiyomi Miyajima, Kazuya Takeda (Nagoya University)

This paper proposes a method of automatically extracting lane change situations from large-scale driving corpora. Naturalistic driving data stored in large-scale corpora has a potential of contributing for developing novel advanced driver-assistance systems based on estimated information about driver’s intent and/or potential risk of accidents. However, direct estimation of such kind of information from stream data is difficult. To address the issue, we apply an unsupervised symbolization method and topic representation to driving data. Driving stream data is converted to sequences of discrete symbols by a non-parametric symbolization method, and then the symbols are characterized by topics which represent typical distribution of driving behavior observed during the symbols. Because these symbols are separated on changing points of driving behavior, similar driving situations are effectively retrieved from sequences of the symbols. For evaluating effectiveness of the symbolization approach, we extract lane change situations based on the topic proportions and their temporal patterns. Distinctive elements of topic proportions and their temporal patterns for lane change situations are extracted by AdaBoost classifier. As a result, proposed approach outperforms baselines with neither topic proportions nor their temporal patterns in terms of extracting lane change situations. This result shows effectiveness of symbols with topic proportions for representing characteristics of driving situations.

16:00-17:40, TuPoPT1.22
22. In-Car Tactical Advice Using Delayed Detector Data
Wouter Schakel, Bart van Arem (Delft University of Technology)

In-car tactical advice is advice that is given in-car concerning the tactical scale, e.g. lane changing and desired speed and headway, and that has been shown to reduce travel time delay. We assess the effects of detector data delay on traffic state prediction and on the effectiveness of in-car tactical advice using microscopic simulation. Interestingly, effectiveness does not reduce with data delays from 0s up to 180s, indicating that for the presented case, congestion is predicted with sufficient accuracy. However, estimation errors in speed and flow increase, and accuracy of advices (including false negatives and positives) decreases. Consequently, compliance, and as a result effectiveness, may be expected to reduce for larger data delay. This paper shows that in-car tactical advice may reduce travel time delay with about 33% even if drivers are attentive and relatively efficient without advice.

16:00-17:40, TuPoPT1.23
23. Performance Comparison of Two Model Based Schemes for Estimation of Queue and Delay at Signalized Intersections
Anusha S. P, Lelitha Vanajakshi, Shankar Subramanian (Indian Institute of Technology, Madras), Anuj Sharma (Iowa State University)

Reliable estimation of performance measures such as queue and delay at intersections is important for the proper management of traffic. The information about these variables is valuable for the development of various traffic control strategies. The spatial nature of queue and delay makes their direct measurement a challenging task. The present study estimated these performance measures for the scenario when the queue ends within the advance detector using the data obtained from loop detectors installed at the entry and the exit of the intersection. A detailed analysis of the data obtained from loop detectors revealed that there were errors in the data. Two model based schemes, namely the occupancy based method and the queue clearance based method, were used for estimation of queue and delay using the erroneous data obtained from loop detectors. The results showed that the queue clearance based method was
performing better while estimating queue and delay compared to the occupancy based method. Thus, the queue clearance based method would be valuable for the estimation of queues and delays while implementing with erroneous field data.

16:00-17:40, TuPoPT1.24
24. Traffic Density Estimation Using Dimensional Analysis
Amritha Sunny, Lelitha Vanajakshi, Shankar Subramanian (Indian Institute of Technology, Madras)

Traffic density, defined as the number of vehicles per unit length, is the primary measure used for quantifying road congestion. However, the direct measurement of this variable is difficult due to its spatial nature and the only method to directly measure it from field is aerial photography. Hence, it is usually estimated from other easily measurable variables such as speed or flow. Some of the reported approaches to obtain density include the input output analysis, fundamental traffic flow relation, and occupancy-based measurements in addition to those based on statistics, machine learning or model-based approaches. However, for better performance, all these methods require the careful selection of the relevant input variables/parameters and their relationships. One way of obtaining these relationships is to perform a dimensional analysis of the variables/parameters involved, identifying the non-dimensional variables/parameters and then obtaining a relationship between them using experimental data. This approach has been attempted for estimating road traffic density in this paper. The appropriate non-dimensional variables/parameters that characterize road traffic flow were first determined and the relation between them was then found out using simulated data. This relationship was subsequently used to estimate density for other datasets and the results were found to be promising.

16:00-17:40, TuPoPT1.25
Jinsoo Kim, Jinhan Jeong, Kyung-young Jhang, Jahng Hyon Park (Hanyang University)

Disturbance propagation and string stability of a large vehicle platoon that consists of a part of the traffic flow is closely related to traffic shockwaves and oscillation. In this respect, the concepts of the estimation and prediction of shockwave propagation speeds and congestion should be considered in order to establish a control strategy for safe conditions without collisions even when the congestion is amplified in an unstable string of the large platoon. This means that an advanced approach for a car-following control strategy, which includes a time delay and non-linearity terms, is necessary for the enhancement of Vehicle Platoon Control (VPC) and the system robustness. In this research, we have demonstrated the effect of the disturbance propagation phenomenon on traffic flow stability. The traffic flow shockwave and oscillation are interpreted in terms of both macroscopic and microscopic approaches. We also discuss how the phenomenon affects VPC systems based on the optimal velocity model (OVM), which is an advanced car-following model. In addition, we improve the OVM, which is called the advanced OVM, by including a term for the delay time and by setting up a boundary condition of acceleration in order to enhance the VPC system and to ensure its robustness.

16:00-17:40, TuPoPT1.26
Simone Formentin, Andrea Giovanni Bianchessi, Sergio Savaresi (Politecnico di Milano)

The free-floating car sharing model is a recently introduced vehicle rental model, which allows customers to return the car anywhere within the operation area, without relying on depot stations. Driven by the flexibility of such a model, the popularity of car sharing has increased rapidly during the last years. However, some critical issues still arise when a user needs to make plans of vehicle usage, since no information is available on future vehicle locations. In this paper, the Vehicle Distance Prediction (VDP) approach is proposed, aimed to predict the distance of the nearest available vehicle at a given future instant. This technique shows great potential also for the service manager, e.g. vehicles could be moved in advance by the staff to balance the fleet distribution. The effectiveness of the proposed prediction approach is assessed on a real dataset taken from a car sharing service in Milan, Italy.

16:00-17:40, TuPoPT1.27
27. Adaptive Dynamic Preview Control for Autonomous Vehicle Trajectory Following with DDP Based Path Planner
Ning Wu, Weiwei Huang, Xiaojun Wu, Zhiwei Song, Qun Zhang, Susu Yao (Institute for Infocomm Research)

For autonomous navigation system of intelligent vehicle, robust and stable control with accurate tracking ability is one of the key requirements. In this paper, we present a systematic controller design approach for autonomous vehicle navigation system. The proposed controller integrates dynamic vehicle model and online updated path model by quadratic programming (QP) cost function, which considers both tracking error and stability. A novel path planner based on the differential dynamic programming (DDP) with consideration of the kinematic feasibility is used. The path tracking accuracy has been improved by utilizing the proposed dynamic preview controller. Promising experimental results showed that the overall navigation system is robust and stable.

16:00-17:40, TuPoPT1.28
28. Torque-Vectoring Stability Control of a Four Wheel Drive Electric Vehicle
Benedict Jaeger, Peter Neugebauer, Reiner Kriesten, Christian Gutenkunst (University of Applied Sciences), Nejila Parspour (University of Stuttgart)

The electrification of the automotive powertrain provides completely new control options regarding the distribution of individual wheel moments. The integration of up to four independently controlled electrical engines in a vehicle allows individual adjustment of driving and braking torques to the current driving situation. Thus, electrical engines create a new kind of dynamic vehicle control. Unlike the Electronic Stability Control (ESC), Torque-Vectoring influences the vehicle dynamics not only through braking forces but also by setting up positive driving torques allowing for a new way of dynamic driving. In this paper two different control algorithms are developed in order to calculate a desired yaw moment to influence vehicle dynamics. The Torque-Vectoring algorithm distributes the yaw moment among the four wheels. The evaluation of the vehicle dynamic simulation has shown that the best results regarding the control quality can be reached by using the Fuzzy control algorithm to optimize the driving stability in extreme driving situations.
29. Inverse Model Control Including Actuator Dynamics for Active Dolly Steering in High Capacity Transport Vehicle  
Mohammad Manjurul Islam, Bengt Jacobson (Chalmers University of Technology), Leo Laine (Volvo Group Trucks Technology)

This paper describes an advance controller designed using the nonlinear inversion technique of a Modelica based simulation tool, such as Dymola, for active dolly steering of a high capacity transport vehicle. Actuator dynamics is included in the inverse model controller. Therefore, it can automatically generate required steering angle request for the dolly axles of the vehicle combination. The resultant controller is transferred as a functional mock-up unit (FMU) to Simulink environment where the actual simulations are conducted. The controller is simulated against a high-fidelity vehicle model of an A-double combination from Virtual Truck Models (VTM) library -- developed by Volvo Group Trucks Technology. Effects of variations of the actual actuator dynamics, with respect to the modeled dynamics in the inverse model controller, on overall vehicle performance are investigated.

30. Optimal Tire Force Allocation for Trajectory Tracking with an Over-Actuated Vehicle  
Hyungchae Park, Chris Gerdes (Stanford University)

As more actuators are implemented, vehicles are becoming over-actuated and obtaining more authority to control individual tire forces. This paper presents a method that utilizes this abundant actuating capability to allocate tire forces optimally with a convex optimization formulation. The basic objective of this optimal allocation is to keep the usage of total tire friction capability equal over the four wheels. Achieving this goal has the advantage of preventing some tires from reaching saturation before other tires do. This algorithm for optimal tire force allocation can be combined with trajectory tracking near the limits of handling to follow the desired speed, heading, and lateral position of a vehicle. Experimental results demonstrate the performance of the method for successful tracking of all three desired trajectory states simultaneously while achieving equal friction usage among the tires.

31. A Comparative Study of Lane Keeping System: Dynamic and Kinematic Models with Look-Ahead Distance  
Chang Mook Kang, Seung-Hi Lee, Chung Choo Chung (Hanyang University)

In this paper, we propose kinematic vehicle lateral motion model based lane keeping system considering look-ahead distance. The state-space model based on the kinematic vehicle lateral motion model is derived and we design the lane keeping system (LKS) based on the kinematic model. The kinematic model based LKS is robust against unknown vehicle parameters variation. Furthermore, to consider look-ahead distance in the kinematic vehicle lateral motion model, we designed output measurement matrix using clothoidal constraints. Hence, we can control the vehicle at look-ahead distance like human driver. Control performance of each model was validated via computational simulation results with CarSim and MATLAB/Simulink, and experimental results with electric power steering system equipped with an Autobox from dSPACE.
driving behavior information. Twelve DSAEs are used to independently extract features from the twelve prepared data sets, and canonical correlation analysis is used to analyze the canonical correlation coefficients between extracted features. Furthermore, we verify the DSAEs’ ability to extract essential driving behavior features from the redundant driving behavior data sets.

16:00-17:40, TuPoPT1.35
35. Calibration-Free Correspondence Finding between Vision and LIDAR Sensors
Egor Sattarov, Sergio Rodriguez, Roger Reynaud (Universite Paris-Sud), Alexander Geperth (ENSTA ParisTech)

We present a learning approach that allows to detect correspondences between visual and LIDAR measurements. In contrast to approaches that rely on calibration, we propose a learning approach that will create an implicit calibration model from training data. Our model can provide three functions: first of all, it can convert a measurement in one sensor into the coordinate system of the other, or into a distribution of probable measurements in case the transformation is not unique. Secondly, using a correspondence measure that we define, the model is able to decide if two visual/LIDAR measurements are likely to come from the same object. This is of profound importance for applications such as object detection or tracking where contributions from several sensors need to be combined. We demonstrate the feasibility of our approach by training and evaluating our system on tracklet in the KITTI database.

16:00-17:40, TuPoPT1.36
36. Modeling the Cost and Coverage of an Ad-Hoc Asset Management System Based on Existing Fleet Vehicles
Dana Pordel, Lars Petersson, Namin Shahlin, Adrián Rebola Pardo (NICTA)

Monitoring road assets such as road signs, utility poles, features of the road itself or other structures close to where vehicles are driving is important. Such assets need to be monitored in order to maintain them and minimize accident fatalities caused by non-compliance. However, traditional surveying methods that utilize dedicated vehicles equipped with high-end expensive sensors turn out to be very costly and hence, surveys can only be carried out every few years. This paper explores the feasibility of equipping existing fleet vehicles, such as taxis, with low-end, low-quality sensors that traverse the road network through their normal daily activities. The cost and coverage of such a new approach is modeled with the help of a dataset T-Drive from Microsoft that provides taxi trajectories for more than 10,000 taxis in Beijing. The paper further estimates the optimal, from a cost perspective, number of taxis needed to survey the region by considering the cost of explicitly surveying areas that have not been covered by the random trajectories of the taxis.

16:00-17:40, TuPoPT1.37
37. Fusion of Laser and Radar Sensor Data with a Sequential Monte Carlo Bayesian Occupancy Filter
Dominik Nuss, Manuel Stuebler, Stephan Reuter, Klaus Dietmayer (University of Ulm), Ting Yuan (MBDNA, Inc), Gunther Krehl (Mercedes Benz Res. & Development North America, Inc)

Occupancy grid mapping is a well-known environment perception approach. A grid map divides the environment into cells and estimates the occupancy probability of each cell based on sensor measurements. An important extension is the Bayesian occupancy filter (BOF), which additionally estimates the dynamic state of grid cells and allows modeling changing environments. In recent years, the BOF attracted more and more attention, especially sequential Monte Carlo implementations (SMC-BOF), requiring less computational costs. An advantage compared to classical object tracking approaches is the object-free representation of arbitrarily shaped obstacles and free-space areas. Unfortunately, publications about BOF based on laser measurements report that grid cells representing big, contiguous, stationary obstacles are often mistaken as moving with the velocity of the ego vehicle (ghost movements). This paper presents a method to fuse laser and radar measurement data with the SMC-BOF. It shows that the doppler information of radar measurements significantly improves the dynamic estimation of the grid map, reduces ghost movements, and in general leads to a faster convergence of the dynamic estimation.

16:00-17:40, TuPoPT1.38
38. Traffic and Vehicle Speed Prediction with Neural Network and Hidden Markov Model in Vehicular Networks
Bingnan Jiang, Yunsi Fei (Northeastern University)

Accurate on-road vehicle speed prediction is important for many intelligent vehicular and transportation applications. It is also challenging because the individual vehicle speed is affected by many factors, e.g., traffic speed, vehicle type, and driver’s behavior, in either deterministic or stochastic ways. This paper proposes a novel vehicle speed prediction method in the context of vehicular networks, where the real-time traffic information is accessible. Traffic speeds of following road segments are first predicted by Neural Networks (NNs) based on historical traffic data. Hidden Markov models (HMMs) are trained by the Baum-Welch algorithm with historical traffic and vehicle data to present the statistical relationship between vehicle speed and traffic speed. The forward-backward algorithm is applied on HMMs to extract vehicle’s speed on each road segment along the driving route. Simulation is set up on the SUMO microscopic traffic simulator with the application of a real Luxembourg highway network and traffic count data. The vehicle speed prediction result shows that our proposed method outperforms other ones in terms of prediction accuracy.

16:00-17:40, TuPoPT1.39
Matej Kubicka, Hugues Mounier, Silviu-Iulian Niculescu (CNRS/Supelec), Arben Gela (ESIEE Paris), Philippe Moulin (IFP Energies Nouvelles)

We present a large-scale dataset for testing, benchmarking, and offline learning of map-matching algorithms. For the first time, a large enough dataset is available to prove or disprove map-matching hypotheses on a world-wide scale. There are several hundred map-matching algorithms published in literature, each tested only on a limited scale due to difficulties in collecting truly large scale data. Our contribution aims to provide a convenient gold standard to compare various map-matching algorithms between each other. Moreover, as many state-of-the-art map-matching algorithms are based on techniques that require offline learning, our dataset can be readily used as the training set. Because of the global coverage of our dataset, learning does not have to be biased to the part of the world where the algorithm was tested.
We study the use of kinematic and dynamic vehicle models for model-based control design used in autonomous driving. In particular, we analyze the statistics of the forecast error of these two models by using experimental data. In addition, we study the effect of discretization on forecast error. We use the results of the first part to motivate the design of a controller for an autonomous vehicle using model predictive control (MPC) and a simple kinematic bicycle model. The proposed approach is less computationally expensive than existing methods which use vehicle tire models. Moreover it can be implemented at low vehicle speeds where tire models become singular. Experimental results show the effectiveness of the proposed approach at various speeds on windy roads.

This paper describes a robust yaw stability controller for commercial vehicles. In the case of commercial vehicles, parameter variations are relatively large, compared to those of passenger vehicles, due to large variations of load conditions. A feasible parameter variation region can be constructed by Monte Carlo method. The parameter variations in commercial vehicles can cause performance deterioration of a yaw stability controller, designed with nominal parameters. To guarantee the robust performance for a yaw stability controller against parameter variations, it is necessary to design a robust one. To design a robust yaw stability controller, the methods of stochastic root locus and parameter sensitivity reduction are adopted. Computer simulation study was conducted to evaluate the proposed controller. From simulation study, it is shown that the proposed robust yaw stability controller is effective against parameter variations in commercial vehicles.

This paper describes an advanced path following control strategy enabling overactuated robotic vehicles like the ROboMObil (ROMO) [1] to automatically follow predefined paths while all states of the vehicle’s planar motion are controlled. This strategy is useful for autonomous vehicles which are guided along online generated paths including severe driving maneuvers caused by e.g. obstacle avoidance.

The proposed approach combines path following, i.e. tracking a plane curve without a priori time parameterization of a trajectory, with feedback based vehicle dynamics stabilization. A path interpolation method is introduced which allows to perform the path following task employing a trajectory tracking controller. Furthermore a tracking controller based on I/O linearization and quadratic programming based control allocation is proposed which allows employing the vehicle’s overactuation in an optimal manner. The work concludes by a simulative evaluation of the controller performance.
making algorithm for autonomous driving on urban road. Specifically, an urban road situation model is proposed first for proper environment representation, thereafter the situation-aware decision making problem is modeled as a Partially Observable Markov Decision Process (POMDP) and solved in an online manner. The proposed algorithm has been extensively evaluated, which is general enough for autonomous driving in various urban road scenarios, including leader following, collision avoidance and traffic negotiation at both T-junction and roundabout.

10:50-12:30, WePoA1.3
3. Prioritizing Collision Avoidance and Vehicle Stabilization for Autonomous Vehicles
Joseph Funke, Matthew Brown, Stephen M. Erlien, Chris Gerdes (Stanford University)

Trajectory generation and trajectory tracking often comprise autonomous vehicle control. Vehicle stabilization is then entrusted to the vehicle's built-in production systems, such as electronic stability control, which constantly augment driving inputs to ensure stability. Some approaches do explicitly consider stabilization and implement permanently active constraints on the vehicle's actions. Situations exist, however, where ensuring vehicle stability could lead to an otherwise avoidable collision. This paper presents an alternative paradigm for autonomous vehicle control that explicitly considers vehicle stability and environmental boundaries as it attempts to track a trajectory: such a mediator can choose to violate short term stability constraints in order to avoid a collision. Model predictive control provides an implementation framework, and an autonomous vehicle demonstrates the viability of the controller as it performs aggressive maneuvers. Driving around a turn at the vehicle's limits exhibits the importance of vehicle stability for autonomous vehicle control. Performing an emergency double lane change, however, highlights a situation where stability criteria must be temporarily violated to avoid a collision.

10:50-12:30, WePoA1.4
4. Multi-Drive Feature Association for Automated Map Generation Using Low-Cost Sensor Data
Markus Schreiber, André-Marcel Hellmund (FZI Research Center for Information Technology), Christoph Stiller (Karlsruhe Institute of Technology)

In this paper, we present an approach targeting the automated road map generation for autonomously driving vehicles using low-cost GPS sensor data in a multi-drive setup. Multiple drives with deployed commodity smartphone and stereo camera system are recorded as input data. To overcome the high position uncertainties of the GPS sensor, the GPS trajectory is fused with ego-motion estimates of the vehicle computed by visual odometry. Landmarks are extracted from the recorded imagery data and fused over all recorded drives. The resulting road map consists of a simple, parametric representation of globally referenced lane markings with low storage impact. The challenging aspect in this work is the feature association between multiple drives. Different characteristics of dashed center lines are exploited for this purpose to handle the low precision of the sensor data. The resulting association information is the building block for graph-based SLAM to optimize vehicle poses and landmarks simultaneously. The approach is finally evaluated on real world data comparing the low-precision sensor data with high-precision sensor data as ground-truth.

10:50-12:30, WePoA1.5
5. Path Planning with Orientation-Aware Space Exploration Guided Heuristic Search for Autonomous Parking and Maneuvering
Chao Chen, Markus Rickert (Fortiss GmbH), Alois Knoll (Technische Universität München)

Due to the nonholonomic constraints of the vehicle kinematics, parking and maneuvering a car in a narrow clustered space are among the most challenging driving tasks. This paper introduces an extended version of Space Exploration Guided Heuristic Search (OSEHS) method, called Orientation-Aware Space Exploration Guided Heuristic Search (OSEHS), to solve the path planning problems for parking and maneuvering. This method considers the orientation of a vehicle in the space exploration phase to achieve knowledge about driving directions. Such information is exploited later in the heuristic search phase to improve the planning efficiency in maneuvering scenarios. This approach is not bound to the specific domain knowledge about a parking or maneuvering task, but obtains the space dimension and orientation information through a generic exploration procedure. Therefore, it is convenient to integrate the maneuvering ability into a general SEHS motion planning framework. Experiments show that the OSEHS approach produces better results than common random-sampling methods and general heuristic search methods.

10:50-12:30, WePoA1.6
6. General Behavior and Motion Model for Automated Lane Change
Hossein Tehrani Nik Nejad, Masumi Egawa, Kenji Muto (DENSO Corporation), Quoc Huy Do, Keisuke Yoneda, Seiichi Mita (Toyota Technological Institute)

Lane change maneuver is a cause for many severe highway accidents and automatic lane change has great potentials to reduce the impact of human error and number of accidents. Previous researches mostly tried to find an optimal trajectory and ignore the behavior model. Presented methods can be applied for simple lane change scenario and generally fail for complicated cases or in the presence of time/distance constraints. Through analysis and inspiring of human driver lane change data, we propose a multi segments lane change model to mimic the human driver for challenging scenarios. We also propose a method to convert behavior/motion selection to a time-based pattern recognition problem. We developed a simulation platform in PreScan and evaluated proposed automatic lane change method for challenging scenarios.

10:50-12:30, WePoA1.7
7. A Practical Trajectory Planning Framework for Autonomous Ground Vehicles Driving in Urban Environments
Xiaohui Li, Zhenping Sun, Qi Zhu, Daxue Liu, Zhen He (National University of Defense Technology)

This paper presents a practical trajectory planning framework towards fully autonomous driving in urban environments. Firstly, based on the behavioral decision commands, a reference path is extracted from the digital map using the LIDAR-based localization information. The reference path is refined and interpolated via a nonlinear optimization algorithm and a parametric algorithm, respectively. Secondly, the trajectory planning task is decomposed into spatial path planning and velocity profile planning. A closed-form algorithm is employed to generate a rich set of kinematically-feasible spatial path candidates within the curvilinear coordinate framework. At the same time, the velocity planning algorithm is performed with considering safety and
smootherness constraints. The trajectory candidates are evaluated by a carefully developed objective function. Subsequently, the best collision-free and dynamically-feasible trajectory is selected and executed by the trajectory tracking controller. We implemented the proposed trajectory planning strategy on our test autonomous vehicle in the realistic urban traffic scenarios. Experimental results demonstrated its capability and efficiency to handle a variety of driving situations, such as lane keeping, lane changing, vehicle following, and static and dynamic obstacles avoiding, while respecting traffic regulations.

10:50-12:30, WePoA1.8
8. Timing of Unstructured Transitions of Control in Automated Driving
Brian Mok, Mishel Johns, Hillary Ive, David Miller, Wendy Ju (Stanford University), Key Jung Lee (Robert Bosch LLC)

With automated driving systems, drivers may still be expected to resume full control of the vehicle. While structured transitions where drivers are given warning are desirable, it is critical to benchmark how drivers perform when transition of control is unstructured and occurs without advanced warning. In this study, we observed how participants (N=27) in a driving simulator performed after they were subjected to an emergency loss of automation. We tested three transition time conditions, with an unstructured transition of vehicle control occurring 2 seconds, 5 seconds, or 8 seconds before the participants encountered a road hazard that required the drivers’ intervention. Few drivers in the 2 second condition were able to safely negotiate the road hazard situation, while the majority of drivers in 5 or 8 second conditions were able to navigate the hazard safely. Similarly, drivers in 2 second condition rated the vehicle to be less likeable than drivers in 5 and 8 second conditions. From the study results, we are able to narrow in on a minimum amount of time in which drivers can take over the control of vehicle safely and comfortably from the automated system in the advent of an impending road hazard.

10:50-12:30, WePoA1.9
9. On Time-Memory Trade-Off for Collision Detection
Albert Rizaldi, Sebastian Söntges, Matthias Althoff (Technische Universität München)

Future collision avoidance systems, which are capable of fully controlling the vehicle, have to make critical decisions in a very short amount of time. To do this, they need to check constantly if their own vehicle’s occupancy collides with the other traffic participants’ occupancy. Those collision checks consume a substantial amount of time and, consequently, the collision avoidance systems could fail to intervene when we have complex scenarios. We propose a new approach to reduce significantly the computation time for collision checks.

10:50-12:30, WePoA1.10
10. Sampling-Based Collision Warning System with Smartphone in Cloud Computing Environment
Hwasoo Yeo, Sehyun Tak, Soomin Woo (KAIST)

For improvement of road safety, many collision-warning systems are developed. In this study, we propose Sampling-based Collision Warning System (SCWS) that overcomes the limitations of existing collision warning systems such as high installation cost, requirement of high market penetration rate, and the lack of consideration of traffic dynamics. SCWS gathers vehicle operation data though smartphones of drivers on the road and shares the information of surrounding vehicles’ movement through a cloud server. From the pool of information on the cloud, SCWS uses sampled data, which indirectly represents the traffic state and traffic changes in the perspective of the leader vehicle. Therefore, SCWS can effectively replace the leader vehicle’s information with the average behavior of sampled surrounding vehicles. The performance of SCWS is evaluated with comparison to Vehicle-to-Vehicle communication based Collision Warning System (VCWS) and Infrastructure based Collision Warning System (ICWS), where VCWS is considered the most similar measure to the actual collision risk in theory, but in practice very difficult to achieve due many limitations, such as high installation cost and market penetration. The result shows that in both aggregation and disaggregation level analysis the proposed SCWS exhibits a similar collision risk trend to the VCWS. Furthermore, the SCWS shows a high potential for practical application because it has the acceptable performance even with a low sampling ratio (40%), requiring a low market penetration rate and low installation cost by using the wide spread smartphone.

10:50-12:30, WePoA1.11
11. Uncertainty Propagation in Criticality Measures for Driver Assistance
Jan Erik Stellet, Jan Schumacher, Wolfgang Branz (Robert Bosch GmbH), J. Marius Zöllner (FZI Forschungszentrum Informatik)

Active safety systems employ surround environment perception in order to detect critical driving situations. Assessing the threat level, e.g. the risk of an imminent collision, is usually based on criticality measures which are calculated from the sensor measurements. However, these metrics are subject to uncertainty. Probabilistic modelling of the uncertainty allows for more informed decision making and the derivation of sensor requirements. This work derives closed-form expressions for probability distributions of criticality measures under both state estimation and prediction uncertainty. The analysis is founded on uncertainty propagation in non-linear motion models. Finding the distribution of model-based criticality metrics is then performed using closed-form expressions for the collision probability and error propagation in implicit functions. All results are illustrated and verified in Monte-Carlo simulations.

10:50-12:30, WePoA1.12
12. Triggering Algorithm Based on Inevitable Collision States for Autonomous Emergency Braking (AEB) in Motorcycle-to-Car Crashes
Giovanni Savino, Marco Pierini (University of Florence), Julie Brown (University of New South Wales), Matteo Rizzi (Folksam), Michael Fitzharris (Monash University)

This study presents a triggering algorithm for a collaborative, motorcycle-to-car collision avoidance system that slows down the car without input of the driver when the collision becomes imminent. The algorithm is based on the concept of inevitable state collisions. Example applications of the
proposed algorithm were obtained via 2D computer simulations representing a data set of real crashes occurred in Italy, Sweden and Australia. Results indicated that the proposed method can apply to typical crash scenarios.

10:50-12:30, WePoA1.13

13. Impact of Positioning Uncertainty of Vulnerable Road Users on Risk Minimization in Collision Avoidance Systems
Philipp Themann, Jens Kotte, Dominik Raudszus, Lutz Eckstein (RWTH Aachen University)

This work describes a methodology to assess the impact of positioning and prediction accuracy on the potential benefit of collision avoidance systems. This work is focused on the positioning and prediction inaccuracies of VRU. The findings discussed here define requirements on the prediction accuracy and for vehicle velocities of 50 km/h the predicted VRU position should provide a standard deviation of less than 55 cm.

10:50-12:30, WePoA1.14

14. Potential of Intersection Driver Assistance Systems to Mitigate Straight Crossing Path Crashes Using U.S. Nationally Representative Crash Data
John Michael Scanlon, Kristofer Kusano, Hampton Clay Gabler (Virginia Tech), Rini Sherony (Toyota Motor Engineering and Manufacturing North America)

Intersection Advanced Driver Assistance Systems (I-ADAS) are active safety systems that have the potential to help prevent/mitigate crashes and injuries in intersection crashes. I-ADAS may use side-looking sensors, e.g. radar and lidar, in order to detect potential collisions with vehicles from crossing paths. The success of I-ADAS depends on the range and azimuth capabilities of these sensors. In order to specify the capabilities of sensors for an I-ADAS, designers need a distribution of range and azimuth between vehicles as they enter intersections prior to crashes. This study generated range and azimuth distributions using crash data from the National Motor Vehicle Crash Causation Survey (NMVCOS) for vehicles just prior to entering the intersection in straight crossing paths (SCP) crashes. Using the reconstructions and specifications in existing radar technology, the potential crash mitigation benefits of this technology were determined. Three radar-based I-ADAS were analyzed using published sensor specifications. The sensors included a wide beam, intermediate beam, and narrow beam. The wide beam I-ADAS was found to detect 20.3% of oncoming vehicles, the intermediate beam was found to detect 89.2% of oncoming vehicles, and the narrow beam was found to detect 98.3% of oncoming vehicles. The results indicate that a narrow beam I-ADAS is the most capable because of its long range detection ability. These results have practical relevance for the design and implementation of I-ADAS.

10:50-12:30, WePoA1.15

15. On Threat Assessment and Collision Avoidance for Articulated Machinery in Low-Speed Scenarios
Stefan Bergquist, Christian Grante (Volvo GTT Advanced Technology & Research.), Jonas Sjoberg (Chalmers University of Technology)

This paper investigates the hypothesis that threat assessment algorithms, developed for passenger cars, can be used for articulated machinery in low-speed scenarios to avoid a majority of the collision accidents. The effect of using a collision avoidance system on a Volvo A25 hauler is investigated in several simulated scenarios with stationary obstacles. It is concluded that the safety benefit is severely limited by the relatively low braking capacity of the machine. Moreover, collisions are difficult to avoid when there is an offset between the machine and obstacle which are likely to occur in unstructured environments. A possible way to increase the safety benefit is to introduce a safety margin around obstacles. Adapting the collision avoidance function to the individual driver can also increase the number of collisions avoided. Both those options do, however, increase the risk for generating false alarms.

10:50-12:30, WePoA1.16

16. Threat Prediction Algorithm Based on Local Path Candidates and Surrounding Vehicle Trajectory Predictions for Automated Driving Vehicles
Jaehwan Kim, Dongsuk Kum (KAIST)

Among others, a reliable threat prediction algorithm is one of the key enabling technologies for the commercialization of automated driving systems and other driver assistance systems. Previous algorithms that use Time-to-Collision (TTC) as a measure of threat tend to assume constant state and constant input. Although the predictability of these algorithms is acceptable within a one second time horizon, it becomes invalid for predictions over one second because yaw rate and acceleration are highly unlikely to be constant. Therefore, in this paper, we propose a threat prediction algorithm that can accurately predict TTC over a longer time horizon based on future trajectory predictions of a surrounding vehicle. First, a comprehensive set of local path candidates is generated along the curvilinear coordinates using a quintic polynomial with respect to arc-length corresponding to the different lateral offsets. Trajectory prediction of a surrounding vehicle is accomplished by introducing target lane detection, which is estimated according to the amount of difference between the current motion and the centerline of the driving lane. Based on these future vehicle trajectories, TTC is computed by comparing the entrance and exit time of two vehicles into and out of the conflict area where the occupied spaces of two vehicles overlap. Finally, in order to provide results, the inverse TTC values obtained above are plotted on a 2-dimensional trajectory plane where each set of the tangential acceleration and the initial yaw acceleration values represents each local path candidate. Thus, these threat assessment results can be directly utilized to determine a driving strategy of autonomous vehicles.

10:50-12:30, WePoA1.17

17. Day and Night-Time Drive Analysis Using Stereo Vision for Naturalistic Driving Studies
Morten Borno Jensen, Mark Philip Philipsen, Thomas Moeslund, Andreas Meigelmane (Aalborg University), Mohan M. Trivedi, Ravi Kumar Satzoda (University of California at San Diego)

In order to understand dangerous situations in the driving environment, naturalistic driving studies (NDS) are conducted by collecting and analyzing data from sensors looking inside and outside of the car. Manually processing the overwhelming amounts of data that are generated in such studies is very comprehensive. We propose a method for automatic data reduction for NDS based on stereo vision vehicle detection and tracking during day- and nighttime. The developed system can automatically register five NDS events, mainly related to intersections, from an existing NDS
Due to the large number and the high variability of possible traffic situations, intersections are among the most accident-prone spots in inner-city traffic. To reliably assist the driving tasks elaborated risk assessment systems are needed. Current approaches are mainly based on the prediction of possible future trajectories of the involved traffic participants. However, considering the variability and combinatorics of intersection-related traffic situations, this becomes unfeasible for limited computational resources. Here, we present an efficient situation hypotheses selection system. The selection process is based on reasoning about whether a particular situation results in a threat for the ego-vehicle's behavior. Our approach combines the results of a probabilistic situation recognition and a fast risk assessment using state-of-the-art regression methods. We show that the proposed system is able to effectively reduce the number of unnecessarily considered situation hypotheses on average by over 80%.

The ability to predict forthcoming car states is crucial for the development of smart assistance systems. Forthcoming car states do not only depend on vehicle dynamics but also on user behaviour. In this paper, we describe a novel prediction methodology by combining information from both sources – vehicle and user – using Gaussian Processes. We then apply this method in the context of high speed car racing. Results show that the forthcoming position and speed of the car can be predicted with low Root Mean Square Error through the trained model.

This paper presents a real-time approach to address the motion artefact related to the Time-of-Flight (ToF) camera's working principle. ToF cameras based on demodulation lock-in pixels estimate depth from the phase-shift between emitted and received modulated near-infrared (NIR) signals, in which four sequential phase-shifted images are required, i.e., four-taps technique. The ToF working principle assumes the scene to be motionless during this time interval. However, and in practice, unreliable depth measurements arise along object boundaries in dynamic scenes, mainly when fast movements are involved. Herein, we propose a robust method to identify those pixels in the resulting depth map that are prominent to be unreliable. Then, we replace their values by the closest reliable ones using the guided filter (GF) and an accurate guidance image, generated from the previously acquired sequential phaseshifted images. The GF has been selected as it presents a better behaviour near edges than alternative edge preserving filters with a major advantage of being a fast and non-approximate linear time algorithm. The experimental evaluation shows that the proposed method satisfactory addresses the motion artefact, even in extreme conditions.

This paper presents a review of recent literature of intersection behavior analysis for three types of intersection participants; vehicles, drivers, and pedestrians. In this survey, behavior analysis of each participant group is discussed based on key features and elements used for intersection design, planning and safety analysis. Different methods used for data collection, behavior recognition and analysis are reviewed for each group and a discussion is provided on the state of the art along with challenges and future research directions in the field.

This work presents a framework to analyze traffic intersections by counting vehicles and pedestrians and assessing their behavior and safety. The major reason of developing this framework is to facilitate manual analyses from the video recordings by only providing detection files, typical paths, distance and conflict points. After tracking and recognizing paths, pedestrian and vehicle trajectories are extracted and their counting, behavior and safety information are estimated. Experimental results include estimated speed profile, turning movement count, waiting time, Time to Intersection (TTI) and Time To Collision (TTC) for two highly cluttered videos of Las Vegas intersections. The accuracy of 90%, 99% and 90% were obtained for vehicles waiting time,
turning movement count and pedestrians crossing count. The semi-automatic system is a comprehensive solution for video based behavior, safety and counting analyses at intersections with high accuracy.

10:50-12:30, WePoA1.24

24. Driver Behavior Modeling Near Intersections Using SVM Based on Statistical Feature Extraction
Seifemichael Bekele Amsalu, Abdullahia Homeifar, Fatemmeh Afgah, Saina Ramyar (North Carolina A&T State University), Arda Kurt (The Ohio State University)

The capability to estimate driver’s intention leads to the development of advanced driver assistance systems that can assist the drivers in complex situations. Developing precise driver behavior models near intersections can considerably reduce the number of accidents at road intersections. In this study, the problem of driver behavior modeling near a road intersection is investigated using support vector machines (SVMs) based on the hybrid-state system (HSS) framework. In the HSS framework, the decisions of the driver are represented as a discrete-state system and the vehicle dynamics are represented as a continuous-state system. The proposed modeling technique utilizes the continuous observations from the vehicle and estimates the driver’s intention at each time step using a multi-class SVM approach. Statistical methods are used to extract features from continuous observations. This allows for the use of history in estimating the current state. The developed algorithm is trained and tested successfully using naturalistic driving data collected from a sensor-equipped vehicle operated in the streets of Columbus, OH and provided by the Ohio State University. The proposed framework shows a promising accuracy of above 97% in estimating the driver’s intention when approaching an intersection.

10:50-12:30, WePoA1.25

25. Classifying Driver’s Uncertainty about the Distance Gap at Lane Changing for Developing Trustworthy Assistance Systems
Fei Yan (University of Oldenburg), Lars Weber, Andreas Luedtke (OFFIS-Institute for Information Technology)

Driver’s uncertainty in lane changing situations could cause longer reaction times and even lead to wrong decisions, which is very dangerous for the critical driving task. We assume that reducing driver’s uncertainty with assistance systems in lane change situations can not only increase traffic safety, but also increase driver’s trust in assistance Systems. In order to develop trustworthy assistance systems, this paper starts from classifying driver’s uncertainty about the distance gap and studies the impact of the distance gap on driver’s uncertainty at lane changing. In the driving simulator experiment, participants were asked to take steering or brake actions in different lane change situations. Their reaction times to an acoustic signal ordering to start changing lanes and subjective certainty scores were collected and analyzed. The results showed that with the constant closing speed of 10 km/h between the ego vehicle and rear vehicle, the brake action was more often preferred than the steering and participants were relatively certain with short reaction times at small distance gaps (< 32m). At large distance gaps (> 44m), the steering was more often chosen than brake actions and participants were also certain with short reaction times. However, when the distance gap was in between (32m, 36m, 40m, 44m), participants were very uncertain and had relatively long reaction times.

10:50-12:30, WePoA1.26

26. Development of Driver-State Estimation Algorithm Based on Hybrid Bayesian Network
Dong Woon Ryu, Hyeon Bin Jeong, Sang Hun Lee, Woon-Sung Lee, Ji Hyun Yang (Kookmin University)

In this study, we develop and evaluate an estimation algorithm of abnormal driving states (drowsiness, distraction, and workload) based on a Hybrid Bayesian Network (HBN) using multimodal information. The HBN algorithm is expected to increase transportation safety by combining merits of both the Bayesian Network and clustering algorithm. In addition, multimodal data efficacy analysis through human-in-the-loop experiments is used to enhance the performance of the driver-state estimation algorithm. Performance results obtained the lowest false alarm rate and fastest calculation speed. The false alarm rate decreased from 18.2 to 15.5%, whereas the calculation speed decreased by 4.35%.

10:50-12:30, WePoA1.27

27. A Transforming Steering Wheel for Highly Automated Cars
Philipp Kerschbaum, Lutz Lorenz (BMW Research & Technology), Klaus Bengler (Technische Universität München)

In the near future, highly automated driving will almost certainly be available in commercial vehicles. Concerning the human-machine interface in such cars, two main issues have to be addressed. First, the detrimental effects of automation have to be avoided. Second, cars should provide an interface that allows the driver to utilize the time while driving highly automated. We conducted a driving simulator study to investigate the concept of geometrical transformation of the steering wheel to address both issues. Therefore, we implemented a prototype steering wheel which changes its shape depending on the current driving mode to improve mode awareness and comfort when driving highly automated. The study was focused on possible negative effects of the mechanical transformation in front of the driver during the take-over process. Results indicate that on average participants reacted faster and took over control later. The number of lane change errors, for example changing lanes without looking into the mirror, even somewhat decreased when using the transforming steering wheel. Furthermore, participants mainly rated the proposed concept as usable without problems during the take-over process.

10:50-12:30, WePoA1.28

28. Analyzing Driver Gaze Behavior and Consistency of Decision Making During Automated Driving
Chiyomi Miyajima, Suguru Yamazaki, Hitoshi Terai, Hiroyuki Okuda, Takatsugu Hirayama, Tatsuya Suzuki, Kazuya Takeda (Nagoya University), Takashi Bando, Kentarou Hitomi, Masumi Egawa (DENSOL Corporation)

We investigate a possible method for detecting a driver’s negative adaptation to an automated driving system by analyzing consistency of driver decision making and driver gaze behavior during automated driving. We focus on an automated driving system equivalent to Level 2 automation per the NHTSA’s definition. At this level of automation, drivers must be ready to take control of the vehicle in critical situations by monitoring the driving environment and vehicle behavior. Since drivers are not required to operate the pedals or steering wheel during automated driving, a driver’s negative adaptation to an automated system needs to be detected from behavior other than vehicle operation. In this study, we focus on driver gaze behavior. We conduct a simulator study to compare the gaze behavior of fifteen drivers during conventional and automated driving. We also
analyze the consistency of driver decision making when changing lanes during conventional and automated driving. Experimental results show that drivers who pay less attention to the road ahead during automated driving tend to be less sensitive to risk factors in the surrounding environment and also tend to make inconsistent lane change decisions during automated driving.

10:50-12:30, WePoA1.29
29. Driver Model with Motion Stabilizer for Vehicle-Driver Closed-Loop Simulation at High-Speed Maneuvering
Youngil Koh, Hyundong Her, Kyongsu Yi (Seoul National University), Kilsoo Kim (Hyundai Motor Company)

This paper describes an integrated driver model for vehicle-driver closed-loop simulation at high speed maneuvering. The proposed driver model is developed to specialize in limit handling, in order to be used as a validation platform of chassis control system. Thus, the proposed driver model emulates human driver's driving characteristics such as, desired path selection from varying preview area, deceleration against losing maneuverability. In high-speed cornering, steering with excessive corner-entry speed causes lateral tire force saturation readily. Sequentially, the lateral tire force saturation induces lateral instability of a vehicle. Deceleration is the most effective manipulation which driver can do. The proposed driver model is designed to utilize capability of tire force tightly, while securing lateral stability of the vehicle. The proposed driver model has been validated via comparison with an expert driver's driving data, collected on the Korea International Circuit in Yeongam, Korea.

10:50-12:30, WePoA1.30
30. Using EEG to Recognize Emergency Situations for Brain-Controlled Vehicles
Teng Teng, Luzheng Bi, Xinan Fan (Beijing Institute of Technology)

This paper proposes a novel method to recognize an emergency situation by translating EEG signals of a disabled driver while he or she uses a brain-machine interface without using his or her limbs to drive a vehicle. EEG signals were first filtered by independent component analysis along with information entropy. And then the sums of powers of theta wave in the power spectrum of EEG signals from 13 channels were used as features of the classifier built by linear discriminant analysis. The pilot experimental results from two participants in a driving simulator indicated that the model recognized emergency situations (e.g., pedestrian sudden occurrence) 400 ms earlier than the response of drivers with a hit rate of 76.4%, suggesting that the proposed method is feasible. The proposed method can be used as a complementary method to the existing ones based on detecting external objects with sensors.

10:50-12:30, WePoA1.31
31. A 3DoF-Sidestick User Interface for Four Wheel Independent Steering Vehicles
Michael Panzirsch, Bernhard Weber (DLR Oberpfaffenhofen)

In the past few years x-by-wire has evolved into the trend-setting technology in the field of transport. It allows for the design of new modular vehicle concepts such as the robotic electric vehicle ROBoMoBil. Through its four wheel robots, which can be accelerated, decelerated and steered independently, a highly maneuverable design is achieved. A fully actuated three degree of freedom sidestick is proposed in this paper as a haptic interface to the three horizontal degrees of motion of the ROBoMoBil. The main focus lies on the user access to the rear wheel steering behavior or to the instantaneous center of rotation respectively. Two approaches have been designed and analyzed to improve the robustness against pilot induced oscillations.

10:50-12:30, WePoA1.32
32. An Efficient Multiple Session Key Establishment Scheme for VANET Group Integration
Cheng-Chi Lee (Fu Jen Catholic University), Yan-Ming Lai, Pu-Jen Cheng (National Taiwan University)

VANET (Vehicular Ad-hoc Network) is the one mainly utilized to create communication networks for vehicles or other roadside devices so that they can quickly share and receive messages. Nevertheless, VANET belongs to the family of wireless networks, which means VANET functions are unsafe. In order to provide safe communication channels, we introduce the key agreements technology to VANET communication. Traditional key agreement schemes, however, are inefficient and would consume too much of the resources especially when they are handling large groups of users or when groups are to be combined. To improve the efficiency, we use the Chinese remainder theorem to build a batch key agreement protocol instead. The improved key for VANET environments is a safer and quicker way to establish communication channels.

10:50-12:30, WePoA1.33
33. Greedy Algorithms for Information Dissemination within Groups of Autonomous Vehicles
Ignacio Latser, Sebastian Kühlmorgen, Andreas Festag, Gerhard Fettweis (Technische Universität Dresden)

Cooperation and information exchange will allow autonomous vehicles to increase their sensing range and maneuver coordinately, thereby greatly enhancing their safety and efficiency. The combination of autonomous driving and vehicular communications will enable Cooperative Autonomous Driving Systems (C-ADS) with stringent requirements. We present two new multi-hop forwarding algorithms specially suited to the dissemination of information in C-ADS: (i) Greedy Broadcast Forwarding, aimed to the distribution of packets within a geographical area, and (ii) Greedy Multicast Forwarding, which delivers packets only to the members of a vehicle group. A performance comparison of the proposed schemes with the broadcast forwarding algorithms defined in the ETSI GeoNetworking standard shows that Greedy Broadcast Forwarding achieves the highest reliability, while Greedy Multicast Forwarding yields the lowest traffic overhead in the considered scenario. These results indicate that the proposed forwarding algorithms are promising candidates to enable multi-hop communications in future C-ADS.

10:50-12:30, WePoA1.34
34. An Efficient Cooperative Lane-Changing Algorithm for Sensor and Communication-Enabled Automated Vehicles
Tanveer Awal, Manzur Murshed, Mortuza Ali (Federation University Australia)

A key goal in transportation system is to attain efficient road traffic through improvement of trip time, fuel consumption and pollutant-emission without compromising safety. In high traffic density lane-changes and merging are often key ingredients to cause safety hazards, traffic breakdowns and travel delay. In this paper, we propose an efficient cooperative lane-changing algorithm CLA for sensor- and communication-enabled automated vehicles to reduce the lane-changing bottlenecks. For discretionary lane-changing, we consider the advantages of the subject vehicle, the follower in the current lane and k (an integer) lag vehicles in the target lane to maximize speed gains and simultaneously...
minimize the impact of lane-change on traffic flow and improve the overall trip time, fuel-consumption and pollutant-emission. CLA dissociates the decision-making point from the actual mandatory lane-changing point and computes a suitable lane-changing slot in order to minimize lane-changing (merging) time. Our algorithm outperforms the potential lane-changing algorithm MOBIL proposed by Kesting et al. in terms of merging time and rate, waiting time, fuel consumption, average velocity and flow (especially at the point in front of the merging point) at the cost of slightly increased average trip time for the mainroad vehicles compared to MOBIL. We also highlight important directions for further research.

10:50-12:30, WePoA1.35
35. Multi-Vehicle Motion Coordination Using V2V Communication
Xiaotong Shen, Zhuang Jie Chong, Scott Drew Pendleton, Wei Liu, Baoxing Qin, Marcelo H Ang Jr (National University of Singapore), James Guo Ming Fu (Singapore-MIT Alliance for Research and Technology)

Vehicle-to-vehicle (V2V) communication enables intention sharing among neighboring vehicles and thereby vehicles’ motion can be coordinated to incorporate collision (or conflict) avoidance. In this paper, we propose a general framework to distribute the computational burden for coordinating multiple vehicles’ stop-or-go motion. We formulate the multi-vehicle motion coordination problem as a total stopping time minimization problem under the constraint of mutual collision avoidance. The minimal stopping time solution, if such exists, is found using the A* search algorithm in the coordination diagram. The solution is executed efficiently by placing temporary virtual obstacles on the desired path. The communication latency is analyzed for practical applications. The simulations show the correctness and efficacy of our algorithm. An on-road experiment involving two autonomous vehicles, each equipped with V2V communication devices, was performed to demonstrate how deadlocks are successfully avoided.

10:50-12:30, WePoA1.36
36. Investigating Communications Performance for Automated Vehicle-Based Intersection Control under Connected Vehicle Environment
Joyoung Lee (New Jersey Institute of Technology), Byungkyu (Brian) Park (University of Virginia)

This paper investigates the wireless communications performance of Cooperative Vehicle Intersection Control (CVIC) powered by the Connected Vehicle (CV) environment. Considering the CV communication standards defined in IEEE 802.11p, IEEE 1609, and SAE J2735, the performances of CV communications were examined under several external factors including the number of On-Board Units (OBUs) and the distance between transceivers by using an off-line simulation framework integrating NCTUns, a wireless communications network simulator, for DSRC communications and VISSIM for vehicular movements. Unlike perfect communications assumptions made in most CV studies in the transportation literature, a case study implementing the simulations of the CVIC algorithm showed that no perfect packet deliveries were observed, resulting in about 48% packet drops at most.

10:50-12:30, WePoA1.37
37. DSRC and Radar Object Matching for Cooperative Driver Assistance Systems
Qi Chen, Ting Yuan, Joerg Hillenbrand, Axel Gern (Mercedes-Benz Research & Development North America), Tobias Roth, Florian Kuhnt, Marius Zoellner (FZI Research Center for Information Technology), Jakob Breu, Miro Bogdanovic, Christian Weiss (Mercedes-Benz Research and Development)

Dedicated Short Range Communication (DSRC) systems will become ubiquitous among vehicles in the near future. Because this technology enables communication between any set of DSRC-equipped vehicles, precise knowledge of these other vehicles is available to the host car. In addition to the DSRC system, onboard radars are able to provide high fidelity dynamics measurements of other objects within the sensing range. Given these two methods of measurement, environmental perception for driver assistance systems can be greatly improved, especially if the measurements are fused together. However, this is not a trivial task because of an inherent data association problem: Given the objects detected by the radar sensor, which one is truly the DSRC message sender? In this paper, we propose a system architecture to fuse DSRC and radar data. This architecture uses a reliable statistical based track-to-track association algorithm in a novel way to solve this data matching problem. We show experimental results of this architecture on a system running in real traffic situations in the U.S.

10:50-12:30, WePoA1.38
38. Compensation of Wireless Communication Delay for Integrated Risk Management of Automated Vehicle
Donghoon Shin, Kyongyi Yi (Seoul National University)

For the generic assessment and the total management of collision risks in urban driving situations, it is important to estimate and represent the target vehicles’ behavior such as yaw rate, absolute velocity and acceleration which are state of the target vehicle. To achieve this, this paper presents a compensation of wireless communication delay for integrated risk management of automated vehicle. Recent developments in vehicle onboard computers and wireless communications devices, also known as dedicated short-range communication (DSRC) devices allow the exchange of information between vehicles (inter-vehicle communications). In an application of vehicle to vehicle (V2V) communication, the most important issue is to handle delay which has a negative impact on safety issue since communication networks generally introduce delays. To cope with this problem, the inter-vehicle communication system is firstly modelled by reflecting signal characteristic. To compensate the communication delay, state augmented estimation algorithm is used based on extended Kalman filters (EKF). The performance of the proposed estimation algorithm is verified via real time simulations.

10:50-12:30, WePoA1.39
39. Safety Beaconing Rate Control Based on Vehicle Counting in WAVE
Hyogon Kim, Yongtae Park, Piao Haiyue, Byungjo Kim (Korea University)

In the IEEF Wireless Access in Vehicular Environment (WAVE) environment, periodic beacon messages enable proximity awareness that helps prevent collisions. One of the barriers that hinder the beacon delivery is congestion, which means that the amount of beacon traffic exceeds the Dedicated Short Range Communication (DSRC) channel capacity. In this paper, we propose a scheme for vehicles to independently adjust the becahning rate based on the
estimated neighbor vehicle population. Unlike previously proposed works, the proposed scheme does not need cross-layer information such as channel busy ratio (CBR) in order to achieve significant beacon throughput. We demonstrate through extensive simulations that this scheme significantly improves the beacon throughput.

10:50-12:30, WePoA1.40
40. Adaptive Decision Algorithms for Data Aggregation in VANETs with Defined Channel Load Limits
Josef Jiru, Karsten Roscher (Fraunhofer ESK), Aboobeker Sidhik Koyamparambil Mammo (University of Deusto)

The main challenges when realizing safety related applications based on vehicle-to-x communication are scalability and reliability. With an increasing number of vehicles, the communication channel must not get congested especially if a large amount of information has to be transmitted over multiple hops to a destination. This challenge can be solved by reducing the data load through data aggregation. In this paper, we present a decentralized congestion control using the channel busy ratio (CBR) on the application layer for an adaptive control of aggregation levels in real time. Adaptive decision algorithms decide which data is aggregated in real time. Two different approaches are compared: One approach relies on two CBR thresholds (min/max) only and one that allows a higher number of CBR thresholds. In both cases, the adaptive aggregation control increases and decreases the data aggregation levels based on these thresholds. Our simulation results show that both approaches are able to adjust the aggregation levels to given channel load thresholds within seconds resulting in improved data quality even in heavy congested situations. Adaptive decision algorithms result in less error introduced by aggregation. The impact of the two aggregation level control approaches is discussed regarding channel load and resulting data precision.

10:50-12:30, WePoA1.41
41. When Will It Change the Lane? a Probabilistic Regression Approach Dealing with Rarely Occurring Events
Julian Schlechttriemen, Andreas Wedel, Gabi Breuel (Daimler AG), Florian Wirthmueller (Illmenau University of Technology), Klaus-Dieter Kuhnert (University of Siegen)

Understanding traffic situations in dynamic traffic environments is an essential requirement for autonomous driving. The prediction of the current traffic scene into the future is one of the main problems in this context. In this publication we focus on highway scenarios, where the maneuver space for traffic participants is limited to a small number of possible behavior classes. Even though there are many publications in the field of maneuver prediction, most of them set the focus on the classification problem, whether a certain maneuver is executed or not. We extend approaches which solve the classification problem of lane-change behavior by introducing the novel aspect of estimating a continuous distribution of possible trajectories. Our novel approach uses the probabilities which are assigned by a Random Decision Forest to each of the maneuvers lane following, lane change left and lane change right. Using measured data of a vehicle and the knowledge of the typical lateral movement of vehicles over time taken from realworld-data, we derive a Gaussian Mixture Regression method. For the final result we combine the predicted probability density functions of the regression method and the computed maneuver probabilities using a Mixture of Experts approach. In a large scale experiment on real world data collected on multiple test drives we trained and validated our prediction model and show the gained high prediction accuracy of the proposed method.

Wednesday, July 1, 2015
WeOrM1: Autonomous / Intelligent Robotic Vehicles
14:00-15:20 E1+2+3 (3F)

Chair: Kyoungchul Kong (Sogang University)
Co-Chair: Yeonsik Kang (Kookmin University)

14:00-14:20, WeOrM1.1
1. Context-Aware Tracking of Moving Objects for Distance Keeping
Wenda Xu, Jarrod Snider, Junqing Wei, John Dolan (Carnegie Mellon University)

We propose a robust object tracking algorithm for distance keeping. Taking advantage of a context-based region of interest, we are able to maximize the performance of each sensor, and reduce the computation time since we only focus on the targets inside the region. Tracking targets in road coordinates enables finding the distance-keeping target on any curved road, while a commercial Adaptive Cruise Control (ACC) system works best on straight roads. We demonstrate that the overall performance of the proposed algorithm is better than that of a commercial ACC system. The distance-keeping target can either be used for lane following for a standalone ACC system or an autonomous vehicle. Our object tracking algorithm can also be extended to find the target of interest for lane changing or ramp merging for an autonomous vehicle.

14:20-14:40, WeOrM1.2
2. The Combinatorial Aspect of Motion Planning: Maneuver Variants in Structured Environments
Philipp Bender, Omer Sahin Tas, Christoph Stiller (FZI Research Center for Information Technology), Julius Ziegler (Atlatec)

Motion planning plays a key role in autonomous driving. In this work, we introduce the combinatorial aspect of motion planning which tackles the fact that there are usually many possible and locally optimal solutions to accomplish a given task. Those options we call maneuver variants. We argue that by partitioning the trajectory space into discrete solution classes, such that local optimization methods yield an optimum within each discrete class, we can improve the chance of finding the global optimum as the optimum trajectory among the maneuver variants. This work provides methods to enumerate the maneuver variants as well as constraints to enforce them. The return of the effort put into the problem modification as suggested is gaining assuredness in the convergency behaviour of the optimization algorithm. We show an experiment where we identify three local optima that would not have been found with local optimization methods.

14:40-15:00, WeOrM1.3
3. Submap-Based SLAM for Road Markings
Elke Rehder, Alexander Albrecht (Karlsruhe Institute of Technology)

Coherent road maps are a prerequisite for autonomous navigation. In case of an unknown environment, grid map and SLAM techniques are widely used. This paper takes a novel approach to vision based mapping of road markings by registration of local occupancy gridmaps for map stitching. We show that with reasonably accurate ego motion measurements, consistent global maps can be constructed from local grid maps. The approach is evaluated on real world data obtained from an autonomous model racing car.
Navigating a car at intersections is one of the most challenging parts of urban driving. Successful navigation needs predicting of intention of other traffic participants at the intersection. Such prediction is an important component for both Advanced Driver Assistance Systems (ADAS) and Autonomous Driving (AD) Systems. In this paper, we present a driver intention prediction model for general intersections. Our model incorporates lane-level maps of an intersection and makes a prediction based on past position and movement of the vehicle. We create a real-world dataset of 375 turning tracks at a variety of intersections. We present turn prediction results based on Hidden Markov Model (HMM), Support Vector Machine (SVM), and Dynamic Bayesian Network (DBN). SVM and DBN models give higher accuracy compared to HMM models. We get over 90% turn prediction accuracy 1.6 seconds before the intersection. Our work advances the state of art in ADAS/AD systems with a turn prediction model for general intersections.
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