PROGRAM BOOK

IEEE 2010
Intelligent Vehicles Symposium
San Diego, CA, USA
The 2010 Intelligent Vehicles Symposium (IV'10) is the premier annual forum sponsored by the IEEE Intelligent Transportation Systems Society (ITSS). Researchers, academicians, practitioners and students from universities, industry, and government agencies are invited to San Diego, CA to discuss research and applications for Intelligent Vehicles and Intelligent Infrastructures, from June 21 to 24.

The three days of technical presentations are characterized by a single session format so that all attendees remain in a single room for multilateral communications in an informal atmosphere, while most of the papers will be poster presentations.

Program Topics include the following categories:

- Driver Assistance Systems
- Automated Vehicles
- Active and Passive Safety
- Vehicle Environment Perception
- Image, Radar, Lidar Signal Processing
- Information Fusion
- Driver State and Intent Recognition
- Looking-In, Looking-Out Perception
- System Architecture
- Smart Infrastructure
- Impact on Traffic Flows
- Cooperative Vehicle-Highway Systems
- Collision Avoidance
- Pedestrian Protection
- Inter-Vehicle Communications
- Dedicated Short Range Communications
- Intelligent Robotic Vehicles
- Vehicle Control
- Decision and Expert Systems
- Communications and Networks
- Human Factors
- Human Machine Interaction
- Novel Interfaces and Displays
- Others

Conference Proceedings

The proceedings CD will be distributed along with registration materials at the conference.
IEEE IV 2010
Committees
Organizing Committee

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Charles Fay (TRB, NAS)
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Hoa Nguyen (SPAWAR)
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Student Affairs
Lili Huang (U.C. Riverside)
Cathy Liu (Univ. of Washington)
Sayanan Sivaraman (U.C. San Diego)

Ph.D. Dissertation Forum
Thao Dang (Daimler)
Shinko Cheng (HRL)
Brendan Morris (U.C. San Diego)

Pre-Symposium Events
Matthew Barth (U.C. Riverside)
Jean-Marc Blosseville (INRETS)
Ingolf Krueger (U.C. San Diego)
Bhaskar Rao (U.C. San Diego)

Exhibitions
Suketu Kamdar (U.C. San Diego)
Swarup Medasani (HRL)
Brendan Morris (U.C. San Diego)
Jurgen Schulze (U.C. San Diego)
Cuong Tran (U.C. San Diego)

Demos
Thomas Bewley (U.C. San Diego)
Kanok Boriboonsomsin (U.C. Riverside)
Jaime Camhi (Volkswagen)
Ganz Chockalingam (U.C. San Diego)
Bart Everett (SPAWAR)
Peter Otto (U.C. San Diego)

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Klaus Dietmayer (Univ. of Ulm)
Azim Eskandarian (George Washington Univ.)
Tarak Gandhi (Google)
Hiroshi Murase (Nagoya Univ.)
Sergiu Nedevschi (Tech. Univ. of Cluj-Napoca)
Urbano Nunes (Univ. of Coimbra)
Cristoph Stiller (Karlsruhe Inst. of Tech.)
Bart Van Arem (Delft Univ. of Tech.)

Poster Awards
Didier Aubert (INRETS/LCPC)
Ching-Yao Chan (ITS, U.C. Berkeley)
Thao Dang (Daimler)
Shabbir Merchant (IIT Bombay)
Jeffrey Miller (Univ. of Alaska, Anchorage)
Thomas Moeslund (Aalborg Univ.)
Jeff Ota (BMW Group)
Yuri Owechko (HRL)
Paul Rybski (Carnegie Mellon Univ.)
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Yukimasa Tamatsu (Japan)
Bart van Arem (Netherlands)
Ljubo Vlacic (Australia)
Yun Wang (USA)
David Ward (UK)
Nic Ward (USA)
IEEE IV 2010
Chair Messages
Welcome Message from General Chair
Mohan M. Trivedi
Intelligent Vehicles and the Golden State

Dear Colleagues,

On behalf of the IV'10 Organizing Committee, it is my pleasure to welcome you to the 2010 IEEE Intelligent Vehicles Symposium, in San Diego, California. Since the first IV Symposium in Tokyo in 1990, the IEEE IV Symposium has earned the reputation as the premier annual event in the world with participants from academia, industry, government, and research institutes coming together to discuss their accomplishments and to learn from their peers. It is a special privilege to welcome the Symposium for the first time to the Golden State of California. California has long played an important role in the growth of the Intelligent Vehicles field (see graphic inside front cover). It was only a few miles from the IV'10 venue, where one of the first major world media events focused on intelligent vehicles was presented in 1997. It showcased autonomous driving in platoons and other Intelligent Transportation related demonstrations. More recently, between 2004 and 2007, leading researchers and engineers were attracted to California to participate in the historic Grand Challenge and Urban Challenge competitions. The aerospace industry in California has developed a leadership position in the Unmanned Air Vehicles industry, with two of the main manufacturers (Global Hawk and Predators) in San Diego. California is also the home of NASA Jet Propulsion Laboratory, which pioneered space robotics, successfully deploying extraterrestrial rovers. California, with a major presence of Navy and the world renowned Scripps Institute of Oceanography at UCSD, continues to develop innovative robotic vehicles for environmental monitoring and defense related applications. The vibrant information technology, communications, digital media, energy, and focused research and industrial activities in California are enabling new generation of, advanced driver assistance, connected vehicles, infotainment, safety and eco-friendly green automobiles and transportation systems.

The program committee, under the leadership of Professor Dan Dailey has organized the technical program composed of papers selected after a rigorous review which offers an excellent exposure to the state-of-the-art and a glimpse in the future. The program also includes keynote talks by leading authorities representing perspectives from three different continents in the Intelligent Vehicles field: Dr. Uwe Franke from Daimler, Professor Katsushi Ikeuchi, of University of Tokyo and Mr. Ray Resendes, from the National Highway and Traffic Safety Administration (USA). In addition to the main technical program you will be able to participate in a variety of forums on Monday. These include (1) Connected vehicles, (2) Eco-friendly Intelligent Vehicles, (3) Human-Centered Intelligent Vehicles, and (4) PhD dissertation Forum featuring presentations by graduate students and comments by a distinguished jury panel.

The program of this scope and nature is made possible by the enthusiastic involvement and efforts of numerous volunteers. I would like to offer a vote of thanks to each and every member of the organizing and program committees. Several individuals and units from our host institute, the University of California at San Diego have offered invaluable support. A group of distinguished faculty and enthusiastic students including Art Ellis, Ingolf Krueger, Falko Kuester, Larry Larson, Scott Makeig, Peter Otto, Hal Pashler, Bhaskar Rao, Ramesh Rao, Frieder Seible, Paul Yu, Matt Barth (UC- Riverside) and most notably Anup Doshi and Brendan Morris offered whatever was requested or required. UCSD units which have made special contributions include the Jacobs School of Engineering, Cal-IT2, Office of Research Affairs, Center for Wireless Communications, and the Computer Vision and Robotics Research Laboratory.

Finally, I thank you for your active participation in IV2010. It is our sincere hope that the 2010 IEEE IV Symposium will offer you a most up-to-date overview of the exciting new developments in the field, stimulating new ideas, foster new contacts and friendships, and provide you pleasant memories of your time spent in our Golden State.

Mohan M. Trivedi, Director, Laboratory for Intelligent and Safe Automobiles (LISA)
University of California at San Diego, La Jolla, CA 92093, USA
Welcome Message from Program Chair
Daniel J. Dailey

Dear Colleagues,

It gives me great pleasure to welcome you to the 2010 IEEE International Symposium on Intelligent Vehicles (IV2010) being held in beautiful San Diego.

IV2010 is the premier international meeting on Intelligent Vehicles attracting attendees from throughout the world and from both academia and industry.

IV2010 is a truly international meeting with papers to be presented representing peer reviewed work from 28 countries and regions: Germany, United States of America, France, Japan, China, Korea, South, Spain, Greece, Italy, Netherlands, Portugal, Sweden, Australia, Canada, Romania, Singapore, Taiwan, Brazil, Czech Republic, Denmark, India, Iran, Israel, Mexico, Morocco, Saudi Arabia, Turkey, United Kingdom.

My thanks to all those who served on the Program Committee and who shouldered the burden of getting multiple reviews for each manuscript submitted. My thanks also the many reviewers who undertook the intellectual task of reading, understanding and rating the many papers submitted to this meeting. IV2010 is made possible by the voluntary contribution of these professionals from the Intelligent Vehicle community.

I hope you will enjoy both the intellectual contributions from the authors as well as the opportunity to interact in person with your peers from Industry and Academia.

Daniel J. Dailey
Program Chair IV2010
University of Washington
Seattle, WA, USA
IEEE IV 2010
Keynote Speakers
Tuesday Keynote (9:00-10:00)

The New ‘Grand Challenge’: Deploying Vehicle Communications
by Raymond Resendes
Chief, Intelligent Technologies Research Division
National Highway Traffic Safety Administration
U.S. Department of Transportation

Abstract: A new generation of sensing and warning systems has emerged that demonstrate the ability to help drivers avoid crashes. NHTSA has conducted cooperative research with the automotive industry that shows that the overall effectiveness of such systems may be improved by using inter-vehicle communications. NHTSA believes that there exists an opportunity to facilitate the accelerated deployment of these systems. Further, NHTSA envisions that crash avoidance systems can develop into an integrated safety concept that avoids and mitigates crashes as well as improves post crash response. While safety is NHTSA’s goal, it is widely understood that V2X systems will ultimately need to support safety, mobility and convenience applications in order to be commercially viable. This presentation will cover the status of V2X in the U.S., a scenario for deployment where V2V takes the lead, and finally what are the greatest technical challenges to achieving deployment.

Bio: In March 2005, Ray Resendes became Chief of the Intelligent Technologies Research Division in the National Highway Traffic Safety Administration (NHTSA). In this capacity he leads the Agency’s efforts to develop new technologies, procedures, and methods to advance the state-of-art in active safety systems. This encompasses management of NHTSA’s ITS activities which promote the development and evaluation of new technologies. In addition, he leads the Advanced Collision Avoidance Technologies Program (ACAT), which is developing the benefit information and evaluation methodologies needed to promote consumer awareness of effective advanced safety technologies.

Before coming to NHTSA, Ray led vehicle safety research at the USDOT Intelligent Transportation Systems Joint Program Office (ITS JPO). He served as the Program Manager for the USDOT Intelligent Vehicle Initiative. In this capacity, he led a multimodal team that conducted essential research for the application of advanced technologies to active safety systems. The major accomplishments of this program included completion of nine field operational tests that documented the safety benefits of advanced collision avoidance systems. And the 100-car Naturalistic Driving Study, which developed a new understanding of driver behavior and reactions that lead to crash situations. Under his leadership the IVI Program also developed the first Dedicated Short Range Communication Systems (DSRC) that enabled the application of vehicle-to-vehicle and vehicle-to-infrastructure communications for safety.

Before coming to U.S. DOT he managed the test and evaluation programs for unmanned ground vehicle systems at the U.S. Army Test and Evaluation Command. Ray has been very active in both the Society of Automotive Engineers (SAE) and the Transportation Research Board (TRB). He has served as a member of the SAE ITS Program Committee and Secretary of the TRB Committee on Vehicle-Highway Automation.

Ray has received numerous performance and honor awards including the Secretary’s Team Award in recognition of his outstanding contributions in developing the ONE DOT IVI Program, and the NHTSA Administrator’s Award for outstanding leadership in management of the NHTSA ITS Initiatives. Ray has 20 years experience in federal service. He has a Bachelor of Science degree in Engineering from State University of New York at Buffalo and a Master of Science degree in Business Administration, Central Michigan University. He is married to Kim Resendes, and has three children, Kaitlin, Ryan and Kelly.
**Wednesday Keynote (13:00-14:00)**

**Four-Dimensional Virtual Cities for Safety, Security and Comfort**

by **Katsushi Ikeuchi**
Professor, Institute of Industrial Science
University of Tokyo

**Abstract:** ITS (Intelligent Transportation Systems) is a key technology for creating a livable society that enjoys safety, efficiency, and comfort through controlling the flow of people, vehicles, and information. While various pieces of information, such as VICS and weather forecast, are available now to a driver through advanced ITS technologies, these pieces of information are still fragmental. Cloud computing and advanced communication technologies can provide additional information, and these factors can be combined into a more comprehensive format, which we refer to as the “four-dimensional virtual cities,” in which drivers experience significantly increased awareness. These four-dimensional virtual cities enable a driver to see current activities anywhere in the city, from any viewpoint, and at any time, as well as future and past activities of the city. Drivers can thus drastically increase their global awareness for achieving safety, efficiency, and comfort.

**Bio:** Katsushi Ikeuchi is a Professor at the Institute of Industrial Science, the University of Tokyo, Tokyo, Japan. He received the Ph.D. degree in Information Engineering from the University of Tokyo, Tokyo, Japan, in 1978. After working at the Artificial Intelligence Laboratory, MIT for three years, the Electrotechnical Laboratory, MITI for five years, and the School of Computer Science, Carnegie Mellon University for ten years, he joined the university in 1996. He currently serves on the IEEE Intelligent Transportation Systems Society Board of Governors, and has served as the program/general chairman of several international conferences, including 1995 IEEE IROS (General), 1996 IEEE CVPR (Program), 1999 IEEE ITSC (General), 2001 IEEE IV, (General) 2003 ICCV (Program) and 2006 IEEE IV Symposium (General). He is an Editor-in-Chief of the International Journal of Computer Vision. He has been a fellow of IEEE since 1998. He was selected as a distinguished lecture of IEEE SP society for the period of 2000-2001. He has received several awards, including the David Marr Prize in computational vision, and IEEE RA society K-S Fu memorial best transaction paper award. In addition, in 1992, his paper, “Numerical Shape from Shading and Occluding Boundaries,” was selected as one of the most influential papers to have appeared in Artificial Intelligence Journal within the past ten years.
Thursday Keynote (13:00-14:00)

With Two Eyes Intelligent Vehicles Perceive Better
by Dr. Uwe Franke
Daimler AG
Böblingen, Germany

Abstract: The performance of future driver assistance systems depends on precision, robustness and completeness of their environment perception. The urban scenario in particular poses high demands on the sensors, since dangerous situations have to be recognized quickly and with high confidence. The dream of a car perceiving its environment with human like performance in order to realize accident free driving can only be reached if the car has two eyes working in stereo – that is my firm belief.

The talk will present the state-of-the-art in space-time computer vision. This covers real-time dense stereo analysis (running on a FPGA) as well as dense optical flow analysis (running on a GPU). Most known stereo systems concentrate on single image pairs. This prohibits the recognition of moving objects like pedestrians, if they are close to other dominant obstacles or partially hidden. A smart fusion of stereo vision and motion analysis is the key to overcome this deficiency. Two strategies will be presented. The so called 6D-Vision principle tracks points with depth known from stereo over two and more consecutive frames and fuses the spatial and temporal information using Kalman filters. Secondly, a scene flow variant will be described that runs at 5 Hz on a standard GPU. This approach simultaneously estimates depth and 3D-motion for every pixel of the image.

The high-quality spatio-temporal information is successfully used to model the world and to detect and track moving obstacles from the moving car. Pedestrian recognition significantly benefits from the dense stereo and motion information. For oncoming vehicles, besides speed and acceleration even the turn-rate can be determined reliably.

Modern schemes like GraphCut together with careful error propagation allow segmenting moving objects precisely even at large distances, where the depth uncertainties cannot be ignored. Efficient scene labelling becomes possible that decides for every pixel whether it belongs to the free-space, a moving object with known motion, a moving object with unknown motion or to the background.

Real-world experiments will illustrate the high performance available in the experimental car – hopefully paving the way towards safer driving.

Bio: Uwe Franke received the Ph.D. degree in electrical engineering from the Technical University of Aachen, Germany, in 1988 for his work on content based image coding. Since 1989 he is with Daimler Research & Development working on vision based driver assistance systems. He developed Daimler’s lane departure warning system (“Spurassistent”) introduced 2000 on trucks. His special interest is in image understanding in complex situations as they occur e.g. at intersections. He has been working on real-time stereo vision since 1996. Recent work is on optimal fusion of stereo and motion, called 6D-Vision and scene flow. Since 2000 he is head of Daimler’s Image Understanding Group and concentrates on vision for increased traffic safety. His team is specialized in object recognition and tracking based on stereoscopic special-temporal perception. Continuously working in the field of intelligent vehicles since 22 years, he is one of the most experienced experts all over the world. In 2002, he was program chair of the IEEE Intelligent Vehicles Conference in Versailles, France.
Special Sessions and Ph.D. Dissertation Forum

Monday
June 21, 2010
There will be several exciting special sessions held in conjunction with IEEE IV 2010 on Monday, June 21. This pre-symposium program is made possible with the enthusiastic participation and generous support of University of California based research units, and associated faculty members and graduate students. We sincerely appreciate their contribution. These parallel sessions will take place simultaneously in the Calit2 Auditorium and Calit2 Theater (both located on the first floor of Atkinson Hall).

**Special Session I**

**9:00-12:00**

**Automotive Software Architecture - Tutorial**

Chair: Professor Ingolf Krueger, UC San Diego

Most innovations in modern cars are driven by electronic components and embedded software. This was brought to light again recently in the context of claims of unintended acceleration and other quality concerns. Consequently, in light of the societal impact cars have on our mobility, quality assurance for automotive systems is a key challenge. Model-based development (MBD) has become a tremendous success story in the automotive domain over recent years; it is one of the key ingredients for a comprehensive quality management approach. In this tutorial I will focus on a key question in this context: “Are we making the models work enough throughout the process?” Or, in other words, do we get enough mileage out of the modeling effort in terms of properties such as reduced development times, increased quality, and overall understanding among development process participants, to name just a few. I will argue that we are just at the beginning of our understanding of the value proposition of MBD, and that creating comprehensive domain-specific models will go a long way towards exploiting MBD effectively throughout the automotive development process.

**Wireless Communications and Intelligent Vehicles: Research and Deployment Issues**

Co-Chairs: Professors Bhaskar Rao (right), Sujit Dey, and Tara Javidi, Center for Wireless Communication, UC San Diego

The goal of the forum is to present and discuss recent advancements and developments in vehicular-based communications. It intends to bring together researchers, professionals, and practitioners to address the recent developments and challenges associated with deployment of V2X (vehicle-to-vehicle, vehicle-to-infrastructure, and vehicle-to-device) network technologies. The 3 hour event will consist of 4 invited presentations on current research and trends in vehicular-based communication followed by a panel discussion consisting of leaders and practitioners from both the automotive and wireless communication communities.

**Special Session II**

**13:00-16:00**

**Eco-Friendly and Energy Efficient Intelligent Vehicles and Systems**

Chair: Professor Matthew Barth, UC Riverside

It is clear that transportation is an essential component of a sustainable society, and with recent attention on energy consumption and greenhouse gas emissions, many researchers have increased their attention on “ECO-ITS” topics. ITS has the potential to reduce fuel consumption and emissions through reducing congestion, facilitating optimal route planning and timing, smoothing accelerations/decelerations and stop-and-go driving, enabling pricing and demand management strategies, and increasing the attractiveness of public transportation mode use. In this forum several research programs will be highlighted, including research being carried out at various institutions in North America, Asia, and Europe. Each participant will briefly provide an overview of their recent ECO-ITS research and discuss future challenges and directions in this field.

**Human-Centered Intelligent Vehicles: Multidisciplinary Perspectives**

Co-Chair: Professor Mohan M. Trivedi, UC San Diego

With recent advancements in advanced sensing, systems, and infrastructure for safe driving, as well as the increasing complexity and ubiquity of “infotainment” devices in vehicles, there are many new challenges to keeping the human safely and effectively in the driving loop. These include issues not limited to reducing distractions while increasing safety and compliance, designing human machine interfaces (HMI) for effective feedback, and accurately monitoring the state of the driver. This forum will bring together researchers and experts from various fields to discuss the important research issues and challenges in developing Human-Centered Intelligent Vehicles.
This year the committee is excited to introduce the Ph.D. Dissertation Forum, which will offer advanced Ph.D. students the opportunity to present their research to a panel of distinguished faculty and industry luminaries. The Monday afternoon forum will consist of a short oral presentation of the work and a panel discussion with world-renowned experts on the research and application potentials. The participants are listed below.

**Analytical Modeling of Delay-Tolerant Data Dissemination in Vehicular Networks**  
Ashish Agarwal, Boston University

**Evaluating and Improving Broadcast Reliability in Vehicular Ad Hoc Networks**  
Rex Chen, University of California, Irvine

**Route Choice: A Behavioral Analysis and Modeling Approach**  
Aly Tawfik, Virginia Tech

**Investigating Posture and Affect Dynamics at Multiple Levels of Details for Active Safety: A Vision-Based Approach**  
Cuong Tran, University of California, San Diego

**Toward Improved Speech Based Emotion Recognition in Driver Assistance Systems**  
Ashish Tawari, University of California, San Diego

**Traffic Sign Detection and Recognition Toward Smart Driver Assistance**  
Keisuke Doman, Nagoya University

**Integrated Vision Systems for Driver Assistance in Intelligent Vehicles**  
Sayanan Sivaraman, University of California, San Diego

**Stereo Vision and Color Image Evaluation for Combined Scene Segmentation and Detection of Traffic Participants**  
Philip Lenz, Karlsruhe Institute of Technology

**Hybrid Models for vision-based Intersection Understanding**  
Andreas Geiger, Karlsruhe Institute of Technology

**LIDAR, Camera, and Inertial Sensors Based Navigation and Positioning Techniques for Advanced ITS Applications**  
Lili Huang, University of California, Riverside

**Vehicle Segmentation and Tracking from Monocular Videos**  
Anh Vu, University of California, Riverside

**Efficient Tracking of Public Transport in Urban Environments**  
Rohit Kumar, Boston University

**A Unified View on Probabilistic Tracking and Situation Assessment**  
Robin Schubert, Chemnitz University of Technology

**Direct Trajectory Optimization of Vehicle Evasive Maneuvers**  
Damoon Soudbakhsh, George Washington University

The distinguished panel of jury members for the Ph.D. Forum will include the following members:

- Prof. Sergiu Nedevschi (Tech. Univ. of Cluj-Napoca)
- Prof. Klaus Dietmayer (Univ. of Ulm)
- Prof. Dan Dailey (Univ. of Washington)
- Dr.-Ing. Uwe Franke (Daimler AG)
- Prof. Katsushi Ikeuchi (Univ. of Tokyo)
- Prof. Fei-Yue Wang (Univ. of Arizona)
- Prof. Alberto Broggi (Univ. di Parma)

Ph.D. Dissertation Forum Coordinator: Dr. Brendan Morris, UC San Diego
IEEE IV 2010
General Information
Welcome Reception

The Welcome Reception will take place in the sunny courtyard of UC San Diego’s Atkinson Hall near the iconic Bear statue. The 180-ton megalithic sculpture is one of 15 outdoor works of art in UC San Diego’s Stuart Collection. Bear warmly welcomes all participants to San Diego to kick off the 2010 IEEE IV symposium.

Banquet

Wednesday, June 23, 18:30-21:00

This year’s Banquet will be hosted at the Birch Aquarium, overlooking one of the most scenic areas of the California coastline in the San Diego suburb of La Jolla. The aquarium is the “public exploration center” of the world-famous Scripps Institute of Oceanography at UC San Diego. The facility hosts over 5,000 animals (380 species) and boasts spectacular views of Torrey Pines State Park, La Jolla, and the Pacific Ocean. The entire breathtaking facility is exclusively reserved for attendees and guests of the IV Symposium.

Awards

Thursday, June 24, 13:00

Awards will be presented for Best Paper and Best Poster categories during the final Keynote Session on Thursday, June 24 at 13:00.

Exhibitions and Demos

Thursday, June 24, 14:00-17:00

Participants are excited to showcase a broad range of exciting demonstrations and exhibits. This event will include participation from a variety of academic, research and industrial organizations. Stay tuned for updated information presented at the IV Symposium.
Some of the exciting exhibits and demonstrations to be displayed at IEEE IV 2010.
IEEE IV 2010
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<td>13:30-14:50 TuD1 Regular Session (Driver Assistance Systems 1)</td>
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Local Contour Patterns for Fast Traffic Sign Detection, pp. 1-6
Parada, Francisco Univ. of Vigo
Alba, Jose L. Univ. of Vigo

Advanced driver assistance systems have strong restrictions for real-time performance. Vision algorithms embedded in these systems need to balance accuracy and computational simplicity and there exists a continuous challenge to increase both goals. In this paper we define a new operator coined as Local Contour Patterns and use it in fast Hough-Transform-based approaches for circle and line detectors. We show an efficient implementation for traffic sign detection, relying only on shape information, that analyzes a 752x480 grayscale image in 40 ms in a Intel 8400 CPU, with a very good performance in real driving conditions.

10:00-11:10 TuB1.2
A New Vision System for Traffic Sign Recognition, pp. 7-12
Gu, Yanlei Nagoya Univ.
Yendo, Tomohiro Nagoya Univ.
Panahpour Tehrani, Mehrdad Nagoya Univ.
Fujii, Toshiaki Tokyo Inst. of Tech.
Tanimoto, Masayuki Nagoya Univ.

In this paper, we introduce a new vision system for traffic sign recognition. The new vision system is a hybrid camera system, including a wide angle camera, a narrow angle camera and control part. The traffic sign candidates are detected in the image of the wide angle camera, based on shape and local feature. The control part of the vision system is adjusted to the correct positions, which makes the narrow angle camera of this system to get a high resolution image of each detected candidate. This high resolution image is used for traffic sign classification. In the new vision system, the traffic sign detection and classification are processed in different resolution images separately. This advantage of the system makes traffic sign recognition at long distance possible.

10:00-11:10 TuB1.3
Target Vehicle Selection Based on Multi Features Fusion Method, pp. 13-19
Wang, Jianqiang Tsinghua Univ.
Liu, Zhifeng Tsinghua Univ.
Yi, Shichun Tsinghua Univ.
Li, Keqiang Tsinghua Univ.

A target selection method based on multi features fusion is proposed to improve the accuracy of target vehicle selection. The parameters consisting of the longitudinal distance, lateral distance, relative speed between objects and the host vehicle, the in-lane probability of objects are regarded as the features of individual vehicles. Firstly, some pre-processes of features data are carried out including Distance Compensation Factor (DCF) correcting and Kalman filtering, which are used to correct the in-lane probability data provided by lidar, track and predict the relative distance and speed of objects to lower the missing rate of vehicle detection respectively. Furthermore a two-layer BP neural network is designed to train the sample data and obtain the importance weight of feature variables; the training output is finally utilized as the index for target recognition. The selection method utilizes the valid information collected by sensors through the fusion of multi vehicle features. Experiments show that the vehicle detection results can be improved and the target selection and tracking accurately can be fulfilled through the proposed method. Even under cut-in conditions, the target can also be switched to the cut-in vehicle in time.

10:00-11:10 TuB1.4
Vehicle Yaw Rate Control Based on Piecewise Affine Regions, pp. 20-25
Benine-Neto, André LCPC/INRETS
Scalzi, Stefano Univ. of Rome Tor Vergata
Netto, Mariana LCPC
Mammar, Said INRETS
Pasillas-Lepine, William Lab. des signaux et systemes, CNRS-Supelec

This paper shows that an active front steering control, that considers the nonlinear behaviour of the tire-road forces, can be designed by parameterizing the vehicle dynamics with respect to the measurable yaw rate and taking into account the steady state behaviour of the vehicle. In order to ensure the tracking of the yaw rate reference signal on the basis of the yaw rate tracking error, despite constant disturbances and parameters uncertainties, the proposed control strategy uses a proportional integral (PI) control, in which the gains depend on the defined parametrized vehicle dynamics. The proposed control system switches depending on the yaw rate as it is a variable measured at low cost. The stability is proved by a piecewise quadratic Lyapunov function using linear matrix inequalities technique. Several simulations, including disturbances rejections and step references, are carried out on a standard nonlinear CarSim D-Class vehicle model to explore the robustness with respect to unmodelled effects such as combined lateral and longitudinal tire forces, pitch, roll and driver dynamics. The simulations confirm that the proposed piecewise linear (PWL) control can greatly improve the vehicle stability and is advantageous in very demanding manoeuvres.

10:00-11:10 TuB1.5
Vehicle Tracking and Motion Prediction in Complex Urban Scenarios, pp. 26-33
Hermes, Christoph Bielefeld Univ.
Einhaus, Julian Daimler AG, Group Res.
Hahn, Markus Daimler AG, Group Res.
Kummert, Franz Bielefeld Univ.
Woehler, Christian Dortmund Univ. of Tech.

The recognition of potentially hazardous situations on road intersections is an indispensable skill of future driver as-
The safety applications are designed to provide drivers with alerts of situational awareness in highway driving scenarios. The objectives of the field tests are to verify the technical approach and to collect user feedback to refine the applications for future implementation. In this paper, the functional descriptions, technical rationales, and hypotheses of experimental design are given. These applications, when deployed with timely alerts to drivers, can potentially increase driver awareness of the driving environment on the road ahead and minimize risks.

10:00-11:10  TuB1.9
**Estimation of Traffic Sign Visibility Toward Smart Driver Assistance**, pp. 45-50
Doman, Keisuke Nagoya Univ.
Deguchi, Daisuke Nagoya Univ.
Takahashi, Tomokazu Nagoya Univ.
Mekada, Yoshito Chukyo Univ.
Ide, Ichiro Nagoya Univ.
Murase, Hiroshi Nagoya Univ.
Tamatsu, Yukimasa DENSO Corp.

We propose a visibility estimation method for traffic signs as part of work for realization of nuisance-free driving safety support systems. Recently, the number of driving safety support systems in a car has been increasing. As a result, it is becoming important to select appropriate information from them for safe and comfortable drive because too much information may cause driver distraction and may increase the risk of a traffic accident. One of the approaches to avoid such a problem is to alert the driver only with information which is easy to miss. Therefore, to realize such a system, we focus on estimating the visibility of traffic signs. The proposed method is a model-based method that estimates the visibility of traffic signs focusing on the difference of image features between a traffic sign and its surrounding region. In this paper, we investigate the performance of the proposed method and show its effectiveness.

10:00-11:10  TuB1.10
**Pedestrian Detection in Near-Infrared Night Vision System**, pp. 51-58
Luo, Yun Robert Bosch LLC
Remillard, Jeffrey Ford Motor Company
Hoetzer, Dieter Robert Bosch LLC

Several premium automotive brands offer night vision systems to enhance the driver’s ability to see at night. Most recent generation night vision systems have added pedestrian detection as a feature to assist drivers to avoid potential collisions. This paper reviews pedestrian detection based on two different sensing technologies: active night vision operating in the near-infrared (NIR) region of the electromagnetic spectrum, and passive night vision operating in the far-infrared (FIR) spectrum. It also discusses the pros and cons of each type of night-vision system with respect to the pedestrian detection capability, the effectiveness for collision avoidance, and the commercial attractiveness. The paper introduces an enhancement to the NIR active lighting scheme that significantly improves the pedestrian detection performance. With improved pedestrian detection performance, we argue that the NIR night vision sys-
A Novel Lane Detection Based on Geometrical Model and Gabor Filter. Zhou, Shengyan, Beijing Inst. of Tech.
Xu, Junjiang, Beijing Inst. of Tech.
Gong, Jianwei, Beijing Inst. of Tech.
Xiong, Guangming, Beijing Inst. of Tech.
Chen, Huiyan, Beijing Inst. of Tech.
Jiang, Yanhua, Beijing Inst. of Tech.

Many people die each year in the world in single vehicle roadway departure crashes caused by driver inattention, especially on the freeway. Lane Departure Warning System (LDWS) is a useful system to avoid those accident, in which, the lane detection is a key issue. In this paper, after a brief overview of existing methods, we present a robust lane detection algorithm based on geometrical model and Gabor filter. This algorithm is based on two assumptions: the road in front of vehicle is approximately planar and marked which are often correct on the highway and freeway where most lane departure accidents happen. The lane geometrical model we build in this paper contains four parameters which are starting position, lane original orientation, lane width and lane curvature. The algorithm is composed of three stages: the first stage is called offline calibration which just runs once after the camera is mounted and fixed in the vehicle. The parameters of camera used for lane detection is accurately estimated by the 2D calibration method [1]; The second stage is called lane model parameters estimation and lane model candidates construction, the first three parameters, starting position, lane original orientation and lane width will be estimated using dominant orientation estimation [9] and local Hough transform. Then the construction of lane model candidates is implemented for the final lane model matching; the third stage is model matching. The proposed lane module matching algorithm is implemented to match the best fitted lane model. The combination of these modules can overcome the universal lane detection problems due to inaccuracies in edge detection such as shadow of tree and passengers on the road. Experimental results on real road will be presented to prove the ef

Maneuver Recognition Using Probabilistic Finite-State Machines and Fuzzy Logic. Hülthagen, Till Daimler AG
Dengler, Ingo Daimler AG
Tamke, Andreas Univ. of Stuttgart
Dang, Thao Daimler AG
Breuel, Gabi Daimler AG

This paper presents a general approach for recognition of driving maneuvers in advanced driver assistance systems (ADAS). Such systems often rely on the identification of driving maneuvers (overtaking, left turn at intersections, etc.) to improve the prediction of potential collisions or to trigger appropriate support for the driver. The proposed maneuver recognition approach combines a fuzzy rule base to model basic maneuver elements and probabilistic finite-state machines to capture all possible sequences of basic elements that constitute a driving maneuver. The proposed method is specifically tailored to ADAS requirements because of its low computational complexity, its flexibility and its straightforward design based on easily comprehensible logical rules. In addition, we propose a suitable training method to optimize the fuzzy rule base. Our approach is evaluated on the recognition of turn maneuvers. Experiments on real data from a test vehicle demonstrate the feasibility of the proposed method.

Neuropsychological Approach to Identify the Risky Driving Behaviors. Danno, Mikio Toyota InfoTechnology Center
Wakabayashi, Akio Chiba Univ.

Driving is a complex behavior that can be affected by an individual’s emotional and cognitive status, and the environment. Since a neuropsychological approach is useful in identifying the complex combination of factors that may cause risky driving behaviors, and because subjective perceptions may misguide the decision-making process, this approach based on brain wave indexes was examined. The merit of this approach is that it enables anyone to make decisions regarding an individual’s ability to drive, despite insufficient information. First, we used a questionnaire survey to identify “risky drivers” and the relationship between traffic accidents and the drivers’ psychosomatic state before traffic accidents. As a result, we found that risky drivers, who made up only 13.6% of respondents, accounted for 56.2% of the total number of accidents. We identified the “risky psychosomatic state” related to the risky driving behaviors. Finally, we proposed a direction for research concerning the neuropsychological approach based on brain wave indexes. These results can be incorporated into advanced driving support systems that grasp the driving environment, control the driver’s psychosomatic state to alleviate his risky psychological traits, and intervene to handle the car inappropriately.

Research on Driver Experience Based Route Planning Method. Li, Man Hitachi (China) R&D Corp.
Wang, Wenjia Hitachi (China) Res. & Development Corp.
Zhang, Yuhe Hitachi (China) Res. & Development Corp.

Conventional navigation systems usually calculate routes based on costs of each road link, which may be length, speed limit, width, real-time traffic condition, etc. Therefore the routes planned by current navigation system may be shortest distance route, shortest time route, expressway route, etc. However, due to inaccurate or delayed information, the calculated routes are not always satisfying. To solve the problem, our route planning method considers drivers’ experience, i.e. frequent routes. Frequent routes...
are the routes along which drivers usually drive between a pair of origin and destination. The route planning results based on frequent routes can fit to drivers’ preferences more precisely than conventional results.

10:00-11:10 TuB1.15
Assessment of Safety Levels and an Innovative Design for the Lane Change Assistant, pp. 83-88
Roelofs, Mark Univ. of Twente
Jin, Lisheng Nanling Campus of Jilin Univ.
van Arem, Bart Delft Univ. of Tech.

In this paper we propose a novel design for the Lane Change Assistant (LCA). For drivers on the highway, LCA advises them on whether it is safe to change lanes under the current traffic conditions. We focus on how the LCA can provide a reliable advice in practice by considering the issues of changing circumstances and measurement uncertainties. Under some generic assumptions we develop a micro-simulation model for the lane change safety assessment. The model is in line with the car following models and lane change algorithms available in literature. It retains a probabilistic character to accurately represent realistic situations. Based on a sensitivity study we are able to develop a robust design for the LCA. In this design the system accounts for the practical uncertainties by including appropriate extra safety distances. The driver interface consists of a spectrum of five LED lights, each operating on a distinct color (varying from red to green) and guaranteeing a certain safety degree. Our results allow car developers to easily acquire reliable designs for the LCA.

10:00-11:10 TuB1.16
Block-Constraint Line Scanning Method for Lane Detection, pp. 89-94
Chen, Long Wuhan Univ.
Li, Qingquan Wuhan Univ.
Mao, Qingzhou Wuhan Univ.
Zou, Qin Wuhan Univ.

Considering the plentiful road markings in China, we present a Block-Constraint Line scanning (BCLS) method for lane detection in this paper. In this method, images are firstly pre-processed by a morphological top-hat transform, and then an imaging model is created for building relationship between lane parameters of the image coordinate and the WGS coordinate, from which target points on lane lines could be retained by a block-constraint line scanning algorithm. Finally, lanes could be extracted by a Progressive Probabilistic Hough Transform (PPHT) and the number of lanes is figured out through clustering. Our method is fast enough to meet real-time requirement. Experiments were carried out on the intelligent vehicle SmartV (Fig.1) on the Wuhan urban roads in China and the results show that this method can efficiently and accurately extract lanes in complex environments, even with the presence of non-lane road markings.

10:00-11:10 TuB1.17
Cross-Layer Location Verification Enhancement in Vehicular Networks, pp. 95-100
Yan, Gongjun Old Dominion Univ.
Olariu, Stephan Old Dominion Univ.
Weigle, Michele C. Old Dominion Univ.

Location, fundamental information, plays a critical role in many applications and network routings in Vehicular Ad-hoc NETworks (VANETs). Therefore, it is of importance to validate the location information. We propose a cross-layer design to achieve location validation. We assume vehicles are installed with radar, GPS and transceiver. On physical layer, radar detection can validate GPS coordinates. On network layer, an agreement of a location can be achieved. On application layer, location information as a set of measurements can be filtered and refined by using a proposed data fusion method. We also present results of simulations and evaluate the location validation methods.

10:00-11:10 TuB1.18
Camera-Based Drowsiness Reference for Driver State Classification under Real Driving Conditions, pp. 101-106
Friedrichs, Fabian Univ. of Stuttgart
Yang, Bin Univ. of Stuttgart

Experts assume that accidents caused by drowsiness are significantly under-reported in police crash investigations (1-3%). They estimate that about 24-33% of the severe accidents are related to drowsiness. In order to develop warning systems that detect reduced vigilance based on the driving behavior, a reliable and accurate drowsiness reference is needed. Studies have shown that measures of the driver’s eyes are capable to detect drowsiness under simulator or experiment conditions. In this study, the performance of the latest eye tracking based in-vehicle fatigue prediction measures are evaluated. These measures are assessed statistically and by a classification method based on a large dataset of 90 hours of real road drives. The results show that eye-tracking drowsiness detection works well for some drivers as long as the blinkings detection works properly. Even with some proposed improvements, however, there are still problems with bad light conditions and for persons wearing glasses. As a summary, the camera based sleepiness measures provide a valuable contribution for a drowsiness reference, but are not reliable enough to be the only reference.

10:00-11:10 TuB1.19
Advisory Speed for Intelligent Speed Adaptation in Adverse Conditions, pp. 107-114
Gallen, Romain LCPC
Hautiere, Nicolas Univ. Paris-Est, INRETS-LCPC
Glaser, Sébastien LCPC

In this paper, we propose a novel approach to compute advisory speeds to be used in an Intelligent Speed Adaptation system (ISA). This method is designed to be embedded in the vehicles. It estimates an appropriate speed by fusing in real-time the outputs of ego sensors which
detect adverse conditions with highway characteristics transmitted by distant servers. The method presents two major novelties. First, we consider that the 85th percentile of observed speeds (V85) is a practised and practicable speed in ideal conditions. We propose to modulate it in adverse conditions (top-down approach). Second, this method allows us taking into account the potential seriousness of crashes using a generic scenario of accident. With this scenario, we estimate the difference in speed that should be applied in adverse conditions so that global injury risk is the same as in ideal conditions.

10:00-11:10 TuB1.20
Validation and Benchmarking for Pedestrian Video Detection Based on a Sensors Simulation Platform, pp. 115-122
Bossu, Jeremie INRETS
Gruyer, Dominique INRETS/LCPC
Smal, Jean-christophe Inst. National de Recherche sur les Transports et leur Securi
Blosseville, Jean-marc INRETS
The evaluation stage is an important part in the validation of ADAS robustness. Moreover, the control and the repetitiveness of the experimentations were very difficult to conduct on real road due to safety reasons. Moreover, the lack of data/sensors or the complexity of the experiment are often very penalizing for a correct and exhaustive evaluation. It is for these reasons that LIVIC launched the development of a software simulation architecture (SiVIC), to support its research activities on ADAS. The use of such a simulation platform can provide both simulated sensors data and a ground truth reference for the validation stages. This paper proposes a general framework and a protocol in order to evaluate the result of pedestrian detection by camera processing.

10:00-11:10 TuB1.21
The See-Through System: A VANET-Enabled Assistant for Overtaking Maneuvers, pp. 123-128
Olaverri-Monreal, Cristina Inst. de Telecomunicações, Departamento de Ciência de Comput Gomes, Pedro Emanuel Rodrigues Inst. de Telecomunicações Fernandes, Ricardo Inst. de Telecomunicações Vieira, Fausto Inst. de Telecomunicações, Faculdade de Engenharia da Univ. Ferreira, Michel Inst. de Telecomunicações
The use of wireless technology based on Vehicular Ad hoc Networks (VANETs) for information exchange can influence the drivers’ behavior towards improving driving performance and reducing road accidents. This information can even be more relevant if it is presented as a video stream. In this paper we propose a system that relies on VANET and video-streaming technology: the See-Through System (STS). The system enhances driver’s visibility and supports the driver’s overtaking decision in challenging situations, such as overtaking a vision-obstructing vehicle. The use of the See-Through System provides the driver with an additional tool for determining if traffic conditions permit starting an overtaking maneuver thus reducing the risk of overtaking. We tested the See-Through System on an experimental vehicle on the road as well as in the context of a driving simulator for real world environment. Results are promising, since the use of the 802.11p standard wireless communication protocol allows a vehicle-to-vehicle connection without significant delay and the totality of the participants regarded the information provided by the STS as useful.

10:00-11:10 TuB1.22
Ecological and Safe Driving Assistance System: Design and Strategy, pp. 129-134
Luu, Hong Tu LIVIC
Nouveliere, Lydie IBISC/Univ. of Evry - LCPC/LIVIC Mammar, Said INRETS
This paper presents a new Advanced Driver Assistant System (ADAS) with an ecological aspect (EDAS). A low fuel consumption problem is formulated coupled to a safety problem (longitudinal spacing). Several discussions are made about the computational time reduction, the choice of an optimization method by comparisons. A fuzzy controller is developed to introduce some safety margins that are integrated in the optimization of the fuel consumption. The simulation results are analyzed to show the consistency of our different choices of the methods and strategies.

10:00-11:10 TuB1.23
Fast Prototyping of a Highly Autonomous Cooperative Driving System for Public Roads, pp. 135-142
Vanholme, Benoit LCPC Gruyer, Dominique INRETS/LCPC Glaser, Sébastien LCPC Mammar, Said INRETS
This paper presents a framework for a fast prototyping of Advanced Driving Assistance Systems (ADAS). The simulation tool SiVIC™ is proposed for drastically reducing development time and costs of a vehicle system design. RT-Maps® is used as a platform for easily encapsulating the system component algorithms and for effortlessly transferring them from a simulation environment to a physical vehicle. With these tools a Highly Autonomous Cooperative Driving System (HACS) has been designed. A perception component uses a combination of sensors to map the environment. In this paper a cooperative, extended perception with infrastructure-to-vehicle communication (I2V) will be proposed. A co-pilot integrates a fast Total Trajectory Exploration (TTE) method that finds a trajectory that is optimal with respect to the sensed environment. A simple controller on the vehicle actuators is used for guiding the vehicle on this trajectory. The cooperation between human and automation is managed by a Driving Mode Selection Unit (MSU) and a Human Machine Interface (HMI). In this paper a vehicle system which allows highly autonomous driving with human cooperation is called a co-system.
Junior 3: A Test Platform for Advanced Driver Assistance Systems, pp. 143-149
Langer, Dirk  Volkswagen of America
Stanek, Ganymed  Stanford Univ.
Mueller-Bessler, Bernhard  Volkswagen Group of America
Huhnke, Burkhard  Volkswagen Group of America

Advanced Driver Assistance Systems (ADAS) are becoming more common in today’s vehicles with more complex functions being implemented in production vehicles. On the research side, significant technology development in hardware and software has been spurred in recent years by the DARPA Grand Challenge and Urban Challenge in 2005 and 2007 respectively. This paper describes ‘Junior 3’, a vehicle built at Volkswagen Group of America’s Electronics Research Lab, based on the knowledge gained from the DARPA Challenges and applied to ADAS functionalities. Specifically we focused on object detection and vehicle positioning capabilities with close to production grade sensors and describe an ‘Autonomous Valet Parking’ and ‘Object Tracking’ application with this system.

Vehicle Detection and Tracking Using Homography-Based Plane Rectification and Particle Filtering, pp. 150-155
Arróspide, Jon  Univ. Pol. de Madrid
Salgado, Luis  UPM

This paper presents a full system for vehicle detection and tracking in non-stationary settings based on computer vision. The method proposed for vehicle detection exploits the geometrical relations between the elements in the scene so that moving objects (i.e., vehicles) can be detected by analyzing motion parallax. Namely, the homography of the road plane between successive images is computed. Most remarkably, a novel probabilistic framework based on Kalman filtering is presented for reliable and accurate homography estimation. The estimated homography is used for image alignment, which in turn allows to detect the moving vehicles in the image. Tracking of vehicles is performed on the basis of a multidimensional particle filter, which also manages the exit and entries of objects. The filter involves a mixture likelihood model that allows a better adaptation of the particles to the observed measurements. The system is specially designed for highway environments, where it has been proven to yield excellent results.

Pedestrian Recognition Based on Hierarchical Codebook of SURF Features in Visible and Infrared Images, pp. 156-161
Bassem, Besbes  National Inst. for Applied Sciences- Rouen
Alexandrina, Rogozan  National Inst. of Applied Sciences- Rouen
Abdelaziz, Bensrhair  National Inst. of Applied Sciences- Rouen

One of the main challenges in Intelligent Vehicle is recognition of road obstacles. Our goal is to design a real-time, precise and robust pedestrian recognition system. We choose to use Speeded Up Robust Features (SURF) and a Support Vector Machine (SVM) classifier in order to perform the recognition task. Our main contribution is a method for fast computation of discriminative features for pedestrian recognition. Fast features extraction is assured by using a hierarchical codebook of scale and rotation-invariant SURF features. We evaluate our approach for pedestrian recognition in a set of images where people occur at different scales and in difficult recognition situations. The system shows good performance in visible and especially in infrared images. Besides, experimental results show that the hierarchical structure presents a major interest not only for maintaining a reasonable feature extraction time, but also for improving classification results.

The “UTDrive” In-Vehicle Voice Activity Detection System, pp. 162-167
Yu, Tao  Center for Robust Speech System, Univ. of Texas atDallas
Hansen, John  Univ. of Texas at Dallas

In this study, we specifically address the problem of in-vehicle voice activity detection (VAD) which has a significant importance for the speech controlled intelligent vehicle. A high performance VAD system is proposed based on microphone array beamforming and Gaussian mixture model. As a binary classification problem, the features and classifiers are investigated under the in-vehicle acoustic environment. Using microphone array, the spatial power ratio can serve as an effective feature for speech activity detection. Further, a discriminative training based Gaussian mixture model classifier is used to directly enhance the VAD receiver operating characteristics (ROC) performance. Through the real data experiment in the UTDrive project, the proposed VAD presents a novel and robust performance against various in-vehicle noisy scenarios, compared to the conventional VAD systems.

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

With the introduction of intelligent driver support systems, vehicles have become more comfortable and safer. But, these systems require new sensors and the information they contain must be efficiently presented to the driver. The cognitive demands for interpreting these signals may prove to be a distraction with negative impact on driving performance. This work describes a unified visualization scheme, the Vehicle Iconic Surround Observer, capable of introducing new surround sensors into a common display environment which quickly conveys critical surround context with minimal driver interpretation.
The proposed algorithm is employed on a real-life traffic video captured using an un-calibrated camera to estimate the speed of individual vehicles in the video frames. The main advantages are that it is a simple yet robust method having lower time complexity and less ambiguity in vehicle speed estimations.

We propose an algorithm of reliable detection of line for unmanned navigation of mobile robots using sensor fusion. To detect the distance and the angle between the robot and the line, we use a vision sensor system and a laser range finder (LRF). Each sensor system runs its own extended Kalman filter (EKF) to estimate the distance and orientation of the line. The vision system processes images being captured using well-known edge detection algorithms, and the LRF detects the line using the measurement of the intensity of the laser beam reflected. However, depending on the condition of the road and ambient light, each sensor gives us wrong measurement of the line or sometimes completely fails to detect it. To resolve such uncertainty, we develop a simple and easy-to-implement sensor fusion algorithm that uses weighted sum of the output of each EKF, and it gives us more reliable estimate of the distance and orientation of the line than each measurement/estimator system.

This paper presents a method for estimating vehicle speed by tracking the motion of a vehicle through a sequence of images. The motion is derived using an equation based on spherical projection which relates the image motion to the object motion. Motion tracking is done via the Kanade-Lucas-Tomasi algorithm. The motion equation is reformulated into a dynamical space state model, for which Kalman and Extended Kalman filter are applied to estimate the object velocity as well as to predict the future location of the features. The proposed algorithm is employed on a real-life traffic video captured using an un-calibrated camera to estimate the number of objects in the tracking step is decreased, and only as an individual cue but also in relation with other contextual information (e.g. head dynamics, facial features, and vehicle dynamics). Some initial results in our experiment following these guidelines show the feasibility and promise of extracting and using 3D driver posture dynamics for driver assistance.

Experimental analyses show promising results.
This paper presents a generic framework for curb detection and reconstruction in the context of driver assistance systems. Based on a 3D point cloud, we estimate the parameters of a 3D curb model, incorporating also the curb adjacent surfaces, e.g., street and sidewalk. We apply an iterative two step approach. First, the measured 3D points, e.g., obtained from dense stereo vision, are assigned to the curb adjacent surfaces using loopy belief propagation on a Conditional Random Field. Based on this result, we reconstruct the surfaces and in particular the curb. Our system is not limited to straight-line curbs, i.e. it is able to deal with curbs of different curvature and varying height.

The proposed algorithm runs in real-time on our demonstrator vehicle and is evaluated in urban real-world scenarios. It yields highly accurate results even for low curbs up to 20 m distance.

Reliable obstacle detection and localization is a key issue for driving assistance systems particularly in urban environments. In this article, a multi-modal perception approach is studied in order to enhance vehicle localization and dynamic objects tracking, in a world-centric map. 3D ego-localization is done by merging a stereo vision system and proprioceptive information coming from vehicle sensors. Mobile objects are detected using a multi-layer lidar that is simultaneously used to characterize a zone of interest in order to reduce the complexity of the perception process. Objects localization and tracking is then performed in the fixed frame which simplifies the scene analysis and understanding. Real experimental results are reported to evaluate the performance of the multi-modal system.
and Simulator Analysis, pp. 232-237
Doshi, Anup Univ. of California, San Diego
Trivedi, Mohan M. Univ. of California at San Diego
Confronted with the broad range of personalities of drivers on the roads today, in-vehicle technology must be able to function either in spite of or in harmony with each driver’s style. Individual drivers act and respond in different manners under various conditions, and many Driver Assistance Systems would benefit from some measure of the driver’s likely behaviors in these conditions. In this study we present several measures of driving style and show how they correlate with the predictability and responsiveness of the driver in several experimental conditions. In the first two experiments, one simulator and one real-world, we find that “aggressive” drivers are more consistent in behaviors and significantly more predictable than “non-aggressive” drivers. In the third experiment, however, we find that though “non-aggressive” drivers are less predictable, they also tend be more receptive of feedback from Driver Assistance Systems. These results could affect the design, effectiveness, and feedback mechanisms of future Driver Assistance Systems.

14:10-14:30 TuD1.3 Driver Behavior Analysis through Speech Emotion Understanding, pp. 238-243
Kamaruddin, Norhaslinda Nanyang Tech. Univ. Singapore
Abdul Rahman, Abdul Wahab International Islamic Univ. Malaysia
Driver behavior is indeed one of the major factors contributing to high number of motor vehicle accidents. Due to the fact that human behavior is always influenced by emotion and emotion can be detected through speech, we attempt to find correlation between driver behavior state and speech emotion to analyze driver behavior. This understanding is important to facilitate the development of driver emotion-al indicator system that can act as some kind of warning system to prevent accidents. Experimental results show potential for driver behavior state detection particularly for sleepy state based on speech emotion recognition approach coupled with fundamental understanding of affection space model. These findings surged us to propose an alternative approach of speech emotion profiling that complement the research mainstream of driver behavior and speech emotion recognition.

14:30-14:50 TuD1.4 Energy Constrained Trajectory Generation for Advanced Driver Assistance Systems, pp. 244-249
Daniel, Jeremie Univ. of Haute Alsace
Birouche, Abderazik Univ. of Haute Alsace
Lauffenburger, Jean-Philippe Univ. of Haute-Alsace
Basset, Michel Univ. of Haute-Alsace
This paper presents a new constrained trajectory generation algorithm dedicated to complex Advanced Driver Assistance Systems (ADAS). Based on the information provided by the digital map database of a navigation system, and considering different constraints related to the road profile, the vehicle and the driver, a convex optimization algorithm generates specific Spline-based trajectories. Characteristically, these trajectories are safe, they stay within the traffic lane borders, at the same time minimize the energy along the path, and finally, they are curvature continuous. The present solution has been tested on several roads and the results show the efficiency of the energy constrained trajectory generation method.

TuE1 Room T1 POSTER SESSION II (Poster Session)
Chair: van Arem, Bart Delft Univ. of Tech.
14:50-16:00 TuE1.1 Development of an Intelligent Master-Slave System between Agricultural Vehicles, pp. 250-255
Zhang, Xi Karlsruhe Inst. of Tech.
This paper presents a method to develop an intelligent master-slave system between agricultural vehicles, which will enable a semi-autonomous agricultural vehicle (slave) to follow a leading tractor (master) with a given lateral and longitudinal offset. In our study not only the follow-up motions but also the site-specific control of the apparatus such as rear and front power lift was considered. In the first part of this paper the recent research works in the area autonomous farming were discussed and the restrictions of these research works were illustrated. In the second part an approach to construct a master-slave system between two agricultural vehicles was demonstrated. In the next part the mathematic modeling of this master-slave system and the simulation results about the control algorithm were demonstrated. Afterwards the result of a real field test was presented and the safety considerations about such an intelligent vehicle system were made.

14:50-16:00 TuE1.2 Road Detection Using Support Vector Machine Based on Online Learning and Evaluation, pp. 256-261
Zhou, Shengyan Beijing Inst. of Tech.
Gong, Jianwei Beijing Inst. of Tech.
Xiong, Guangming Beijing Inst. of Tech.
Chen, Huiyan Beijing Inst. of Tech.
Iagnemma, Karl Massachusetts Inst. of Tech.
Road detection is an important problem with application to driver assistance systems and autonomous, self-guided vehicles. The focus of this paper is on the problem of feature extraction and classification for front-view road detection. Specifically, we propose using Support Vector Machines (SVM) for road detection and effective approach for self-supervised online learning. The proposed road detection algorithm is capable of automatically updating the training data for online training the SVM classifier which reduces the possibility of misclassifying road and non-road classes and improves the adaptability of the road detection algorithm. The algorithm presented here can also be seen as a novel framework for self-supervised online learning in
the application of classification-based road detection algorithm on intelligent vehicle.

14:50-16:00 TuE1.3
Robust Positioning in Safety Applications for the CVIS Project, pp. 262-268
Gruyer, Dominique INRETS/LCPC
Pecheberti, Steve LCPC
Gingras, Denis Intelligent Materials and Systems Inst. Univ. de Sherbrooke
Dupin, Francis INRETS/LCPC

This paper describes hybrid fusion module used in a strong localization context (POMA) for embedded vehicle applications. This work has been developed in order to give an answer to the POMA (Positioning, Maps and local referencing) sub project objectives. These objectives are to provide, for a set of high level applications, a positioning service included a service quality, a metric accuracy (lane) and a robust result. This work is involved in CVIS European project. The use of IMM approach in the Hybrid Fusion module will be justified in comparison to the different current probabilistic methods. The IMM, contrary to the non-modular methods, is based on the discretization of the vehicle evolution space into simple maneuvers, represented each by a simple dynamic model such as constant velocity or constant turning etc. This allows the method to be optimized for highly dynamic vehicles. The application of this positioning service will be presented in a real time embedded architecture. The presented results are based on real measurements collected from representatives scenarios (test track, peri-urban road, highway). These results show a real interest in using the new IMM method in order to reach the POMA’s objectives.

14:50-16:00 TuE1.4
Dynamic Level of Detail 3D Occupancy Grids for Automotive Use, pp. 269-274
Schmid, Matthias Roland Univ. of the Bundeswehr Munich
Maehlisch, Mirko Daimler AG
Dickmann, Jürgen Daimler AG
Wuensche, Hans Joachim Univ.

In this paper, a generic approach for three-dimensional environment representation is presented. Scans from range finders are accumulated into a three-dimensional occupancy grid. A probabilistic measurement model is used to represent measurement uncertainties. Free regions are modelled as well and contribute to a precise representation of the environment. In order to acquire a feasible three-dimensional grid, a hierarchical data structure is proposed. As a positive result, the level of detail and respectively the grid resolution is controllable by the application or by the content. As an example application, it will be shown how height information can be derived from a sensor with one horizontal scan plane only.

14:50-16:00 TuE1.5
Characterization of the Reception Environment of GNSS Signals Using a Texture and Color Based Adaptive Segmentation Technique, pp. 275-280
Cohen, Andrea Univ. of Tech. of Belfort-Montbéliard
Meurie, Cyril Univ. of Tech. of Belfort-Montbéliard
Ruichek, Yassine Univ. of Tech. of Belfort-Montbéliard
Marais, Juliette French National Institute for Transport and Safety Research

This paper is focused on the characterization of GNSS signals reception environment by estimating the percentage of visible sky. A new segmentation technique based on a color watershed using an adaptive combination of color and texture information is proposed. This information is represented by two morphological gradients, a classical color gradient and a texture gradient based on co-occurrence matrices. The segmented images are then used as input for a k-means classifier in order to determine the percentage of visible sky in fish-eye images. The obtained classification results are evaluated to demonstrate the effectiveness and the reliability of the proposed approach.

14:50-16:00 TuE1.6
Automatic Generation of a Highly Accurate Map for Driver Assistance Systems in Road Construction Sites, pp. 281-286
Wimmer, Andreas Univ. of Ulm
Jungel, Tobias Univ. of Ulm, Inst. of Measurement, Control, and Microt
Glueck, Manuel Univ. of Ulm, Inst. of Measurement, Control, and Microt
Dietmayer, Klaus Christian Jürgen Univ. of Ulm

Road construction sites often are the reason for traffic jams and accidents due to the reduced road width. Driver assistance systems for these demanding environments highly benefit from a digital representation of the road layout. This digital map includes all important infrastructure elements, such as barriers, temporary road markings and guiding reflector posts. The paper describes the automatic generation of a detailed and highly accurate “Road Work Map” using video camera and laser scanners.

14:50-16:00 TuE1.7
ObjectFlow: A Descriptor for Classifying Traffic Motion, pp. 287-293
Geiger, AndreasKIT
Kitt, Bernd KIT

We present and evaluate a novel scene descriptor for classifying urban traffic by object motion. Atomic 3D flow vectors are extracted and compensated for the vehicle’s egomotion using stereo video sequences. Votes cast by each flow vector are accumulated in a bird’s eye view histogram grid. Since we are directly using low-level object flow, no prior object detection or tracking is needed. We demonstrate the effectiveness of the proposed descriptor by comparing it to two simpler baselines on the task of classifying more than 100 challenging video sequences.
into intersection and non-intersection scenarios. Our experiments reveal good classification performance in busy traffic situations, making our method a valuable complement to traditional approaches based on lane markings.

14:50-16:00  TuE1.8

**Fusion of Occupancy Grid Mapping and Model Based Object Tracking for Driver Assistance Systems Using Laser and Radar Sensors**, pp. 294-300

Bouzouraa, Mohamed Essayed, AUDI AG
Hofmann, Ulrich, Audi AG Ingolstadt

In this paper, we present a novel environment perception system based on an occupancy grid mapping and a multi-object tracking. The goal of such a system is to create a harmonic, consistent and complete representation of the vehicle environment as a base for future advanced driver assistance systems. In addition to a mathematical formulation of the problem we present a robust algorithm to detect dynamic obstacles from the occupancy map and show how both, the mapping process and the tracking can benefit from each other. Therefore, the concept of moving objects with associated dynamic cells is introduced. The presented techniques are applicable to both 2D and 3D mapping and can be also extended to correct the ego motion from the occupancy map and the object tracks. Unlike many publications over the last years our work provides real time performance and an accurate detection of obstacles with real laser and radar sensors and can fulfill the requirements of future driver assistance systems.

14:50-16:00  TuE1.9

**A Fusion Method of Data Association and Virtual Detection for Minimizing Track Loss and False Track**, pp. 301-306

Lim, Young-Chul, Daegu Gyeongbuk Inst. of S&T
Lee, Chung-Hee, Daegu Gyeongbuk Inst. of S&T
Kwon, Soon, Daegu Gyeongbuk Inst. of S&T
Lee, Jong-Hun, Daegu Gyeongbuk Inst. of S&T

In this paper, we present a method to track multiple moving vehicles using the global nearest neighborhood (GNN) data association (DA) based on 2D global position and virtual detection based on motion tracking. Unlike the single target tracking, multiple target tracking needs to associate observation-to-track pairs. DA is a process to determine which measurements are used to update each track. We use the GNN data association not to lost track and not to connect incorrect measurements. GNN is a simple, robust, and optimal technique for intelligent vehicle applications with a stereo vision system that can reliably estimates the position of a vehicle. However, an incomplete detection and recognition technique bring low track maintenance due to missed detections and false alarms. A complementary virtual detection method adds to GNN method. Virtual detection is used to recover the missed detection by motion tracking when the track maintains for some periods. Motion tracking estimates virtual region of interest (ROI) of the missed detection using a pyramidal Lukas-Kanade feature tracker. Next, GNN associates the lost tracks and virtual measurements if the measurement exists in the validation gate. Our experimental results show that our tracking method works well in a stereo vision system with incomplete detection and recognition ability.

14:50-16:00  TuE1.10


Michalke, Thomas, Daimler AG
Kastner, Robert, Darmstadt Univ. of Tech.
Fritsch, Jannik, Honda Res. Inst. Europe GmbH
Goerick, Christian, Honda Res. Inst. Europe GmbH

Newly emerging, highly complex Advanced Driver Assistance Systems (ADAS) fuse the output of various system modules (e.g., lane detection, object classification). Such knowledge fusion is realized in order to gain additional information of the environment allowing for complex system tasks as path planning, the active search for specific objects and task-specific analysis of the environment. As part of our previous work, we realized a highly generic type of such ADAS using biological principles. The present contribution offers a novel approach for the detection of curbstones and elevated roadsides in inner-city that relies on biological principles taking inspiration from the human neural signal processing. The gathered results can be fused to an ADAS in order to improve the quality of various other system percepts and allow additional system tasks.

14:50-16:00  TuE1.11

**Probabilistic Representation of the Uncertainty of Stereo-Vision and Application to Obstacle Detection**, pp. 313-318

Perrollaz, Mathias, INRIA
Aubert, Didier, INRETS/LCPC
Spalanzani, Anne, INRIA

Stereo-vision is extensively used for intelligent vehicles, mainly for obstacle detection, as it provides a large amount of data. Many authors use it as a classical 3D sensor which provides a large tri-dimensional cloud of metric measurements, and apply methods usually designed for other sensors, such as clustering based on a distance. For stereovision, the measurement uncertainty is related to the range. For medium to long range, often necessary in the field of intelligent vehicles, this uncertainty has a significant impact, limiting the use of this kind of approaches. On the other hand, some authors consider stereo-vision more like a vision sensor and choose to directly work in the disparity space. This provides the ability to exploit the connectivity of the measurements, but roughly takes into consideration the actual size of the objects. In this paper, we propose a probabilistic representation of the specific uncertainty for stereo-vision, which takes advantage of both aspects - distance and disparity. The model is presented and then applied to obstacle detection, using the occupancy grid framework. For this purpose, a computationally-efficient implementation based on the u-disparity approach is given.
14:50-16:00   TuE1.12
Multiple Track 4D-Road Representation, pp. 319-324
Baer, Michael   AUDI AG
Hofmann, Ulrich   Audi AG Ingolstadt
Gies, Stefan   Volkswagen AG
In this paper we will present a geometric lane representation which enables a 4D-lane tracker to handle ambiguous, non-parallel and even crossing lane marking tracks in complex situations. The introduced geometry model contains lateral independent tracks which lie on top of the surface of a continuous shape that is formed like the road surface within a specific preview and is bent in horizontal, vertical and torsional way. Due to a more precise shape representation the association of measured to expected features is eased and therefore the approach leads to a noticeable improvement of stability of the tracking system. The introduced state description achieves a decoupling of dynamic ego movement and stationary lane markings to enhance the robustness furthermore. Based on the increased number of estimated tracks the computing effort of the feature extraction rises linearly and the estimation effort approximately quadratically. This challenge is met by a selective innovation mechanism which allows a comparable calculation time and is presented below as well.

14:50-16:00   TuE1.13
Fast Human Detection with Cascaded Ensembles on the GPU, pp. 325-332
Bilgic, Berkin   Massachusetts Inst. of Tech.
Horn, Berthold K.P.   MIT
Masaki, Ichiro   MIT
We investigate a fast pedestrian localization framework that integrates the cascade-of-rejectors approach with the Histograms of Oriented Gradients (HoG) features on a data parallel architecture. The salient features of humans are captured by HoG blocks of variable sizes and locations which are chosen by the AdaBoost algorithm from a large set of possible blocks. We use the integral image representation for histogram computation and a rejection cascade in a sliding-windows manner, both of which can be implemented in a data parallel fashion. Utilizing the NVIDIA CUDA framework to realize this method on a Graphics Processing Unit (GPU), we report a speed up by a factor of 13 over our CPU implementation. For a 1280x960 image our parallel technique attains a processing speed of 2.5 to 8 frames per second depending on the image scanning density, which is similar to the recent GPU implementation of the original HoG algorithm in [3].

14:50-16:00   TuE1.14
Attention-Based Traffic Sign Recognition with an Array of Weak Classifiers, pp. 333-339
Kastner, Robert   Darmstadt Univ. of Tech.
Michalke, Thomas   Daimler AG
Burbach, Thomas   Darmstadt Univ. of Tech.
Fritsch, Jannik   Honda Res. Inst. Europe GmbH
Goerick, Christian   Honda Res. Inst. Europe GmbH
Currently available traffic sign recognition systems typically focus on a single class of traffic sign and therefore, the algorithms are optimized to find only this specific class. To this end, a number of approaches for real time capable classification of mostly circular signs exist. Nevertheless, to simultaneously recognize a number of classes a different way has to be taken. This paper presents a real-time capable approach, which uses a two-tiered process independent of the diameter of the sign to cope with all distances. The first stage is our attention system, parameterized to find a number of different types of sign classes. The output of our attention system is a region of interest with a potential traffic sign candidate. The second stage is an array of weak classifiers similar to the idea of Viola and Jones [1], computing a probability value for each of the sign classes. As application area we focus on inner city and therefore, evaluate on the most important traffic sign classes of Stop and Give Way. Nevertheless, the approach can also detect Warning signs and is easily extensible to additional sign classes. The evaluation results show the reliability and mark it as first step towards an overall traffic sign recognition.

14:50-16:00   TuE1.15
Camera-Based Bidirectional Reflectance Measurement for Road Surface Reflectivity Classification, pp. 340-347
Roser, Martin   Karlsruhe Inst. of Tech. (KIT)
Lenz, Philip   Karlsruhe Inst. of Tech.
In this paper we propose a novel framework for road reflectivity classification in cluttered traffic scenarios by measuring the bidirectional reflectance distribution function of road surfaces from inside a moving vehicle. The predominant restrictions in our application are a strongly limited field of observations and a weakly defined illumination environment. To overcome these problems, we estimate the parameters of an extended Oren-Nayar model that considers the diffuse and specular behavior of real-world surfaces and extrapolates the surface reflectivity measurements to unobservable angle combinations. Model ambiguities are decreased by utilizing standardized as well as customized reflection characteristics. In contrast to existing approaches that require special measurement setups, our approach can be implemented in vision-based driver assistance systems using radiometrically uncalibrated gray value cameras and GPS information. The effectiveness of our approach is demonstrated by a successful classification of the road surface reflectance of expressway scenes with low error rates.

14:50-16:00   TuE1.16
Automatic Recognition of Railway Signs Using SIFT Features, pp. 348-354
Safety in railways is mostly achieved by automated operation using a specialized infrastructure. However, many tasks still rely on the decisions and actions of a human crew. Aiming at improving safety in such situations, we present an approach for recognizing railway signals and signs in video sequences taken by an in-vehicle camera. Our approach is based on a model automatically learned from examples,
built from clusters of features extracted by a modified version of SIFT. It does not require the examples and inputs to be obtained under controlled conditions or with specific camera parameters/positioning, being robust to arbitrary weather and lighting, deterioration, motion blur and perspective distortion. We demonstrate the feasibility of our approach by showing that it performs better than a shape-based matching method when recognizing a railway signal with particularly challenging characteristics under realistic conditions.

14:50-16:00  TuE1.17
Sensor Fusion-Based Pedestrian Collision Warning System with Crosswalk Detection, pp. 355-360
Suzuki, Shigetaka  Tokyo Univ. of Agriculture and Tech.
Raksincharoensak, Pongsathorn  Tokyo Univ. of Agriculture and Tech.
Shimizu, Ikuko  Tokyo Univ. of Agriculture and Tech.
Nagai, Masao  Tokyo Univ. of Agriculture and Tech.
Adomat, Rolf  Continental

This paper describes a pedestrian collision warning system with crosswalk detection feature based on sensor fusion of a monocular camera and a millimeter wave radar. The method to decide about the presence of a pedestrian is based on the assumption that objects moving along a crosswalk can be interpreted as pedestrians under certain circumstances. The advantage of the described solution is its robustness and effectiveness since it is limited to crosswalks. The camera can be used to detect the crosswalk. Data from both sensors can then be used to infer about the presence of a pedestrian. The sensor fusion algorithm which combines data from the sensors is explained. Then the paper describes a warning concept which provides auditory alarm and visual information about the presence of a crosswalk as well as pedestrians to a driver, depending on the estimated collision probability. Finally, test drives on an experimental vehicle are presented and the results verify that the proposed warning system is running in practice.

14:50-16:00  TuE1.18
MRF-Based Road Detection with Unsupervised Learning for Autonomous Driving in Changing Environments, pp. 361-368
Guo, Chunzhao  Toyota Tech. Inst.
Mita, Seiichi  Toyota Tech. Inst.
McAllester, David  Toyota Tech. Inst. at Chicago

This paper presents a vision-based approach with unsupervised learning for robust, accurate and stable detection of the drivable road to deal with autonomous driving in changing environments. This approach is based on a formulation of stereo with homography as a Maximum A Posteriori (MAP) problem in a Markov Random Field (MRF). Under this formulation, we develop an alternating optimization algorithm that alternates between computing the binary labeling and learning the optimal parameters from the stereo pair itself. The labeling is optimized by minimizing a well-defined energy function that consists of matching energy, smoothness energy and tracking energy. The parameters, including nine homography parameters and four MRF parameters, are learned online by applying a hard Expectation Maximization (EM) algorithm to maximize conditional likelihood. The proposed automatic parameter tuning procedure not only improves the accuracy of road detection but also makes the approach adaptive to changing environments without any a priori knowledge of the road. Experimental results show the optimality as well as adaptability of the proposed approach on a wide variety of challenging roads with changing environments.
emotion recognition methods as they are relatively more consistent across cultures and nations. Emotions have a serious effect on driving. Human beings in negative and sometimes positive emotional states can be distracted which will increase the risk of driving. This paper presents an EEG-based emotion recognition system. Mutual information and magnitude squared coherence are applied to investigate the interconnectivity between 8 scalp regions. A study was performed to collect 8 channels of EEG data from 26 healthy right-handed subjects in experiencing 4 emotional states while exposed to audio-visual emotional stimuli. After feature extraction, 10-fold cross-validation was then performed using the KNN and SVM classifier. The results showed existence of different kind of functional brain connectivity in different emotional states.

14:50-16:00 TuE1.21
A Voting Strategy for Visual Ego-Motion from Stereo, pp. 382-387
We present a procedure for egomotion estimation from visual input of a stereo pair of video cameras. The 3D egomotion problem, which has six degrees of freedom in general, is simplified to four dimensions and further decomposed into two two-dimensional subproblems. The decomposition allows us to use a voting strategy to identify the most probable solution, avoiding the random sampling (RANSAC) or other approximation techniques. The input constitutes of image correspondences between consecutive stereo pairs, i.e. feature points do not need to be tracked over time. The experiments show that even if a trajectory is put together as a simple concatenation of frame-to-frame increments, it comes out reliable and precise.

14:50-16:00 TuE1.22
Fusing Vision and LIDAR -- Synchronization, Correction and Occlusion Reasoning, pp. 388-393
Schneider, Sebastian Univ. of the Bundeswehr Munich Himmelsbach, Michael Univ. of the Bundeswehr, Munich Luettel, Thorsten Univ. of the Bundeswehr Munich Wünsche, Hans Joachim Univ.
Autonomous navigation in unstructured environments like forest or country roads with dynamic objects remains a challenging task, particularly with respect to the perception of the environment using multiple different sensors. The problem has been addressed from both, the computer vision community as well as from researchers working with laser range finding technology, like the Velodyne HDL-64. Since cameras and LIDAR sensors complement one another in terms of color and depth perception, the fusion of both sensors is reasonable in order to provide color images with depth and reflectance information as well as 3D LIDAR point clouds with color information.

In this paper we propose a method for sensor synchronization, especially designed for dynamic scenes, a low-level fusion of the data of both sensors and we provide a solution for the occlusion problem that arises in conjunction with different viewpoints of the fused sensors.

14:50-16:00 TuE1.23
Robust Road Marking Extraction in Urban Environments Using Stereo Images, pp. 394-400
Sebsadj, Yazid CETe de l'EST Tarek, Jean-Philippe Univ. Paris-Est, INRET-LSPC Foucher, Philippe CETe de l'Est Charbonnier, Pierre LRPC
Most road marking detection systems use image processing to extract potential marking elements in their first stage. Hence, the performances of extraction algorithms clearly impact the result of the whole process. In this paper, we address the problem of extracting road markings in high resolution environment images taken by inspection vehicles in an urban context. This situation is challenging since large special markings, such as crosswalks, zebras or pictographs must be detected as well as lane markings. Moreover, urban images feature many white elements that might lure the extraction process. In prior work an efficient extraction process, called Median Local Threshold algorithm, was proposed that can handle all kinds of road markings. This extraction algorithm is here improved and compared to other extraction algorithms. An experimental study performed on a database of images with ground-truth shows that the stereovision strategy reduces the number of false alarms without significant loss of true detection.

14:50-16:00 TuE1.24
Detecting Unusual Pedestrian Behavior Toward Own Vehicle for Vehicle-To-Pedestrian Collision Avoidance, pp. 401-405
Nakatsuho, Kota Meijo Univ. Yamada, Keiichi Meijo Univ.
Pedestrian protection is an important issue for intelligent vehicles. This paper proposes a new approach for predicting the possibility of a collision between a vehicle and a pedestrian. Almost all pedestrian behavior toward vehicles observed in the real world is considered safe. Therefore, pedestrian behavior that deviates from usual pedestrian behavior indicates a possibility where the vehicle must take urgent evasive action to avoid collision with the pedestrian. From such a viewpoint, this paper proposes a method for predicting whether the pedestrian behavior deviates from usual pedestrian behavior. Usual pedestrian behavior as observed from the vehicle is modeled with machine learning to detect whether a new observed behavior deviates from the model of the usual pedestrian behavior. The effectiveness of the proposed method is demonstrated with an experiment conducted in a simple road environment.

14:50-16:00 TuE1.25
Global Positioning Using a Digital Map and an Imaging Radar Sensor, pp. 406-411
Szczołt, Magdalena Daimler AG Serfling, Matthias Daimler AG Löhlein, Otto Daimler AG Schüle, Florian Daimler AG
This contribution presents a lane estimation system for night applications which covers distances up to 140 m in rural environment. The high detection range is essential for upcoming warning systems to decide whether a detected object is on the road and thus of immediate importance for the driving task. In order to realize a robust lane detection system we present a fusion system that combines the information provided by an imaging radar system and a digital map. The digital map is used to calculate the shape of the road. Past measurements of the radar sensor are integrated over time into a local map using an egomotion estimator. A particle filter realizes the matching of the digital and local map resulting in an accurate position of the vehicle on the digital map. This positioning algorithm enables an estimation of the position of the lane in front of the vehicle at high distances.

14:50-16:00  TuE1.26
**Road Course Estimation in Occupancy Grids**, pp. 412-417
Konrad, Marcus Univ. of Ulm
Szczoł, Magdalena Daimler AG
Dietmayer, Klaus Christian Jürgen Univ. of Ulm
This paper presents a novel approach for road course estimation on rural roads using a multilayer laser scanner. The measurements of the sensor are used to build an occupancy grid as a representation of a local map. This mapping step uses a new free space function and a novel method for detecting and eliminating moving objects. Based on this map a feature extraction algorithm yields road border feature points. A Levenberg-Marquardt based optimization fits a flexible two-part road course model to these feature points.

14:50-16:00  TuE1.27
**On-Road Vehicle Detection During Dusk and at Night**, pp. 418-423
Schamm, Thomas FZI Forschungszentrum Informatik von Carlowitz, Christoph FZI Forschungszentrum Informatik
Zöllner, J. Marius FZI Forschungszentrum Informatik
The video-based on-road detection of vehicles at daytime allows driver assistance systems to avoid collisions and thereby improve safety, and realize comfort functions, like the well known adaptive cruise control. However, at nighttime, common video sensor based vehicle detection algorithms can’t be used, because most state-of-the-art features, like shadows, symmetry and others, cannot be measured. The on-road detection of vehicles at night is an obligatory feature for modern driver assistance systems, because those systems have to provide assistance functionality at day-time and at night-time, either. In this work, vehicles in front of the own car are recognized by detection of their front or rear lights, using a perspective blob filter and subsequently searching for corresponding light pairs. For preceding vehicles, the activity of the third break light is estimated, to distinguish the maneuver state of the vehicle. Experiments show the robustness of the approach during dusk and at night sequences.

14:50-16:00  TuE1.28
Kim, Kyungnam HRL Lab. LLC
Owechko, Yuri HRL Lab. LLC
Medasani, Swarup HRL Lab. LLC
The Contextual Visual Dataspaces (CVD) is a real-time representation of an automotive environment that combines automated 3D modeling and semantic labeling of a scene with dynamic object detection using infrastructure cameras. Our automotive active safety concept uses CVD to detect and track dynamic objects of interest, geo-register them into the semantically labeled 3D world space, analyze the paths of vehicles and pedestrians, infer intent and therefore make more accurate predictions of potential collisions, and finally give alerts to drivers and pedestrians and provide them with real-time situational awareness. The CVD system was demonstrated in a blind curve collision warning scenario.

14:50-16:00  TuE1.29
**The Recognition and Tracking of Traffic Lights Based on Color Segmentation and CAMSHIFT for Intelligent Vehicles**, pp. 431-435
Gong, Jianwei Beijing Inst. of Tech.
Jiang, Yanhua Beijing Inst. of Tech.
Xiong, Guangming Beijing Inst. of Tech.
Tao, Gang Beijing Inst. of Tech.
Chen, Huiyan Beijing Inst. of Tech.
The recognition and tracking of traffic lights for intelligent vehicles based on a vehicle-mounted camera are studied in this paper. The candidate region of the traffic light is extracted using the threshold segmentation method and the morphological operation. Then, the recognition algorithm of the traffic light based on machine learning is employed. To avoid false negatives and tracking loss, the target tracking algorithm CAMSHIFT (Continuously Adaptive Mean Shift), which uses the color histogram as the target model, is adopted. In addition to traffic signal pre-processing and the recognition method of learning, the initialization problem of the search window of CAMSHIFT algorithm is resolved. Moreover, the window setting method is used to shorten the processing time of the global HSV color space conversion. The real vehicle experiments validate the performance of the presented approach.

14:50-16:00  TuE1.30
**Online Visualization of Noisy 3D Point Clouds: From Monocular Image Sequences to Synthetic Views**, pp. 436-442
Pagel, Frank Fraunhofer IOSB
Ring, Jochen Fraunhofer Inst. of OStI
This paper addresses the generation and visualization of noisy 3D point clouds. The goal is to extract 3D information from image sequences in real-time and to transform the resulting noisy point clouds into a representation with dense surfaces and an intuitive character. Therefore a bridge is built from image sequence analysis to computer graphics. A point cloud is calculated from a single camera.
by using state of the art algorithms for egomotion estimation and dense 3D reconstruction. Due to inaccuracies in the measurement process and hence of the resulting depth maps, a degree of uncertainty of the 3D data is defined. This additional information can be used to filter the point cloud in space and time. We present an approach to filter and polygonize weighted point clouds and visualize it by mapping image texture on the resulting surface.

14:50-16:00 TuE1.31
Calibration Considerations for Hybrid VANET Simulation, pp. 443-448
Haran, James  Univ. of Illinois at Chicago
Nelson, Peter C.  Univ. of Illinois at Chicago
The simulation of intervehicle communication (IVC) in a Vehicular Ad-Hoc Network (VANET) requires the modeling of traffic movement patterns and the simulation of wireless communication between the vehicles which act as mobile nodes within the wireless network. This paper discusses the calibration and fitness of the JIST/SWANS network simulator for use in hybrid VANET simulation using readily available wireless hardware. The associated research creates a hybrid simulation platform coupling the microscopic transportation modeling of flow and vehicle movement with a wireless simulator to offer analysis on wireless interaction in a vehicular network. Although the ultimate goal of this research is to model the behavior of a handheld Intelligent Traveler Assistant (ITA) device, this paper concerns the validation of the ad-hoc wireless portion of the SWANS simulator.

14:50-16:00 TuE1.32
Vehicle Steering Maneuvers with Direct Trajectory Optimization, pp. 449-453
Soudbakhsh, Damoon  The George Washington Univ.
Eskandarian, Azim  The George Washington Univ.
Chichka, David  The George Washington Univ.
Steering control systems have been used to develop vehicle automated lane change maneuvers or evasive maneuvers for collision avoidance. Most of these systems have used predetermined desired trajectories to perform the required maneuvers. In this study, an optimal trajectory is found while ensuring minimization of lateral acceleration throughout the maneuver. Collocation technique was used to numerically solve the nonlinear programming problem. The results show a near optimal trajectory can be achieved. The generated trajectory is compared to that of a fifth-order polynomial. The resultant trajectory was substantially better than the polynomial one, with both a lower peak and the overall lateral accelerations.

16:00-16:20 TuF1.1
Vision-Based Bicyclist Detection and Tracking for Intelligent Vehicles, pp. 454-461
Cho, Hyunggi  Carnegie Mellon Univ.
Rybski, Paul  Carnegie Mellon Univ.
Zhang, Wende  GM R&D
This paper presents a vision-based framework for intelligent vehicles to detect and track people riding bicycles in urban traffic environments. To deal with dramatic appearance changes of a bicycle according to different viewpoints as well as nonrigid nature of human appearance, a method is proposed which employs complementary detection and tracking algorithms. In the detection phase, we use multiple view-based detectors: frontal, rear, and right/left side view. For each view detector, a linear Support Vector Machine (SVM) is used for object classification in combination with Histograms of Oriented Gradients (HOG) which is one of the most discriminative features. Furthermore, a real-time enhancement for the detection process is implemented using the Integral Histogram method and a coarse-to-fine cascade approach. Tracking phase is performed by a multiple patch-based Lucas-Kanade tracker. We first run the Harris corner detector over the bounding box which is the result of our detector. Each of the corner points can be a good feature to track and, in consequence, becomes a template of each instance of multiple Lucas-Kanade trackers. To manage the set of patches efficiently, a novel method based on spectral clustering algorithm is proposed. Quantitative experiments have been conducted to show the effectiveness of each component of the proposed framework.

16:20-16:40 TuF1.2
High-Accurate Vehicle Localization Using Digital Maps and Coherency Images, pp. 462-469
Mattern, Norman  Chemnitz Univ. of Tech.
Schubert, Robin  Chemnitz Univ. of Tech.
Wanielik, Gerd  Chemnitz Univ. of Tech.
Accurate, reliable, and cheap vehicle localization is one important task in current automotive research activities. It enables technologies like cooperative systems or enhanced map based assistance systems. There are a wide variety of approaches to reach this higher accuracy. The algorithm presented in this paper utilizes image landmarks in combination with a low-cost Global Navigation Satellite System (GNSS) receiver and vehicle odometry to achieve this. While similar approaches often extract features from camera images and match those features with map information, the algorithm presented in this work directly transforms map feature data, creating a image of map features, like the camera would see it. The evaluation of this image prediction uses the coherency value, which is derived from the structure tensor. By predicting the whole image the incorporation of the map information is moved from feature level to signal level. The likelihood
models used for the evaluation of the coherency image are
derive from real, manually labeled data. We present very
promising results of a test drive in an area with complex in-
tersection. Those results are compared to Ground truth data.

16:40-17:00  TuF1.3
Pedestrian Tracking in Infrared from Moving Vehicles,
pp. 470-477
Jüngling, Kai  Fraunhofer IOSB
Arens, Michael  Fraunhofer IOSB
The automatic detection and tracking of pedestrians in im-
agery constitute important and challenging problems both
in computer vision and driver assistance systems. We
address these problems for the case of a forward look-
ing monocular infrared camera under strong vehicle in-
duced camera motion. An integrated detection & tracking
strategy is introduced based on a state-of-the-art feature
based object detector originally developed for images in
the visual spectrum. The proposed pedestrian detection al-
gorithm can be applied to both infrared and visual imag-
ery. We show the difficulties arising from the specifics of
infrared data under strong camera motion and how to
tackle these problems by replacing common motion mod-
els like the Kalman filter by a feature matching approach.

17:00-17:20  TuF1.4
Improved Visibility of Road Scene Images under Hetero-
geneous Fog, pp. 478-485
Tarel, Jean-Philippe  Univ. Paris-Est, INRETS-LCPC
Hautiere, Nicolas  Univ. Paris-Est, INRETS-LCPC
Cord, Aurelien  Univ. LIVIC, INRETS-LCPC
Gruyer, Dominique  INRETS/LCPC
Halmaoui, Houssam  Univ. LIVIC, INRETS-LCPC

One source of accidents when driving a vehicle is the pres-
ence of homogeneous and heterogeneous fog.
Fog fades the colors and reduces the contrast of the ob-
served objects with respect to their distances.
Various camera-based Advanced Driver Assistance Systems
(ADAS) can be improved if efficient algorithms are designed
for visibility enhancement of road images. The visibility en-
hancement algorithm proposed in [1] is not dedicated to
road images and thus it leads to limited quality results on
images of this kind. In this paper, we interpret the algorithm
in [1] as the inference of the local atmospheric veil subject
to two constraints. From this interpretation, we propose an
extended algorithm which better handles road images by
taking into account that a large part of the image can be as-
sumed to be a planar road. The advantages of the proposed
local algorithm are its speed, the possibility to handle both
color images or gray-level images, and its small number of
parameters. A comparative study and quantitative evalu-
ation with other state-of-the-art algorithms is proposed on
synthetic images with several types of generated fog. This
evaluation demonstrates that the new algorithm produces
similar quality results with homogeneous fog and that it is
able to better deal with the presence of heterogeneous fog.

17:20-17:40  TuF1.5
Visual Odometry Based on Stereo Image Sequences
with RANSAC-Based Outlier Rejection Scheme, pp.
486-492
Kitt, Bernd  KIT
Geiger, Andreas  KIT
Lategahn, Henning  Karlsruhe Inst. of Tech. Inst. of
Measurement and
A common prerequisite for many vision-based driver as-
sistance systems is the knowledge of the vehicle’s own
movement. In this paper we propose a novel approach for
estimating the egomotion of the vehicle from a sequence of
stereo images. Our method is directly based on the tri-
focal geometry between image triples, thus no time ex-
pensive recovery of the 3-dimensional scene structure is
needed. The only assumption we make is a known camera
geometry, where the calibration may also vary over time.
We employ an Iterated Sigma Point Kalman Filter in com-
bination with a RANSAC-based outlier rejection scheme
which yields robust frame-to-frame motion estimation even
in dynamic environments. A high-accuracy inertial mea-
surement unit is used to evaluate our results on challeng-
ing real-world video sequences. Experiments show that
our approach is clearly superior compared to other filter-
ing techniques in terms of both, accuracy and run-time.

17:40-18:00  TuF1.6
Motion Based Vehicle Identification in Car Video, pp.
493-499
Jazayeri, Amirali  IUPUI
Cai, Hongyuan  IUPUI
Zheng, Jiang Yu  IUPUI
Tuceryan, Mihran  IUPUI

This work aims at detecting and tracking vehicles in in-
car video. Rather than enhancing shape analysis of vari-
ous vehicle types and road situations, this work focuses
on vehicle and background motions because they are
more general than shapes and colors of cars in various
road environments. Basic features are tracked stably using
corners, intensity peaks, and horizontal line segments. We
use the HMM in the temporal domain to separate back-
ground and moving vehicles in the video. To realize this,
we model the image motion of vehicles and background
probabilistically according to the scene characteristic and
vehicle driving mechanism, as well as the joint distribu-
tion of horizontal position and velocity of scenes. The identifi-
cation and tracking are robust to various illumination and
environments and the processing is performed in real time.
The identification results based on motion only is good and
a better result can be achieved further by fusing the motion
result with the results from shape analysis.
Sensing Requirements for a 13, 000 Km Intercontinental Autonomous Drive, pp. 500-505
Broggi, Alberto  
Univ. of Parma
Bombini, Luca  
Univ. degli Studi di Parma
Cattani, Stefano  
Univ. of Parma
Ceri, Pietro  
Univ. of Parma
Fedriga, Rean Isabella  
Univ. of Parma

This paper presents the design issues that were considered for the equipment of 4 identical autonomous vehicles that will drive themselves without human intervention on an intercontinental route for more than 13,000 km. Autonomous vehicles have been demonstrated able to reach the end of a 220 miles off-road trail (in the DARPA Grand Challenge), to negotiate traffic and obey traffic rules (in the DARPA Urban Challenge), but no one ever tested their capabilities on a long, intercontinental trip and stressed their systems for 3 months in a row. This paper presents the technological challenge of a set of vehicles that will run the VisLab Intercontinental Autonomous Challenge (VIAC). The challenge is scheduled to take place during the 2010 World Expo in Shanghai, China (and precisely from July 10, 2010 to Oct 10, 2010). Being currently under preparation, this paper focuses on the development, the vehicles’ technical details, and the challenge itself. Other following papers will describe the outcome of the challenge and its results.

Stadtpilot: Driving Autonomously on Braunschweig’s Inner Ring Road, pp. 506-511
Wille, Joern Marten  
Tech. Univ. Braunschweig
Saust, Falko  
Tech. Univ. Braunschweig
Maurer, Markus  
TU Braunschweig

The development of the autonomous vehicle named “CarOline” for the 2007 DARPA Urban Challenge was a great opportunity to demonstrate the abilities of the Technische Universität Braunschweig in the research field of autonomous driving. Among 11 teams out of the initially 89, the CarOLO team mastered the challenges to qualify for the final DARPA Urban Challenge event. Based on this experience, the Technische Universität Braunschweig is currently working on the follow-up project “Stadtpilot” with the objective to drive fully autonomously on Braunschweig’s entire ring road, which is known as the arterial road of its inner city traffic. This paper introduces the “Stadtpilot”-Project in the context of the Urban Challenge experience and identifies the differences to previous activities in this research context. The scientific claim will be shown in contrast to the Urban Challenge scenario. Completely new concepts are required to master the challenges of realizing autonomous driving in the domain of Braunschweig’s inner ring road. An approach for the comprehensive treatment of path-planned sections is shown that realizes complex and precise autonomous driving maneuvers in a real urban environment and is observed as the first major success of the “Stadtpilot”-Project. Curvature optimized trajectories are generated over the whole roadway that are independent from the way driving decisions are found.

Fast Collision Checking for Intelligent Vehicle Motion Planning, pp. 518-522
Ziegler, Julius  
Karlsruhe Inst. of Tech.
Stiller, Christoph  
Karlsruhe Inst. of Tech.

We present a method for fast collision checking that is suitable for application in motion planning for intelligent vehicles. One of the difficulties that arises in this domain is the fact that typical, car-like autonomous vehicles cannot easily be approximated by a rotationally invariant disk shape. Instead, the orientation of the vehicle must be accounted for explicitly. Our proposal is to decompose the vehicle shape into several disk shaped primitives, so that the task of collision checking can be broken down into few very simple collision tests. We also propose a highly optimized method to perform these primitive collision tests that requires a minimum of arithmetic operations.

Research on the Quantitative Evaluation System for Ground Unmanned Vehicles, pp. 523-527
Xiong, Guangming  
Beijing Inst. of Tech.
Zhao, Xijun  
Beijing Inst. of Tech.
Liu, Haiou  
Beijing Inst. of Tech.
Zhang, Haojie  
Beijing Inst. of Tech.
Chen, Huiyan  
Beijing Inst. of Tech.

The first Chinese ground unmanned vehicles competition
Camera arrays are easily exchangeable. Thus, system dynamics attain adequate tracking performance. To widen the applicability of using cameras for visual tasks such as saccades and smooth pursuit movements, we use state-space control to ensure nearly time-optimal control performance is achieved. For smooth pursuit movements, we use sliding-mode control with a switching line, designed such that the control system exploits the parallelism in computation via the NVIDIA CUDA programming model, which is a software platform for solving non-graphics problems in a massively parallel high-performance fashion. This implementation makes use of the work-efficient scan algorithm that is explained in [5]. Treating the rows and the columns of the target image as independent input arrays for the scan algorithm, our method manages to expose a second level of parallelism in the problem. We compare the performance of the parallel approach running on the GPU with the sequential CPU implementation across a range of image sizes and report a speed up by a factor of 8 for a 4 megapixel input. We further investigate the impact of using packed vector type data on the performance, as well as the effect of double precision arithmetic on the GPU.

Active multi-focal vision systems are designed to perform visual tasks such as saccades and smooth pursuit movements. Saccades are fast movements to a given position, which is a time-optimal control problem. Smooth pursuit movement is used to follow moving objects and is a tracking control problem. Therefore, we use a hybrid approach for the control of our vision system. For saccades, we use sliding-mode control with a switching line, designed such that nearly time-optimal control performance is achieved. For smooth pursuit movement, we use state-space control to attain adequate tracking performance. To widen the applicability of our multi-focal vision system, it is designed such that cameras are easily exchangeable. Thus, system dynamics is subject to change, which implies the need for adaptive control. This paper presents the design of the resulting hybrid adaptive controller together with experimental results.

Vehicle-to-vehicle wireless communication is a key component of tomorrow's cooperative safety applications. However, the wireless link is susceptible to effects such as shadowing which can cause communication failures. Such failures may in turn lead to hazardous traffic situations when safety applications cease to function. By monitoring communication QoS and adapting to changes, effects of link failure may be mitigated, however this requires a specification of the application QoS requirements. In this paper, we combine the T-Window reliability QoS metric with a spatial component, allowing us to capture the dependencies between VANET QoS requirements and road geometry. The proposed representation can be used both at design-time, to characterize applications, and at run-time for QoS monitoring and adaptation purposes.
plied in the evaluation of probe car system. The shortcomings of each method is shown through data analysis of field tests. In order to overcome those shortcomings, a method is proposed for evaluating probe car system in this paper.

09:50-11:00 WeB1.7
**Fast Segmentation of 3D Point Clouds for Ground Vehicles**, pp. 560-565
Himmelsbach, Michael Univ. of the Bundeswehr, Munich von Hundelshausen, Felix Univ. of the Bundeswehr Munich Wuensche, Hans Joachim Univ. of the Bundeswehr
This paper describes a fast method for segmentation of large-size long-range 3D point clouds that especially lends itself for later classification of objects. Our approach is targeted at high-speed autonomous ground robot mobility, so real-time performance of the segmentation method plays a critical role. This is especially true as segmentation is considered only a necessary preliminary for the more important task of object classification that is itself computationally very demanding. Efficiency is achieved in our approach by splitting the segmentation problem into two simpler subproblems of lower complexity: local ground plane estimation followed by fast 2D connected components labeling. The method’s performance is evaluated on real data acquired in different outdoor scenes, and the results are compared to those of existing methods. We show that our method requires less runtime while at the same time yielding segmentation results that are better suited for later classification of the identified objects.

09:50-11:00 WeB1.8
**A Sensor Network for Urban Traffic Information Acquisition**, pp. 566-571
Zhang, Hesheng Beijing Jiaotong Univ.
An architecture of sensor network for urban traffic information acquisition is proposed. The hybrid communication modes include CAN, ZigBee and Ethernet, which can satisfy the requirements of wired and wireless, real-time and massive data transmission. The various kinds of nodes and the prototype sensor network were developed and deployed in Beijing. The test results show the architecture, hybrid communication mode, various sensor nodes and the sensor network proposed in the paper are practical and feasible. This kind of sensor network can be used in traffic surveillance to resolve the problems of present information acquisition.

09:50-11:00 WeB1.9
**CO-Simulation Trace Analysis (COSITA) Tool for Vehicle Electronic Architecture Diagnosability Analysis**, pp. 572-578
Khelif, Manel Univ. de Tech. de Compiègne Tahan, Oussama Univ. de Tech. de Compiègne - France Shawky, M. Univ. de Tech. de Compiègne
In this paper we present a CO-Simulation Trace Analysis (COSITA) tool in order to analyze functional/architectural properties, in the automotive field. These properties should enhance a specific design requirement that we call functional/architectural diagnosability. The validation process is applied on a real automotive experimental embedded platform called DIAFORE based on several Electronic Control Units. In the design phase of a System Development Life Cycle, we aim to analyze the functional/architectural diagnosability by analyzing its properties (observability, reachability, etc.), using a co-simulation-based approach. In this paper, our objective is to verify that the analysis made on the real platform is consistent with the theoretical analysis made on the co-simulation results. We believe that simulating a functional model is not sufficient to analyze system properties, because each hardware instantiation has its own properties constraints and limitations. Therefore, a hardware architecture characteristics modification may change the system requirements correctness. Hence, we co-simulate the Hardware (HW) and Software (SW) models, and then we analyze the interaction between them, by analyzing the co-simulation trace. For co-simulation, we use SystemC and Matlab/Simulink tool, with objectively selected simulation scenarios reflecting the system behavior.

09:50-11:00 WeB1.10
**A Secure and Privacy Protecting Protocol for VANET**, pp. 579-584
Before the deployment of any vehicular communication system, security and privacy issues have to be resolved. In this paper, for achieving secure and privacy preserving communications, easily implementable PKI-based protocol is proposed. Security requirements for vehicular communications is defined and detailed definition of the scheme, which uses shared asymmetric keys and PKI techniques to provide anonymous and secure communications, is given. Furthermore, proposed protocol is evaluated against the defined security requirements. Providing privacy and security, proposed scheme does not introduce any complexity and computational overheads.

09:50-11:00 WeB1.11
**Vision-Based Onboard Unit for Inattentive Driving Warning and Car-Following Control**, pp. 585-590
Chang, Tang-Hsien National Taiwan Univ. Wang, Chieh National Taiwan Univ.
In this study, we develop an low-cost Advanced Safety Vehicle (ASV) onboard unit that integrates driving warning and car-following control systems on a vision-based platform for laboratory and real-time experiments. This onboard unit mainly consists of three systems including the lateral departure warning System (LDWS), the forward vehicle collision warning system (FVCWS), and the adaptive car-following control system. This onboard system has been validated in laboratory experiments that we have higher than 95% accuracy among 76 tested scenarios. In addition, the results of total 2000-kilometer real-time field tests indicate the characteristics of high accuracy and low false alarm, and fur-
An effective lane detection algorithm is a basic, yet fundamental component of both autonomous navigation and advanced road safety systems; this paper presents an approach that produces reliable results exploiting a robust polyline matching technique. The proposed solution has been designed from the ground up so that only very limited hardware resources are required: just one camera is used, and the processing is fast enough to be compatible with mainstream DSP units.

Optimal Omnidirectional Sensor for Urban Traffic Diagnosis in Crossroads, pp. 597-602
Ghorayeb, Ali MIS-UPJV
Potelle, Alex CREA
Mouaddib, El Mustapha Univ. of Picardy jules Verne
Devendeville, Laure Univ. de Picardie

In this paper we present an optimal omnidirectional visual sensor which can replace perspective camera network for traffic diagnosis. The proposed system has the advantage, by the number and the designed mirror, to generate a single view of the crown and junction ways of the crossroads by maximizing the number of useless pixels. So, the percentage of pixels utilized directly for subsequent phases of image processing is optimal. We describe the methodology used to design such a sensor. In addition, to assess our sensor, we also developed image processing methods that provide useful indicators for estimating the state of the traffic as the crossroads occupancy rate, the vehicle speed and the flow of vehicles. Finally, we compare this optimal sensor to others that consist of parabolic, hyperbolic or spherical mirror to observe the scene. We prove that optimal sensor has better results than others.

Cambruzzi, Eduardo Federal Inst. of Science and Tech. of Bahia
Farines, Jean-Marie Federal Univ. of Santa Catarina
Macedo, Raimundo Jose Federal Univ. of Bahia
Kraus Jr., Werner Federal Univ. of Santa Catarina

The capacity to detect component failures is an important characteristic for fault-tolerant distributed systems. This article presents a failure detector suitable for Vehicular Ad hoc NETworks (VANETs) environments. The detector is composed of two parts: a detector for the communication link and a detector of process failure. While the link detector verifies the validity of a link between two processes, the process’ failure detector adapts itself to the mobility of the vehicles and variations in the communication load in the network. Simulation results show that the detector presents a low number of false suspicions and a short detection time.

Determining Time to Traverse Road Sections Based on Mapping Discrete GPS Vehicle Data to Continuous Flows, pp. 615-620
Miller, Jeffrey Univ. of Alaska, Anchorage
Kim, Sun-il Univ. of Alaska, Anchorage
Ali, Muhammad Univ. of Alaska, Anchorage
Menard, Timothy Univ. of Alaska, Anchorage

In this paper, we present and analyze an algorithm for mapping discrete GPS data gathered from vehicles to a continuous flow of data to determine the time to traverse a road section. Vehicle-tracking devices are installed in 80 probe vehicles in the Anchorage area, and a specific roadway section was chosen as a test section. Drivers for this study drove from before the start of the test roadway section past the end of the test roadway section, measuring the time to travel from the start to the finish of the test roadway section. The vehicle-tracking devices report speed and location every 10 seconds. From this data, we calculated the amount of time to traverse the test roadway section using our proportional model and compared it to the actual amount of time it took to traverse the test roadway section. We performed the analysis assuming the vehicle-tracking devices were reporting location every 10 seconds, 20 seconds, 30 seconds, 40 seconds, 50 seconds, and 60 seconds. With an average actual time to traverse the test roadway section of 2 minutes 28 seconds, the error rate based on the proportional model was between 1.8% - 9.2% (2.7-13.1 seconds), based on how frequently the vehicle was reporting its location. Merely taking the average speed on the edge from the vehicle reporting its speed and location during those same durations had an error rate between 14.2%-25.8% (24.7-41.1 seconds). Our results show that the proportional model has a small error rate (1.8% with 10 second reporting time) and can accurately demonstrate the robustness of the proposed system.
represent the time to traverse roadway sections based on discrete readings from a small number of probe vehicles.

09:50-11:00  WeB1.17
**Geographic Information for Vision–Based Road Detection**, pp. 621-626
Alvarez, José M.  Univ. Autonoma de Barcelona
Lumbreras, Felipe  Univ. Autonoma de Barcelona
Gevers, Theo  Intelligent Systems Lab. Amsterdam, Faculty of Science, Univ.
López, Antonio M.  Univ. Autonoma de Barcelona

Road detection is a vital task for the development of autonomous vehicles. The knowledge of the free road surface ahead of the target vehicle can be used for autonomous driving, road departure warning, as well as to support advanced driver assistance systems like vehicle or pedestrian detection. Using vision to detect the road has several advantages in front of other sensors: richness of features, easy integration, low cost or low power consumption. Common vision-based road detection approaches use low-level features (such as color or texture) as visual cues to group pixels exhibiting similar properties. However, it is difficult to foresee a perfect clustering algorithm since roads are in outdoor scenarios being imaged from a mobile platform. In this paper, we propose a novel high-level approach to vision-based road detection based on geographical information. The key idea of the algorithm is exploiting geographical information to provide a rough detection of the road. Then, this segmentation is refined at low-level using color information to provide the final result.

The results presented show the validity of our approach.

09:50-11:00  WeB1.18
**Scalable and Location-Aware ITS Content Management in Vehicular Environments**, pp. 627-633
Elshenawy, Mohamed  Univ. of Regina
EL-Darieby, Mohamed  Univ. of Regina
Abdulhai, Baher  Baher Univ. of Toronto

ITS solutions require distributing content to vehicles traveling on streets and highways. This is becoming a more natural evolution in response to the pervasiveness of wireless devices in vehicles and urban areas. We propose a scalable ITS content delivery architecture. The architecture adopts a hierarchical architecture of content delivery servers. The architecture utilizes the concepts and mechanisms of service-orientation to address the stringent requirements of vehicular requirements. The architecture also efficiently organizes services based on their location relevancy. We define algorithms and message structure used within the architecture to manage content services and efficiently deliver them to vehicles. Those algorithms include content service addition, updating, deletion, discovery, consumption and maintenance across different infrastructure nodes. We evaluate the benefits of the proposed scheme using OMNET++ simulator. Our results show that the architecture efficiently delivers content to vehicle traveling at moderate speeds as well as separated by average separation distances.

Outside of these ranges, and due to extensive workloads of service delivery requests or requests to maintain delivery session, the communications overhead of the architecture increases decreasing the efficiency of the architecture.

09:50-11:00  WeB1.19
**Evaluating Sensor Effects on Perception Performance**, pp. 634-639
Franz, Stefan  Daimler AG
Willersinn, Dieter  Fraunhofer IOSB
Kroschel, Kristian  Fraunhofer IOSB

The performance of perceptive systems depends on the quality of the input data. In this contribution an approach to evaluate perception performance, as a function of quality of the sensor data is presented. Standardized quality metrics support the imaging sensors performance measurement. Several imaging setups are analyzed with real world experiments. The output of each setup is processed offline to track down performance differences with respect to the quality of sensor data. An adapted measurement is computed to measure the sensor performance with respect to the data quality for the involved perceptive components.

The measured performance is assessed by processing the data of different, simultaneously recorded imaging setups for the task of feature extraction of road lanes.

09:50-11:00  WeB1.20
**Cruise Control with Adaptation and Wheel Torque Constraints for Improved Fuel Economy**, pp. 640-645
Kahveci, Nazli E.  Ford Motor Company
Ioannou, Petros  Univ. of Southern California

Cruise controllers are used to automatically control the speed of motor vehicles. In order to maintain a desired vehicle speed the controller takes over the throttle in a cruise control system which proves particularly useful for long drives. Adaptive Cruise Control (ACC) systems have additional capabilities such as automatic braking or dynamic set-speed type controls and hence can accommodate changes in cruise speed required to adapt to changing road conditions. We propose that further improvements in fuel economy can be achieved by considering the vehicle’s longitudinal dynamics as an input-constrained system and the wheel torque as the corresponding constrained input. We effectively address the resulting input saturation nonlinearity by employing our adaptive anti-windup compensator design. Simulation results are used to compare the performance of the original cruise control system allowing for the full-range of wheel torque and the ACC system where the wheel torque is forced to remain within the user-defined limits for improved fuel economy.

09:50-11:00  WeB1.21
**Vision-Based Online-Calibration of Inertial Gaze Stabilization**, pp. 646-651
Unterholzner, Alois  Univ. of the Bundeswehr Munich
Rohland, Michael  Univ. of the Bundeswehr Munich
Schweitzer, Michael  Univ. of Federal Armed Forces
Wuenschke, Hans Joachim  Univ.

Active gaze stabilization is of vital importance for the use
of high resolution tele-cameras in autonomous vehicles. Small aperture angles together with large focal lengths cause high sensitivity to rotational vehicle motion induced e.g. by bumps or braking. Due to large latencies in image processing only gaze stabilization based on inertial sensors is fast enough to ensure stable images. As this is a feed-forward control, imperfections of the sensor or the stabilizing actuator may result in undesirable image motion. To further enhance image stabilization we developed a novel vision-based online-calibration of the inertial angular rate sensor of our camera platform. Thus we are able to incorporate visual feedback into the gaze stabilization, while keeping the high bandwidth of the inertial sensor.

In this paper we will use a commercial motion sensor that has been originally designed for application in an optical computer mouse. We will show that, by well-considered dimensioning of the optical part of the system, this sensor can measure velocities in a range that is typical for automotive application. The result is a highly integrated, low-cost, angle sensitive motion sensor that does not exhibit slip effects. We evaluate this sensor through testing on a vehicle that is equipped with reference sensors, with special consideration on the advantages of this measurement principle over conventional wheel speed sensors.

09:50-11:00 Web1.22

Joint Optimization of Control Network Design in Time and Space Domains, pp. 652-657
Kim, Seongwoo Seoul National Univ.
Choi, Mideum Seoul National Univ.
Seo, Seungwoo Seoul National Univ.
Control networks are widely deployed on mass produced mobile systems such as automotive systems, airplanes, and mobile robots. Previous works on control networks have focused on guaranteeing controllability, predictability, and dependability in the time domain because control networks manipulate actuators directly, and hence are highly related to safety. However, in contrast to data networks, control networks severely affect the manufacturing cost, fuel efficiency, and space effectiveness of mobile systems due to additional network devices, control unit (CU) arrangements, and task assignments. These problems have become more important as CUs have been extensively deployed in real systems in the pursuit of intelligence and energy efficiency. Therefore, system design using control networks must be considered with respect to the time and space domains simultaneously. We propose a design method to minimize space resources due to control networks in the target system while satisfying time constraints. We formulate this problem as a matching problem and provide an effective solution. Through extensive simulations, we demonstrate that our methodology is very effective and scalable, and saves significant time, space, and cost in control networks.

09:50-11:00 Web1.23

Low-Cost Sensors for Image Based Measurement of 2D Velocity and Yaw Rate, pp. 658-662
Joos, Malte Karlsruhe Inst. of Tech.
Ziegler, Julius Univ. of Karlsruhe
Stiller, Christoph Karlsruhe Inst. of Tech.
Numerous applications require precise determination of the motion of a textured surface. Image based sensors are attractive for this purpose, since they are contactless and do not suffer from slip effects. Moreover, they do not only measure scalar speed, but can determine velocity as a 2d vectorial quantity, and, if two sensors are combined, can even observe yaw rate of the surface. If this kind of sensor is mounted inversely on a vehicle, it can determine its motion by measuring the relative displacement of the road surface.

09:50-11:00 Web1.24

A SOA-Based Middleware Concept for In-Vehicle Service Discovery and Device Integration, pp. 663-669
Eichhorn, Michael Tech. Univ. Munchen
Pfannenstein, Martin Tech. Univ. Muenchen
We present a novel middleware approach for in-vehicle service discovery and device integration that is based on the concept of Service-oriented Architectures (SOA). In order to be able to identify a suitable SOA system, we define a series of criteria the SOA platform should fulfill. These criteria take into account the specific requirements of the automotive domain. Based on these criteria we compare nine different SOA standards and show why the Device Profile for Web Services standard is most suitable as the middleware of an in-car infotainment and communication system.

09:50-11:00 Web1.25

Simulation and Calibration of Infrastructure Based Laser Scanner Networks at Intersections, pp. 670-675
Meissner, Daniel Alexander Univ. of Ulm
Dietmayer, Klaus Christian Jürgen Univ. of Ulm
Dietmayer, Klaus Christian Jürgen Univ. of Ulm
Accident analysis shows that intersections are a focal point for accidents in urban areas. Due to that, traffic monitoring at intersections has attached much attention. A major part of the Ko-PER project, which is part of the research initiative Ko-FAS, promoted by the Federal Ministry of Economics and Technology of Germany, is the infrastructure based perception of all dynamic objects inside an intersection. In this project, a novel system of detecting and tracking objects inside intersections using multiple 4-layer laser scanners is proposed. To reduce occlusions and maximize the observed area the sensors are mounted high over ground-level to achieve a bird’s eye view of the scene. One difference between laser scanners and video cameras is the difficulty to identify the area of the street, which can be observed by laser sensors, especially when the monitored area is plain like roads. Therefore, a realistic 3D simulation of the urban intersection and the laser range scanners was implemented. Based on this simulation, a method to calibrate the sensors was developed. The technique is easy to use and due to the 3D model of the intersection we were able to verify the proposed calibration tool.

09:50-11:00 Web1.26

Improved Vision-Based Lane Tracker Performance Using Vehicle Localization, pp. 676-681
In this paper, we present improved lane tracking using vehicle localization. Lane markers are detected using a bank of steerable filters, and lanes are tracked using Kalman filtering. On-road vehicle detection has been achieved using an active learning approach, and vehicles are tracked using a Condensation particle filter. While most state-of-the-art lane tracking systems are not capable of performing in high-density traffic scenes, the proposed framework exploits robust vehicle tracking to allow for improved lane tracking in high density traffic. Experimental results demonstrate that lane tracking performance, robustness, and temporal response are significantly improved in the proposed framework, while also tracking vehicles, with minimal additional hardware requirements.

**Role of Directional Wireless Communication in Vehicular Networks**, pp. 688-693

Agarwal, Ashish Boston Univ.

Enabling safety in vehicles is an ongoing challenge for the automotive sector. One approach towards enhancing safety is to increase knowledge within a vehicle of the actions of vehicles in the vicinity. Increased awareness is essential for activating the safety systems to take evasive or precautionary actions in the event of an incident. Wireless radio communication has emerged as a key enabler for exchanging safety information. Several initiatives across the world have considered various radio communication technologies to implement safety communication. However, there are significant constraints to utilizing wireless radio communication. In this article, we discuss briefly the challenges in enabling safety communication with wireless radio in the context of vehicular networks. We introduce the on-going work in utilizing free space optical communications as an enabler for inter-vehicle safety communication. As a first step, we compare with the current 802.11 standard implementation for achievable performance. Given that the two technologies are inherently different, directional versus omni-directional, we seek to identify the scenarios where each technology is best suited. Particularly, we compare packet delivery ratio (PDR), throughput and average packet delay of the two enabling technologies, under assumptions, in the context of increasing vehicle traffic density. Our results demonstrate that a directional technology such as free-space optics is less susceptible to contention scenarios. As a result, the performance in high density scenarios is better than that can be achieved from using omni-directional long-range technologies such as 802.11.
broadcast transmissions of inter vehicular communication. We present adaptive back off strategy which is based on
the concept that there exists an optimum contention window (CW) period in a broadcast CSMA/CA system, given the fixed
number of users. We also propose a simple probabilistic approach for retransmission which is based on analyzing the
local information. Simulation results shows the improvement in the throughput using adaptive back-off and probabilistic re-
transmission strategies compared to fixed back-off strategy.

09:50-11:00 WeB1.31
Multiple Pedestrian Tracking Using Viterbi Data
Association, pp. 706-711
Azim, Asma Lab. d'Informatique de Grenoble
Aycard, Olivier UJF-INRIA
To address perception problems we must be able to track
dynamic objects of the environment. An important issue of
tracking is the association problem in which we have to as-
sociate each new observation with one existing object in the
environment. This problem is complex: unfortunately, the
number of observations generally does not correspond to
the number of objects. Moreover, the number of objects is
difficult to estimate since one object might be temporarily oc-
cluded or unobserved simply because objects can enter or
go out of ranges of vehicle sensors. Moreover, the percep-
tion sensors or the object detection process might generate
false alarm measurements. In this paper, we propose a new
solution to solve the multiple objects tracking problem, us-
ing the Viterbi algorithm (VA). It is an established optimisa-
tion technique for discrete Markovian systems that has been
extensively used in speech recognition. In this paper, we
present an extension of VA to solve multiple objects tracking
in clutter environment and show some experimental results
on multiple pedestrian tracking and also some quantitative
comparisons with MHT algorithm.

WeC1 Room T1
Driver Assistance Systems 2 (Regular Session)
Chair: Nedevschi, Sergiu Tech. Univ. of Cluj-Napoca

11:00-11:20 WeC1.1
Design of a New GIS for ADAS Oriented Applications, pp. 712-716
Ammoun, Samer INRIA
Nashashibi, Fawzi Mines Paris - ParisTech
Bargeton, Alexandre Ec. des Mines de Paris (ParisTech)
In this paper, we will present the design and the implementa-
tion of a new generation of maps specially designed for the
ADAS-like applications. We will focus on the design of the
map, the data structure and the choice of road attributes.
We will present also the design of a software that enables
our intelligent vehicle to perform as a mapping system for
advanced attributes acquisition.

11:20-11:40 WeC1.2
Assessment of Adequate Overtaking Margin (AOM) for
an Overtaking Assistance System, pp. 717-722
Hohm, Andree Tech. Univ. Darmstadt
Winner, Hermann Tech. Univ. Darmstadt
On two-lane rural roads, a large number of overtaking
accidents happen. In most cases fatalities or serious
casualties are the consequence. Often, inaccurate as-
essment of the traffic situation is identified as the major
cause. Hence, the development of a driver assistance
concept for these scenarios promises a high safety ben-
efit. This paper shows the results of tests conducted on
a test track determining the major parameters for gain-
ing maximum driver-acceptance of such a system.

11:40-12:00 WeC1.3
Stereo Assist: Top-Down Stereo for Driver Assistance
Systems, pp. 723-730
Stein, Gideon MobiiEye Vision Tech. Ltd.
Shashua, Amnon Hebrew Univ. Jerusalem
Gdalyahu, Yoram Mobileye Vision Tech. Ltd.
In this paper we propose a top-down approach to stereo
for use in driver assistance systems. This is an asymmetric
configuration where monocular object detection and range
estimation is performed in the primary camera and then
that image patch is aligned and matched in the secondary
camera. The stereo distance measure from the matching,
assists in target verification and improved distance
measurements. This approach, Stereo-Assist, shows sig-
nificant advantages over the classical bottom-up approach
of first computing a dense depth map and then using the
depth map for object detection. The new approach can pro-
vide increased object detection range, reduced computa-
tional load, greater flexibility in camera configurations (we
are no longer limited to side-by-side stereo configurations),
greater robustness to obstructions in part of the image and
mixed camera modalities FIVIS can be used. We show
results with two novel configurations and show how mon-
ocular object detection allows for simple online calibration
of the stereo rig.
The IMM filter integrates the estimates from a kinematic vehicle model and a dynamic vehicle model. While the kinematic vehicle model is suitable for low-speed and low-slip driving conditions, the dynamic vehicle model is more appropriate for high-speed and high-slip situations. In urban environment, we need accurate and precise estimation of vehicle state for real time navigation and control. This paper presents an architecture to fuse different data from onboard sensors to estimate the vehicle state when observations are noisy. We are trying to compensate the GPS errors by data fusion from different sensors in a probabilistic way. A particle filter with joint observation model has been proposed to real timely estimate the vehicle state. An adaptive joint observation model has been developed to fuse different observations according to accuracy and reliability of the corresponding sensor. Finally a navigation architecture has been proposed for fully autonomous driving with dynamic obstacles. Experiments with real vehicle show the proposed method is able to estimate the vehicle state precisely when the individual observations fail to be enough accurate.

A unified Bayesian approach for tracking and situation assessment is proposed. The method is illustrated on the example of a system which automatically determines lane change maneuver recommendations. The presented results using both simulated and real data show that the proposed approach is capable of providing a unified approach of handling uncertainties for ADAS applications.

A unified Bayesian approach for tracking and situation assessment is proposed. The method is illustrated on the example of a system which automatically determines lane change maneuver recommendations. The presented results using both simulated and real data show that the proposed approach is capable of providing a unified approach of handling uncertainties for ADAS applications.

A confidence measure for vehicle tracking based on a generalization of Bayes estimation is proposed. We review and assess existing approaches of obtaining such confidence measures and conclude that the proposed approach is reliable and practical.
measures. We propose a new method of computing a probability of existence by relaxing the underlying assumption of a Bayes estimator. The benefits of this approach compared to a standard Bayes estimator are demonstrated and illustrated by experimental results.

**WeE1 Room T1**  
**Poster Session 4 (Poster Session)**  
Chair: Blosseville, Jean-marc INRETS

16:00-17:10 WeE1.1  
**Context-Aware Pedestrian Detection Using LIDAR**, pp. 773-778  
Oliveira, Luciano Inst. of Systems and Robotics - Univ. of Coimbra  
Nunes, Urbano Inst. for Systems and Robotics

LIDAR-based object detection usually relies on geometric feature extraction, followed by a generative or discriminative classification approach. Instead, we propose to change the way of detecting objects using LIDAR by means of not only a featureless approach, but also inferring context-aware relations of object parts. For the first feature, a coarse-to-fine segmentation based on beta-skeleton random graph is proposed; after segmentation, each segment is labeled, and scored by a Procrustes analysis. For the second feature, after defining the sub-segments of each object, a contextual analysis is in charge of assessing levels of intra-object or inter-object relationship, ultimately integrated into a Markov logic network. This way, we contribute with a system which deals with partial segmentation, also embodying contextual information. The system proof-of-concept is in pedestrian detection, but the rationale of the approach can be applied to any other object after the definition of its physical structure. The effectiveness of the proposed method was assessed over a data set gathered in challenging scenarios, with a significant gain in accuracy over a full segmentation version of the system.

16:00-17:10 WeE1.2  
**Minimisation of Alignment Error between a Camera and a Laser Range Finder Using Nelder-Mead Simplex Direct Search**, pp. 779-786  
Osgood, Thomas James Univ. of Warwick  
Huang, Yingping Warwick Univ.  
Young, Ken Univ. of Warwick

Presented in this paper is a novel method to calibrate the coordinate systems used by two separate sensor devices for the purposes of sensor fusion. In this example the sensors are a camera and a LIDAR device which are observing the same scene from different viewpoints. Using a synthetic set of corresponding 2D image co-ordinates and 3D LIDAR measurements as reference data the task of aligning re-projected estimations with reference measurements was posed as an optimisation problem. The objective of the optimisation is to find a set of calibration parameters (external offsets and internal camera parameters) which minimise the sum of squared errors between the reference image co-ordinates and the re-projected data. The re-projected data is obtained by transforming the reference LIDAR measurements using the calibration parameters and the errors are defined as the straight-line distance between each reference and re-projected pixel pair. Using the Nelder-Mead simplex search method calibration parameters were found in under a second such that the sum of squared errors across a data set of 200 points was less than 0.19 i.e. average error per pixel of 0.031px. The method finds both internal and external calibration factors and makes no assumptions about the model. Furthermore if a second optimisation pass is made the error can be reduced to almost zero using only 4 reference pairs assuming these points are selected correctly.

16:00-17:10 WeE1.3  
**3D-Segmentation of Traffic Environments with U/V-Disparity Supported by Radar-Given Masterpoints**, pp. 787-792  
Teutsch, Michael Karlsruhe Inst. of Tech. (KIT)  
Dr. Heger, Thomas Robert Bosch GmbH  
Schamm, Thomas FZI Forschungszentrum Informatik  
Zöllner, J. Marius FZI Forschungszentrum Informatik

3D-segmentation of a traffic scene with two-dimensional row- and column-disparity-histograms, namely u/v-disparities, has become more and more popular for modern stereo-camera-based driver assistance systems due to its fast computation in real-time, few memory requirements and robustness against noisy or intermittent data. In this paper, we present a novel approach to support this pure vision-based method by projecting preprocessed radar-signals directly to u-disparity-space. We called the projection result “masterpoints”. This data fusion on low feature-level improved the segmentation process and increased the obstacle detection rate significantly. No assumptions about obstacle-type or -size are needed. Furthermore, the algorithms can be parallelized easily and run in real-time.

16:00-17:10 WeE1.4  
**High-Speed-Camera Image Processing Based LED Traffic Light Detection for Road-To-Vehicle Visible Light Communication**, pp. 793-798  
Premachandra, H.C.N. Nagoya Univ.  
Yendo, Tomohiro Nagoya Univ.  
Panahpour Tehrani, Mehrdad Nagoya Univ.  
Yamazato, Takaya Nagoya Univ.  
Okada, Hiraku Saitama Univ.  
Fujii, Toshiaki Tokyo Inst. of Tech.  
Tanimoto, Masayuki Nagoya Univ.

As one of ITS technique, a new visible light road-to-vehicle communication system at intersections is proposed. In this system, the communication between a vehicle and an LED traffic light is conducted using an LED traffic light as a transmitter, and an on-vehicle high-speed camera as a receiver. The LEDs in the transmitter emit light in high frequency and those emitting LEDs are captured by the high-speed camera for making communication. Here, the luminance value of LEDs in the transmitter should be captured in consecutive frames to achieve effective communication. For this...
purpose, first the transmitter should be found, then it should be tracked in consecutive frames by processing the images from the high-speed camera. In this paper, we propose new effective algorithms for finding and tracking the transmitter, which result in an increased communication speed, compared to the previous methods. Experiments using appropriate images showed the effectiveness of the proposals.

16:00-17:10 WeE1.5
**Pattern Recognition by Cluster Accumulation**, pp. 799-804
Bhatia, Amit NCSU
Snyder, Wesley NCSU
Bilbro, Griff NCSU

When objects in images are small or blurred enough, geometric features are inadequate for reliable pattern recognition. We introduce the Pattern Recognition by Cluster Accumulation (PRCA) method to show that pattern recognition performance can be improved in this situation by using radiometric features for object detection. In addition, PRCA uses clustering to provide feature selection and dimensionality reduction. It uses accumulation to provide robustness against translation, rotation, cluster shape distortion, and inappropriate splitting or merging of clusters. We find that PRCA performs faster than normalized cross correlation and faster than mutual information methods.

16:00-17:10 WeE1.6
**Moving Obstacle Detection Using Cameras for Driver Assistance System**, pp. 805-812
Nishigaki, Morimichi Honda R&D Co., Ltd.
Aloimonos, Yiannis Univ. of Maryland

Moving obstacles have potentially higher risks of collision than stationary obstacles in traffic. Therefore, it is meaningful to detect moving obstacles by sensors equipped on a car for drive assistance applications. We propose two algorithms to detect moving obstacles using camera(s) depending on the relative motion between cameras and obstacles. Since camera(s) moves along with the subjective car, it is challenging to find actually moving obstacles in image sequences. The first algorithm identifies moving obstacle regions in images by checking conflicts between image motion and epipolar constraint when obstacles move in different direction from cameras’ motion. The second algorithm identifies moving obstacle regions in images by finding disparity differences between stereo and motion especially when obstacles move in same direction as cameras’ motion. Experiments show not only qualitative performance of our detection algorithm, but also quantitative accuracy of ego-motion and optical flow estimation in our algorithm.

16:00-17:10 WeE1.7
**Robust Visual Surveillance Based Traffic Information Analysis and Forewarning in Urban Dynamic Scenes**, pp. 813-818
Shao, Jie Tongji Univ.
Jia, Zhen United Tech. Res. Center
Li, Zhi-peng Tongji Univ.

Liu, Fuqiang Tongji Univ.
Zhao, Jianwei United Tech. Res. Center
Peng, Pei-Yuan United Tech. Res. Center

Forewarning to avoid potential traffic accidents is of great importance for Intelligent Transportation Systems (ITS). Under pedestrian and vehicle mixed traffic conditions like urban road intersections, traffic monitoring and forewarning have especially important values. Therefore in this paper a novel urban traffic information analysis and forewarning system is presented. Our system contains modules including object detection based on background subtraction; object tracking based on Multiple Hypotheses Tracking; and object status judgment based on forewarning logic for abnormality detection. Different from other approaches, we improve object tracking by fusing object’s position, size, velocity and its multi-part color histogram for data association. Through fusion we can better handle foreground object missing, merging and splitting problems during the tracking process. To enhance the practicality of our system, forewarning logic is designed according to different use cases for traffic abnormality detection, which is defined based on our extensive study on traffic status monitoring. Experiments with short and long video sequences show robust and accurate results of abnormality detection and forewarning under conditions of varying view angles, zoom depths, backgrounds, and frame rates. All the experimental results run at real-time frame rates (ge 25 fps) on standard hardware, which is suitable for actual ITS applications.

16:00-17:10 WeE1.8
**Occupancy Grid Computation from Dense Stereo and Sparse Structure and Motion Points for Automotive Applications**, pp. 819-824
Lategahn, Henning Karlsruhe Inst. of Tech. Inst. of Measurement and
Derendarz, Wojciech Volkswagen AG
Graf, Thorsten Volkswagen AG
Kitt, Bernd KIT
Effertz, Jan Volkswagen AG

We present a complete processing chain for computing 2D occupancy grids from image sequences. A multi layer grid is introduced which serves several purposes. First the 3D points reconstructed from the images are distributed onto the underlying grid. Thereafter a virtual measurement is computed for each cell thus reducing computational complexity and rejecting potential outliers. Subsequently a height profile is updated from which the current measurement is partitioned into ground and obstacle pixels. Different height profile update strategies are tested and compared yielding a stable height profile estimation. Lastly the occupancy layer of the grid is updated. To assess the algorithm we evaluate it quantitatively by comparing the output of it to ground truth data illustrating its accuracy. We show the applicability of the algorithm by using both, dense stereo reconstructed and sparse structure and motion points. The algorithm was implemented and run online on one of our test vehicles in real time.
context information, is critical to timely intervention. Altered situation awareness, which requires a significant amount of vulnerable road user protection. Research has shown that deaths is sufficiently high to justify research in the area of pedestrian fatalities, the absolute number of accident related deaths is sufficiently high to justify research in the area of vulnerable road user protection. Research has shown that situation awareness, which requires a significant amount of context information, is critical to timely intervention. Altered pedestrian behavior, due to traffic regulation, requires context information. For example, crosswalk presence and location knowledge can be of importance in pedestrian crossing scenarios. Therefore this paper discusses the implementation of a crosswalk detection algorithm, using Fourier transformation, augmented bipolarity, inverse perspective mapping template matching and edge orientation ratios for classification.

16:00-17:10   WeE1.12  
**LIDAR-Based Road and Road-Edge Detection**, pp. 845-848  
Zhang, Wende  GM R&D

In this paper, a LIDAR-based road and road-edge detection method is proposed to identify road regions and road-edges, which is an essential component of autonomous vehicles. LIDAR range data is decomposed into signals in elevation and signals projected on the ground plane. First, the elevation-based signals are processed by filtering techniques to identify the road candidate region, and by pattern recognition techniques to determine whether the candidate region is a road segment. Then, the line representation of the projected signals on the ground plane is identified and compared to a simple road model in the top-down view to determine whether the candidate region is a road segment with its road-edges. The proposed method provides fast processing speed and reliable detection performance of road and road-edge detection. The proposed framework has been verified through the DARPA Urban Challenge to show its robustness and efficiency on the winning entry Boss vehicle.

16:00-17:10   WeE1.13  
**Multilayer Lidar-Based Pedestrian Tracking in Urban Environments**, pp. 849-854  
Sato, Seiichi  Graduate school of Doshisha Univ.  
Hashimoto, Masafumi  Doshisha Univ.  
Takita, Manabu  Graduate School of Doshisha Univ.  
Takagi, Kiyokazu  DENSO Corp.  
 Ogawa, TakashiDENSO Corp.

This paper presents a method for pedestrian tracking in urban environments using in-vehicle multilayer laser lidar (MLLR). The MLLR that we developed irradiates the laser in six scanning planes by a polygon mirror mechanism, and thus objects with height are observed with the plural scanning planes. MLLR outputs are modified by GPS data and are mapped onto a grid map. Pedestrians are found based on the occupancy grid method, and they are tracked via Kalman filter in conjunction with global nearest neighboring (GNN) based data association. A track management method improves tracking accuracy in real worlds. Our tracking algorithm works well in a low-performance computer environment. The experimental results in different scenarios such as intersection and on the community road validate the proposed method.
Lots of rear end collisions due to driver inattention have been identified as a major automotive safety issue. A short advance warning can reduce the number and severity of the rear end collisions. This paper describes a Forward Collision Warning (FCW) system based on monocular vision, and presents a new vehicle detection method: appearance-based hypothesis generation, template tracking-based hypothesis verification which can remove false positive detections and automatic image matting for detection refinement. The FCW system uses time to collision (TTC) to trigger the warning. In order to compute time to collision (TTC), firstly, haar and adboost algorithm is utilized to detect the vehicle; Secondly, we use simplified Lucas-Kanade algorithm and virtual edge to remove false positive detection and use automatic image matting to do detection refinement; Thirdly, hierarchical tracking system is introduced for vehicle tracking; Camera calibration is utilized to get the headway distance and TTC at last. The use of a single low cost camera results in an affordable system which is simple to install. The FCW system has been tested in outdoor environment, showing robust and accurate performance.

16:00-17:10  WeE1.17

**Drivable Road Region Detection Using a Single Laser Range Finder for Outdoor Patrol Robots**, pp. 877-882

Shin, Yoojin Korea Univ.
Jung, Changbae Korea Univ.
Chung, Woojin Korea Univ.

For outdoor navigation, it is necessary to find the relevant features of outdoor road environments and detect drivable region for robot's motion. This paper presents a methodology for extracting the drivable road region by detecting the prominent road features and obstacles through a single laser range finder. The prominent features of roads are curbs and the road surface. The laser range finder is mounted on the mobile robot, looks down the road with a small tilt angle, and obtains two-dimensional range data. The proposed method is computationally more efficient in comparison with vision-based techniques and applicable for various road conditions in target environment. Experimental results confirm the reliability of the algorithm.

16:00-17:10  WeE1.18


Haselhoff, Anselm Univ. of Wuppertal
Kummert, Anton Univ. of Wuppertal

In this paper a new crosswalk detection strategy is presented. The application area is narrowed down to driver assistance systems to guarantee a reliable detection result and to benefit from the properties of a vehicle mounted camera. The main contribution of this paper is an efficient method to detect line segments that are typical for road markings like lanes and crosswalks. Therefore an adaptive Haar-like filter is applied by means of an integral image, where the pass-band of the filter is adjusted according to the distance from the vehicle. The detected segments are then combined to regions of interest by means of prior
knowledge of crosswalk dimensions. These regions are then passed to a simple classifying module that utilizes a set of moment invariants for classification. The final detection result is then tracked by a standard Kalman filter.

16:00-17:10 WeE1.19
Road Obstacle Classification with Attention Windows, pp. 889-895
Prokhorov, Danil Toyota Res. Inst. NA
A learning system for detection and classification of road obstacles, such as vehicles and non-vehicles, is proposed which utilizes information from multiple sensors. An advanced range sensor guides a selection of candidate images provided by the camera for subsequent analysis. A competition based learning algorithm is used to distinguish between representations of different obstacles. High classification accuracy is demonstrated in a realistic variety of driving conditions in the presence of intentional data mislabeling in the two-class setup with state-of-art image descriptors.

16:00-17:10 WeE1.20
Fast and Reliable Recognition of Supplementary Traffic Signs, pp. 896-901
Nienhüser, Dennis FZI Forschungszentrum Informatik Gunpp, Thomas FZI Forschungszentrum Informatik Zöllner, J. Marius FZI Forschungszentrum Informatik Natroshvili, Koba HARMAN International / BECKER Automotive Systems
Supplementary traffic signs are used to alter the meaning of other traffic signs. Assistance systems that recognize traffic signs therefore must also recognize supplementary signs to evaluate their influence on the meaning of detected traffic signs. We propose an algorithm which is able to detect supplementary signs in the vicinity of other signs using a novel rectangle segmentation algorithm. Support vector machines are used for the classification and rejection of other objects. The combination of both components permits to recognize a supplementary sign in less than 40ms. First quantitative results for a test set with four different supplementary sign types show a very good classification accuracy of more than 96%.

16:00-17:10 WeE1.21
Real Time 3D Terrain Elevation Mapping Using Ants Optimization Algorithm and Stereo Vision, pp. 902-909
Cappalunga, Andrea Univ. of Parma Cattani, Stefano Univ. of Parma Broggi, Alberto Univ. of Parma McDaniel, Michael Caterpillar Inc. Dutta, Susmita Caterpillar
Reliable perception of terrain slope and terrain traversability, is a key-feature for any off-road unmanned ground vehicle, as well as for any Driver Assistance Systems designed to work in extreme environments, like mining. In this paper we want to present an innovative technique to build a 3D elevation map of the traversable terrain from a world’s 3D dense data set, in real time. The 3D points are grouped into lateral and longitudinal equally spaced slices, then they are projected onto the corresponding slices’ reference planes. The projections are then analyzed by a biologically inspired Optimization Algorithm able to segment points into terrains inlier and outlier; the resulting 2D terrain slopes represent an optimal terrain approximation along each slice. Finally, the 2D approximations are merged together, to create the overall 3D terrain surface. The algorithm has been successfully tested with 3D data provided by a stereo camera system mounted on a Cat wheel loader operating in a mining environment.

16:00-17:10 WeE1.22
Pedestrian Detection Based on Maximally Stable Extreme Regions, pp. 910-914
Frolov, Vadim Karlsruhe Inst. of Tech. Puente León, Fernando Karlsruhe Inst. of Tech.
This paper presents a new approach to generate hypotheses about the presence of pedestrians in an infrared image. Information about maximally stable extremal regions is used to locate the warmest regions on the image, which are considered to be potential human heads. To capture the complete human body, these regions are scaled based on the range data of a lidar sensor. Closely related regions are merged into one bigger region to avoid the segmentation which arises from the heterogeneous heating emission of a dressed human. Additionally, the area and perimeter of each potential pedestrian are examined to discard artificial objects. The optimal decision measure is sought so that all pedestrians are extracted from a scene. All remaining hypotheses should be further processed with a statistical classifier.

16:00-17:10 WeE1.23
A New Anti-Aliasing Approach for Improved Motion-Based Object Detection Using Linear Filters, pp. 915-920
Schauland, Sam Univ. of Wuppertal Velten, Jörg Univ. of Wuppertal Kummert, Anton Univ. of Wuppertal
In this paper a new anti-aliasing approach for motion-based object detection using linear shift invariant (LSI) filters is presented. Originating from the field of signal processing, LSI-filter-based motion detection has been topic of research for a long time, though due to low computational power of contemporary computers the developed systems have been unfeasible for application in mass products like driver assistance systems. However, recent progress in hardware in conjunction with decreasing costs makes using linear filters a very interesting alternative of increasing performance of common approaches. One of the most important factors falsifying the object detection results obtained using linear shift invariant (LSI) is aliasing. This is mainly caused by the low temporal resolution of the camera signal which leads to the fact that the sampling theorem does not hold for objects moving at high speed in the image plane. In general, aliasing errors cannot be removed after sampling. Under certain conditions, however, their impact on the filter result can be successfully decreased using the approach presented in this paper. The applicability of the new approach is demonstrated using scenes record-
ed by a camera installed in a blind spot warning system.

16:00-17:10  WeE1.24
Visual Classification of Coarse Vehicle Orientation Using Histogram of Oriented Gradients Features, pp. 921-928
Rybksi, Paul  Carnegie Mellon Univ.
Huber, Daniel  Carnegie Mellon Univ.
Morris, Daniel D.  General Dynamics Robotic Systems
For an autonomous vehicle, detecting and tracking other vehicles is a critical task. Determining the orientation of a detected vehicle is necessary for assessing whether the vehicle is a potential hazard. If a detected vehicle is moving, the orientation can be inferred from its trajectory, but if the vehicle is stationary, the orientation must be determined directly. In this paper, we focus on vision-based algorithms for determining vehicle orientation of vehicles in images. We train a set of Histogram of Oriented Gradients (HOG) classifiers to recognize different orientations of vehicles detected in imagery. We find that these orientation-specific classifiers perform well, achieving an 88% classification accuracy on a test database of 284 images. We also investigate how combinations of orientation-specific classifiers can be employed to distinguish subsets of orientations, such as driver’s side versus passenger’s side views. Finally, we compare a vehicle detector formed from orientation-specific classifiers to an orientation-independent classifier and find that, counter-intuitively, the orientation-independent classifier outperforms the set of orientation-specific classifiers.

16:00-17:10  WeE1.25
A Robust and Efficient Face Tracking Kernel for Driver Inattention Monitoring System, pp. 929-934
Dong, Yanchao  Kumamoto Univ.
Hu, Zhencheng  Kumamoto Univ.
Uchimura, Keiichi  Kumamoto Univ.
For the application of Driver Inattention Monitoring System this paper propose a zero-order binocular face tracking kernel and an efficient face shape registration approach. This kernel tracks such parameters as the face position & orientation, the eyeball yaw & pitch, the eyelids animation and the mouth & jaw animation. From the view of computational cost, accuracy and robustness against registration error, camera calibration error and measurement noise, the proposed zero-order binocular face tracking kernel has shown robustness and efficiency.

16:00-17:10  WeE1.26
Improving Stereo Camera Depth Measurements and Benefiting from Intermediate Results, pp. 935-940
Høflund, Carsten  Aalborg Univ.
Moeslund, Thomas  Aalborg Univ.
Madsen, Claus  Aalborg Univ.
Trivedi, Mohan M.  Univ. of California at San Diego
This paper presents a method for improving the disparity values obtained with a stereo camera by applying an iconic Kalman filter and known ego-motion. The improvements are demonstrated in an application of determining the free space in a scene as viewed by a vehicle-mounted camera. Using disparity maps from a stereo camera and known camera motion, the disparity maps are first filtered by an iconic Kalman filter, operating on each pixel individually, thereby reducing variance and increasing the density of the filtered disparity map. Then, a stochastic occupancy grid is calculated from the filtered disparity map, providing a top-down view of the scene where the uncertainty of disparity measurements are taken into account. These occupancy grids are segmented to indicate a maximum depth free of obstacles, enabling the marking of free space in the accompanying intensity image. Even without motion of the camera, the quality of the disparity map is increased significantly. Applications of the intermediate results are discussed, enabling features such as motion detection and quantifying the certainty of the measurements. The evaluation shows significant improvement in disparity variance and disparity map density, and consequently an improvement in the application of marking free space.

16:00-17:10  WeE1.27
Global Environment Interpretation from a New Mobile Mapping System, pp. 941-948
Smadja, Laurent  VIAMETRIS
Ninot, Jerome  VIAMETRIS
Gavrilovic, Thomas  VIAMETRIS
We present in this article different algorithms designed for automatic road environment interpretation, from a large amount of data, acquired by embedded sensors. Road markings and traffic signs are extracted then interpreted by means of original image processing techniques whereas road geometry is computed through lidar range data analysis. The outputs of all these algorithms are gathered into a single tool, which manages a precise and global geographic database in order to produce advanced maps. These maps can further be used for intelligent navigation.

16:00-17:10  WeE1.28
Methods of Target Recognition for UWB Radar, pp. 949-954
Sakkila, Laila  Univ. of valenciennes
Rivenq, Atika  Univ. of valenciennes
Tatkeu, Charles  INRETS
Elhillali, Yassin  Univ. of Valenciennes
Ghys, Jean-Pierre  INRETS
Rouvaen, Jean Michel  Univ. of Valenciennes
With the growth of embedded components (GPS, radar, cameras…), road vehicle becomes more and more intelligent and reassuring. The concept of the intelligent vehicle is to make it able to analyze, individually and independently, the external data before transmitting them to the driver. In recent years, ideas for studies and research programs on this concept have proliferated in different environments. The cars now have tools to control speed, manage traffic and ensure the avoidance collision task. A radar, that allows to detect obstacles in the road environment and to alert the driver, is one
of the very powerful devices, even essential to ensure the safety of road users. This device has the advantage of being effective anytime (fog, rain ...). The arrival of Ultra Wide Band (UWB) technology for radar application allows the development of compact and relatively cheap sensors. Dedicated to military applications, radar devices using UWB are now a good tool of detecting obstacles for many applications in life everyday. These sensors could be used to measure distances and positions with greater resolution than existing radar devices or to obtain images of objects buried underground or placed behind surfaces. This paper is focused on the study of UWB radar signatures to identify the type of obstacles.

16:00-17:10 WeE1.29
Hoerwick, Markus Tech. Univ. Munich
Siedersberger, Karl-Heinz AUDI AG
As drivers back out of the driving task, when transported automatically by an intelligent car for a longer time, they are not always able to react properly, if a driver take over request occurs. This paper presents two ways, how to deal with this problem within the scope of a functional safety concept. Therefor, the difference between fully automatic and autonomous driving assistance systems is explained. Afterwards two different strategies to reach a safe state in consequence of a system boundary crossing are proposed. In the first case the fall back state is reached by a driver take over, in the second case by an automatic, active fail-safe mechanism. Subsequently the necessary components for monitoring and reaching a safe state and their embedment in a basic, functional architecture of a driving assistance system are described. In this context, special regard is paid to aspects of redundancy as well. In the end it is concluded, that the safety concept proposed here is crucial for guaranteeing enduring safety in an automatically driving car and in consequence for making automatic driving functions commercially ready for serial production.

16:00-17:10 WeE1.30
Model-Based Detection and Tracking of Objects Using a 3D-Camera, pp. 961-966
Schindler, Andreas Univ. of Passau
In modern driver assistance systems the environment perception especially the detection of vulnerable road users plays an important role. The analysis of such traffic scenes demands reliable and robust information on objects and their position. In this context a 3D-camera offers a promising concept in providing both lateral resolution and depth information to supply this task. This paper presents models and methods for the detection and the tracking of objects using the range data of a 3D-camera. For that purpose the depth information of a 3D-camera is used for the reconstruction of the traffic scenario. Special and adapted methods of the field of machine learning allow to analyze the re-projected structures in order to extract object measurements from the sensors raw data. Finally stochastic state estimation is applied to propagate object hypotheses taking into account the measurements. The proposed methodology facilitates the integration and support of standard environment perception techniques used in todays advanced driver assistance systems.

16:00-17:10 WeE1.31
Vehicle on Board Platform: Communications Test and Prototyping, pp. 967-972
Hernandez, Unai Univ. of Deusto
Perallos, Asier Univ. of Deusto
Sainz, Nekane Univ. of deusto
Angulo, Ignacio Univ. of Deusto
This paper describes the process of prototyping and testing an in-vehicle embedded system with allows the driver to communicate with his vehicle, with the gadgets inside it (PDAs, cellular, sensor networks, and so on) and with the road infrastructure in order to consume intelligent transport services. The result of the presented work is an on board prototype and two services which have been developed to validate some characteristics of this embedded prototype.

16:00-17:10 WeE1.32
Pedestrian Detection Algorithm for On-Board Cameras of Multi View Angles, pp. 973-980
Kamijo, Shunsuke The Univ. of Tokyo
Fujimura, Kaichi The Univ. of Tokyo
Shibayama, Yuuki The Univ. of Tokyo
In this paper, a general algorithm for pedestrian detection by on-board monocular camera which can be applied to cameras of various view ranges in unified manner. The Spatio-Temporal MRF model extracts and tracks foreground objects as pedestrians and non-pedestrian distinguishing from background scenes as buildings by referring to motion difference. During the tracking sequences, cascaded HOG classifiers classify the foreground objects into the two classes of pedestrians and non-pedestrians. Before the classification, geometrical constraints on the relationship between heights and positions of the objects are examined to exclude the non-pedestrian objects. This pre-processing contributed to reducing the processing time of the classification while maintaining the classification accuracy. Due to the benefit of the tracking that the classifier can make decision totally considering Regions of Interest (ROIs) with same ID during consecutive images, this algorithm can operates quite robustly against noises and classification errors at each image frame.

WeF1 Room T1
Image, Radar, Lidar Signal Processing 2
(Regular Session)
Chair: Broggi, Alberto Univ. of Parma

17:10-17:30 WeF1.1
Real-Time Multi-Vehicle Tracking Based on Feature Detection and Color Probability Model, pp. 981-986
Huang, Lili Univ. of California, Riverside
Barth, Matthew Univ. of California-Riverside
As traffic surveillance technology continues to grow world-
wide, computer vision-based vehicle tracking is becoming increasing important. One of the key challenges with vehicle tracking is dealing with high density traffic, where occlusion often leads to foreground splitting and merging errors. In order to help solve this problem, global features such as color or local features like corners can be used for tracking. However, tracking based on global features or local features alone does not work well with a high amount of occlusion. In this paper, we propose a real-time multi-vehicle tracking approach, which combines both local feature tracking and a global color probability model. In cases with low occlusion, corner feature detection and tracking algorithm can be used to estimate vehicle positions and trajectories. When there is a high degree of occlusion, corner features can be tracked to provide position estimates of moving objects. Then a color probability can be calculated in the occluded area to determine which object each pixel belongs to. This approach is scalable to both stationary surveillance video and moving camera video. Experimental results from a challenging transportation video clip are presented.

17:30-17:50 WeF1.2
Particle Grid Tracking System for Stereo Vision Based Environment Perception, pp. 987-992
Danescu, Radu Gabriel Tech. Univ. of Cluj Napoca
Oniga, Florin Ioan Tech. Univ. of Cluj Napoca
Nedevschi, Sergiu Tech. Univ. of Cluj-Napoca

This paper presents an occupancy grid tracking solution based on particles. The particles will have a dual nature – they will denote hypotheses, as in the particle filtering algorithms, but they will also be the building blocks of our modeled world. The particles have position and speed, and they can migrate in the grid from cell to cell depending on their motion model and motion parameters, but they will also be created and destroyed using a weighting-resampling mechanism specific to particle filter algorithms. An obstacle grid derived from processing a stereovision-generated elevation map is used as measurement information, and the measurement model takes into account the uncertainties of the stereo reconstruction. The resulted system is a flexible, real-time tracking solution for dynamic unstructured driving environments.
in the case of a lower resolution radar sensor it is shown that it is suitable to apply super-resolution algorithms to achieve the accuracy of a higher resolution laserscanner. Finally, a novel histogram based approach for road boundary detection with lidar and radar sensors is presented.

09:00-09:30  ThA1.1
On-Road Vehicle Tracking Using Deformable Object Model and Particle Filter with Integrated Likelihoods, pp. 1014-1021
Takeuchi, Akihiro  Toyota Tech. Inst.
Mita, Seiichi  Toyota Tech. Inst.

This paper proposes a novel method for vehicle detection and tracking using a vehicle-mounted monocular camera. In this method, features of vehicles are learned as a deformable object model through the combination of a latent support vector machine (LSVM) and histograms of oriented gradients (HOG). The vehicle detector uses both global and local features as the deformable object model. Detected vehicles are tracked by using a particle filter with integrated likelihoods, such as the probability of vehicles estimated from the deformable object model and the intensity correlation between different picture frames. Tracking likelihoods are iteratively used as the a priori probability for the next frame. The experimental results showed that the proposed method can achieve an average vehicle detection rate of 98% and an average vehicle tracking rate of 87% with a false positive rate of less than 0.3%.

09:30-09:50  ThA1.2
Reliable Automotive Pre-Crash System with Out-Of-Sequence Measurement Processing, pp. 1022-1027
Muntzinger, Marc  Daimler AG
Aeberhard, Michael  Daimler AG
Zuther, Sebastian  Daimler AG
Maehlis, Mirko  Daimler AG
Dietmayer, Klaus Christian Jürgen  Univ. of Ulm
Schmid, Matthias Roland  Univ. der Bundeswehr München
Dickmann, Jürgen  Daimler AG

In an automotive pre-crash application, it is vital to quickly and accurately estimate the position and velocity of objects in the frontal area of the vehicle. To improve such estimations, several radar sensors are fused to detect objects. Due to their different performance characteristics, their measurements can arrive at the pre-crash processing unit out-of-sequence. This work presents several techniques to integrate measurements into a tracking algorithm that arrive with such an out-of-sequence measurement (OOSM) scenario. A comprehensive complexity analysis of the algorithms is also presented. Most importantly, the algorithms are run on a test vehicle during real crash scenarios. The algorithms’ performance is evaluated against reference data from a highly accurate laser scanner. It is shown that using advanced OOSM algorithms in pre-crash systems significantly increases performance and reduces computational cost compared to previous approaches.
Java card based system facilitates offline and online passengers identifications at the various checking points by the Saudi authorities. Wireless access to the internet is a vital layer in the proposed architecture as it allows for tracking, trip planning and on-line identity verification. Experimental results for wireless access to the internet show that HSPA is better than WiMAX as it offers acceptable quality of service at vehicle speed that exceeds 120kmph.

09:50-11:00   ThB1.4

**Autonomous Driving of Intelligent Vehicle BIT in 2009 Future Challenge of China**, pp. 1049-1053
Xiong, Guangming Beijing Inst. of Tech.
Zhou, Peiyun Beijing Inst. of Tech.
Zhou, Shengyan Beijing Inst. of Tech.
Zhao, Xijun Beijing Inst. of Tech.
Zhang, Haojie Beijing Inst. of Tech.
Gong, Jianwei Beijing Inst. of Tech.
Chen, Huiluan Beijing Inst. of Tech.

The 2009 Future Challenge - Intelligent Vehicle and Beyond (FC’09) was held in Xi’an, China. Our intelligent vehicle named BIT participated in all competitions at this event. This paper describes BIT’s system structure and its capabilities. BIT combines a global path planning method and local path planning to drive the vehicle to address the challenges posted by the unknown competition environment. A novel curve tracking strategy based on preview and curve bisector is developed for complex paths such as U-turn. For recognizing traffic lights, Haar feature and AdaBoost algorithm are used to train and obtain traffic light classifiers. Normalization of every candidate region in RGB and HSV spaces is performed and compared with a threshold to fulfill the verification. The experiment describes BIT’s performance and the conclusion sets forth the main work in the next step.

09:50-11:00   ThB1.5

**An Object-Oriented Design of a World Model for Autonomous City Vehicles**, pp. 1054-1059
Furda, Andrei Griffith Univ.
Vlacic, Ljubo Griffith Univ.

This paper presents an object-oriented world model for the road traffic environment of autonomous (driverless) city vehicles. The developed World Model is a software component of the autonomous vehicle’s control system, which represents the vehicle’s view of its road environment. Regardless whether the information is a priori known, obtained through on-board sensors, or through communication, the World Model stores and updates information in real-time, notifies the decision making subsystem about relevant events, and provides access to its stored information. The design is based on software design patterns, and its application programming interface provides both asynchronous and synchronous access to its information. Experimental results of both a 3D simulation and real-world experiments show that the approach is applicable and real-time capable.

09:50-11:00   ThB1.6

**Autonomous Ground Vehicle Navigation Method in Complex Environment**, pp. 1060-1065
Yang, Yi Beijing Inst. of Tech.
Fu, Mengyin Beijing Inst. of Tech.
Yang, Xin Beijing Inst. of Tech.
Xiong, Guangming Beijing Inst. of Tech.
Gong, Jianwei Beijing Inst. of Tech.

In this paper, a 3D laser point cloud-based navigation method for autonomous ground vehicles in complex environment is proposed. With a coordinate transformation of laser data from sphere to cylinder, environment perception cylinder is configured. In the cylinder, terrain traversability is predicted through analysis on radial and tangential slope of 3D point cloud. In addition, the candidate point cloud of traversable region has been extracted. Furthermore, navigation circle contained with direction information is built up based on the candidate point cloud. Extended experimental results demonstrate that the method allows autonomous ground vehicle to move safely and correctly in complex environment.

09:50-11:00   ThB1.7

**Development of a Collaborative Vehicle Collision Avoidance System**, pp. 1066-1071
Konstantinidis, Evdokimos Lab. of Medical Informatics, Medical School, AristotleUniversity
Patoulidis, George Tech. Educational Inst. (TEI) of Western Macedonia

Advanced systems for driver assistance in combination with new preventive safety systems offer great potential for collision avoidance, reducing accident severity and increasing occupant protection. This paper presents the development and evaluation of a system targeting to vehicle collision avoidance in emergency situations. The proposed system provides the nearby vehicles with information about possible accident involvement. The main feature of the proposed system is the wireless communication among vehicles during normal driving in case of emergency situations. The wireless communication is originated by a vehicle in emergency state while the vehicles in range get benefit of the transmitted information. The wireless communication packet is comprised of the type of the vehicle, which originates the transmission, the description of the current situation, and the geographical position of the vehicle which is provided by a Geographical Positioning System (GPS) module. The critical issues and other technical challenges in developing these systems will be explored.

09:50-11:00   ThB1.8

**Truck Automation Operational Concept Alternatives**, pp. 1072-1077
Shladover, Steven E. Univ. of California, Berkeley

This paper defines a comprehensive range of operational concepts for automating the driving of heavy trucks. These concepts are defined in terms of the amount of driving func-
tionality that is transferred from the driver to the automat-
ed system and the roadway conditions in which the trucks 
would operate. With the minimum amount of automation 
(providing only safety warnings to drivers) it should be fea-
sible and safe to operate in any roadway environment, but 
with the maximum use of automation operations must be 
restricted to simplified and protected driving environments 
to keep the complexity of the automation challenges trac-
table. This systematic classification of operational concept 
alternatives is intended to help stakeholders who are inter-
ested in truck automation to focus on specific alternatives.

09:50-11:00   ThB1.9
Safety Verification of Autonomous Vehicles for Coor-
dinated Evasive Maneuvers, pp. 1078-1083
Althoff, Matthias Tech. Univ. München
Althoff, Daniel Tech. Univ. München
Wollherr, Dirk Tech. Univ. München
Buss, Martin TU Muenchen
The verification of evasive maneuvers for autonomous ve-
hicles driving with constant velocity is considered. Modeling 
uncertainties, uncertain measurements, and disturbances 
can cause substantial deviations from an initially planned 
evasive maneuver. From this follows that the maneuver, 
which is safe under perfect conditions, might become un-
safe. In this work, the possible set of deviations is computed 
with methods from reachability analysis, which allows to ver-
ify evasive maneuvers under consideration of the mentioned 
uncertainties. Since the presented approach has a short re-
sponse time, it can be applied for real time safety decisions. 
The methods are presented for a numerical example where 
two autonomous cars plan a coordinated evasive maneu-
er in order to prevent a collision with a wrong-way driver.

09:50-11:00   ThB1.10
On Worst Case Performance of Collision Avoidance 
Systems, pp. 1084-1091
Nilsson, Jonas   Volvo Car Corp.
Ödblom, Anders C.E.   Volvo Car Corp.
Automotive Collision Avoidance and Mitigation (CA/CM) 
systems help drivers to avoid collisions through autonomous 
interventions by braking or steering. If the decision to inter-
vene is made too early, the intervention can become a nuis-
sance to the driver and if the decision is made too late, the 
safety benefits of the intervention will be reduced. Decision 
timing is thus crucial for the successful operation of a CA/CM 
system. The decision to intervene is commonly taken when 
a threat function reaches a specific threshold. The dimen-
sionality of the input state space for the threat function is in 
general very large making exhaustive evaluation in real ve-
hicles expensive and time consuming. This paper presents 
a method for efficient estimation of a lower bound on CA/CM 
system performance, i.e. the worst case performance. The 
method is applied on an example system for a set of longi-
tudinal single object escape scenarios. Results show signifi-
cant variation in worst case decision timing across scenarios.

09:50-11:00   ThB1.11
Object Related Reactive Offset Maneuver, pp. 1092-
1097
Hecker, Falk    Univ. of the Bundeswehr Munich
Luettel, Thorsten    Univ. of the Bundeswehr Munich
Wuenschke, Hans Joachim    Univ.
This paper describes a method for an object related reac-
tive offset maneuver increasing the number of action al-
ternatives for an autonomous ground vehicle. The method 
aims at a variety of time-critical maneuvers as for ex-
ample merging into moving traffic, changing lanes, pass-
ing other traffic participants as well as emergency obstacle 
avoidance without having to replan a path using high-level 
planning methods. It is especially targeted at autonomous 
driving on country roads. As oncoming traffic increases 
the relative speed between participants, a quick reponse 
to changes of the traffic situation are critically important. 
Moreover the method does not require constant vehicle 
velocities throughout a lane change maneuver as most 
existing approaches do. Simulations show improvements 
of the behaviour capabilities of an autonomous vehicle 
using the presented lateral reactive offset maneuvers.

09:50-11:00   ThB1.12
Driving Risk Classification Based on Experts 
Evaluation, pp. 1098-1103
S. Siordia, Oscar    Univ. Rey Juan Carlos
Martín de Diego, Isaac    Univ. Rey Juan Carlos
Conde, Cristina    Univ. Rey Juan Carlos
Reyes Salgado, Gerardo    Centro Nacional de In-
vestigación y Desarrollo Tecnológico
Cabello, Enrique    Univ. Rey Juan Carlos
A novel multidisciplinary system for the automatic driving 
risk level classification is presented. The data considered 
includes the three basic traffic safety elements (driver, road, 
and vehicle), as well as knowledge from traffic experts. The 
driving experiments were conducted in a truck cabin simu-
lator handled by a professional driver, considering the most 
common real-world environments. Each traffic expert evalu-
ate the driving risk on a 0 to 100 visual analogue scale. The 
driver, road and vehicle information was used to train five 
different data mining algorithms in order to predict the driv-
ing risk level. The benefits of the completeness of the data 
considered in our system are presented and discussed.

09:50-11:00   ThB1.13
The Delay of Bus Near a Stop When Mixed Traffic Flow 
Is Considered, pp. 1104-1109
Lu, Lu   Tsinghua Univ.
Su, Yuelong   Tsinghua Univ.
Yao, Danya   Tsinghua Univ.
Peng, Lihui   Tsinghua Univ.
Ding, Mang   Tsinghua Univ.
Xu, Runmin   Tsinghua Univ.
This paper studies the following driving scenario that 
is common in China and many Asian developing coun-
tries: a bus has to temporarily occupy the bicycle lane 
in order to stop and pick up passengers, where the
mixed traffic flow is composed of motorized vehicles and bicycles. A special cellular automation model is proposed to examine the governing factors that influence the delay of a bus near a bus stop. Vehicle inflow rate, bicycle inflow rate and bus inflow rate are specially addressed. Finally, some useful suggestions are presented.

09:50-11:00 ThB1.14
Overview of a Dynamic Evaluation of Collective Taxi Systems Providing an Optimal Performance, pp. 1110-1115
Lioris, Jennie Eugenie ENPC
Cohen, Guy Ec. Ponts ParisTech
de La Fortelle, Arnaud ENSMP

When considering the need for an intelligent transportation mode based upon the fact that car travel is still the consumer's first choice, we decided to explore the idea of collective taxis. More precisely, we are seeking to provide an autonomous high quality door-to-door service, affordable by almost everyone, covering the entire urban area, simply by allocating in an optimal way more than one passenger to each vehicle and using the latest available information regarding traffic conditions, etc. Because this system is far less unconstrained than most public transportation systems, it has high potentialities in terms of performance and flexibility, but it is consequently very difficult to manage and to design optimally. Therefore, we present a discrete event simulation tool and show how it can be used to conceive, optimise and compare decision algorithms, achieve sound trade-off between conflicting performance indicators and assess the efficiency of the system in various contexts.

09:50-11:00 ThB1.15
A 802.11p Prototype Implementation, pp. 1116-1121
Carona, Duarte ISEL - Inst. Superior de Engenharia de Lisboa
Serrador, Antonio ISEL
Mar, Pedro Univ. of Aveiro, Inst. de Telecomunicações
Abreu, Ricardo Matos Inst. de Telecomunicacoes
Ferreira, Nuno Univ. da Madeira
Meireles, Tiago Univ. da Madeira
Matos, João Nuno Pimentel Silva Univ. de Aveiro
Lopes, Jorge Brisa Innovation and Tech.

This paper presents an IEEE 802.11p full-stack prototype implementation to data exchange among vehicles and between vehicles and the roadway infrastructures. The prototype architecture is based on FPGAs for IF and baseband purposes, using 802.11a based transceivers for RF interfaces. Power amplifiers were also addressed, by using commercial and in-house solutions. This implementation aims to provide technical solutions for Intelligent Transportation Systems (ITS) field, namely for tolling and traffic management related services, in order to promote safety, mobility and driving comfort through the dynamic and real-time cooperation among vehicles and/or between vehicles and infrastructures. The performance of the proposed scheme is tested under realistic urban and suburban driving conditions. Preliminary results are promising, since they comply with major 802.11p standard requirements.

09:50-11:00 ThB1.16
Multiple Hypothesis Tracking for Automated Vehicle Perception, pp. 1122-1127
Thomaidis, Georgios Inst. of Comm. and Comp. Syst.
Spinoulas, Leonidas National Tech. Univ. of Athens
Lytrivis, Panagiotis Inst. of Comm. & Comp. Syst.
Ahroholdt, Malte Volvo Tech. AB
Grubb, Grant Volvo Tech. AB
Amditis, Angelos Inst. of Communications and Computer Systems

The use of multiple hypothesis tracking has proven to provide significant performance benefits over the single hypothesis GNN or the PDA algorithm. Automotive sensors like radars, laser-scanners or vision systems are being integrated into vehicles for commercial or scientific purposes, in increasing numbers over the last years. As a result, there is profound literature on this area and several approaches have been proposed to the problem of multi-target, multi-sensor target tracking. The most advanced vehicle applications allow the use of highly or even fully automated driving. Of course, these applications require an accurate, robust and reliable perception output so that the vehicle can be driven autonomously. The HAVEit EU project investigates the application and validation of automated vehicles applications, technologies that are going to have great impact in transport safety and comfort. In this paper the MHT algorithm is applied to real sensor data, installed in Volvo Technology vehicle demonstrating Automated Queue Assistance. In conjunction with simulated scenarios, the benefits in tracking performance compared to conventional GNN tracking are presented.

09:50-11:00 ThB1.17
Improving Performance of Inter-Vehicle Communication Using LMS Adaptive Circular Array Antenna, pp. 1128-1133
Yamamoto, Ken Tokyo Univ. of Science
Ohno, Kohei Tokyo Univ. of Science
Itami, Makoto Tokyo Univ. of Science

In this paper, LMS (Least Mean Square) adaptive array antenna is applied to IVC (Inter-Vehicle Communication) in order to reduce interference which is caused by surrounding vehicles. The LMS adaptive array antenna has a characteristic that the control of directivity is possible according to surrounding radio wave condition, if the receiving vehicle knows the information of the target vehicle. Under the case where the adaptive array antenna was used in IVC systems, packet error rate characteristic, throughput performance and improvement in near-far problem are evaluated by comparing with the performance of the IVC system using omni-directional antenna.

09:50-11:00 ThB1.18
Hybrid Fusion Scheme for Pedestrian Detection Based on Laser Scanner and Far Infrared Camera, pp. 1134-1139
Garcia, Fernando Univ. Carlos III de Madrid
Olmeda, Daniel Univ. Carlos III
Armingol Moreno, José María  Univ. Carlos III de Madrid
de la Escalera, Arturo  Univ. Carlos III de Madrid
The lack of trustworthy sensors makes ADAS applications a tough task. In this paper a fusion approach that uses two sensors: far infrared camera vision and a laser scanner to detect pedestrian for ADAS applications is presented. Both sensors have different field of view thus different detection zones are created according to the number of sensors available. The proposed algorithm combines low and high level information, providing a hybrid fusion scheme. Experimental results show that pedestrian detections are improved thanks to the use of several sensors.

09:50-11:00  ThB1.19
Dynamic Network Flow Modeling Based on Cell Probe Data, pp. 1140-1145
Dong, Shen  Tsinghua Univ.
Qin, Xiao  South Dakota State Univ.
Zhang, Yi  Univ. of Wisconsin - Madison
Shi, Qixin  Tsinghua Univ.
Ran, Bin  Univ. of Wisconsin at Madison
Dynamic demands are the basic inputs of some existing dynamic assignment function. However, current data collection technologies do not directly support all the requirements of Dynamic Traffic Assignment (DTA) models. As a new traffic data collection technology, cell probe data could provide link flow, travel time and dynamic traffic demand at the same time. But these parameters are partial for a network. A common signal transition event for cell probe technologies can be used to track dynamic boundary flow and summarize the number of cell phones in Location Area (LA). And link flow on boundary links can be estimated. When a cell phone crosses a LA, travel time is recorded. Dynamic traffic demand in the paper is divided into two parts: commuter traffic demand and unstable traffic demand. Stable traffic demand follows the Dynamic User Equilibrium (DUE) principles while the traffic flow due to unstable traffic demand can be considered as background traffic. In the paper, a background flow-based DTA (BF-DTA) model is forecast dynamic traffic flow of the network is presented in detail. Several cases generated via simulation programs are discussed and compared; and errors of travel time are calculated to demonstrate the precision of the proposed model.

09:50-11:00  ThB1.20
Design of a Modular Demonstrator for Safety Application Systems: The CVIS Project, pp. 1146-1151
Pechbert, Steve  LCPC
Gruyer, Dominique  INRETS/LCPC
Gingras, Denis  Intelligent Materials and Systems Inst. Univ. de Sherb
Dupin, Francis  INRETS/LCPC
This article describes the design of a modular demonstrator (Enhanced Driver Awarness - EDA) aimed at integrating various safety embedded vehicular applications. Two goals are achieved with this demonstrator: the first one is to provide a complete set of useful function in order to develop safety applications; the other one is to allow multiple services to run simultaneously on the same vehicle sharing information to improve their potential. This demonstrator has been used in the European CVIS project, which aim is to provide a set of technologies defined for embedded safety vehicle application.

09:50-11:00  ThB1.21
Motion Compensation for Obstacle Detection Based on Homography and Odometric Data with Virtual Camera Perspectives, pp. 1152-1158
Miksch, Michael  Univ. of Stuttgart
Yang, Bin  Univ. of Stuttgart
Zimmermann, Klaus  Sony Deutschland GmbH
In this paper we present a method to compensate the image motion of a monocular camera on a moving vehicle in order to detect obstacles. Due to the camera motion, the road surface induces a characteristic image motion between two camera shots. The motion of the camera is determined by the use of odometric data received from the CAN-bus, and the position and orientation of the road is continuously estimated with camera self-calibration. This all leads to a motion field which is predicted based on homography. To prevent the drawbacks of the real camera perspective, different virtual camera perspectives are presented in combination with motion compensation. Possible virtual perspectives are the bird’s eye view and image rectification. In addition, a non-linear camera model is used which does not limit the range of obstacle detection to a certain distance and efficiently uses the available image information.

09:50-11:00  ThB1.22
A Browsing and Retrieval System for Driving Data, pp. 1159-1165
Naito, Masashi  Nagoya Univ.
Miyajima, Chiyomi  Nagoya Univ.
Nishino, Takanori  Nagoya Univ.
Kitaoka, Norihide  Nagoya Univ.
Takeda, Kazuya  Nagoya Univ.
A browsing and retrieval system for driving data with a multi-modal data browser, a high speed retrieval function, and a fast browsing function that skips redundant scenes. For sharing data with several users, this system can be available via network from PCs or smartphones. This system uses time-series active search, which has been successfully used for fast search of audio and video data, as the algorithm of retrieval function. This system can retrieve the scenes similar to the input scene from 80 thousand scenes in a few seconds. Retrieval performance was compared in various retrieval conditions by changing codebook size of vector quantization for histo-
Dynamic Transmission Range in Inter-Vehicle Communication with Stop-And-Go Traffic, pp. 1166-1171
Chen, Rex   Univ. of California, Irvine
Yang, Hao   Univ. of California, Irvine
Jin, Wen-Long  Univ. of California
Regan, Amelia  Univ. of California, Irvine

Inter-vehicle communication is a promising way to share and disseminate real-time and nearby safety information on the road. However, several pressing open questions require solutions in order to achieve high reliability and efficiency with these systems. Further, previous studies have shown that the mobility model can significantly influence the communication performance in vehicular networks. In this paper, we analyze communication in stop-and-go waves and propose a method to optimize an important network parameter, the transmission range, based on traffic pattern measures. Our findings suggest a transmission range adjustment scheme that achieves high reliability by considering network coverage and packet reception rates.

Calibration of Non-Overlapping Cameras in Vehicles, pp. 1178-1183
Pagel, Frank   Fraunhofer IOSB

Cameras are getting smaller and cheaper. So a cost-effective usage of multi-camera systems in vehicles gets more and more attractive. In many cases it is desirable to cover the whole environment all around the vehicle. But often design restrictions and energy consumption do not allow constellations of cameras with overlapping field of views. However, for a common and geometric usage of the extracted information, e.g., in structure from motion tasks, it is necessary to know the relative alignment of the cameras, which are the extrinsic calibration parameters. This paper addresses the extrinsic calibration of a multi-camera rig with non-overlapping field of views on a mobile platform. As the field of views do not necessarily overlap, common calibration methods based on corresponding image points between the camera views will fail. This problem can be overcome by using the mobility of the platform. A pattern-based method for extrinsic calibration of the camera rig on a mobile platform is presented.

Using Multiple Correspondence Analysis for Large Driving Signals Database Exploration. Example with Lane Narrowing and Curves, pp. 1184-1189
Loslever, Pierre Univ. de Valenciennes
Popieul, Jean-Christophe    Univ. de Valenciennes
Simon, Philippe Univ. de Valenciennes
Todoskoff, Alexis       Univ. of Angers

In most driving studies, several factors (at least two, i.e. individual and time) and many variables are collected via multidimensional signals (MS). This article suggests starting the analysis while keeping the three main aspects of time, i.e. simultaneity, chronology and duration. To achieve this aim, with the possibility to show nonlinear relationships, a MS set exploratory investigation is performed using the pair space-time windowing/Multiple Correspondence Analysis. This article shows how intra and inter-individual differences can be underscored.

The Effect of Vehicular Distance Distributions and Mobility on Vehicular Communications, pp. 1190-1194
Nagel, Robert    Munich Univ. of Tech.

In vehicular ad-hoc networks, physical parameters of traffic flow (traffic density and velocities), directly relate to networking parameters (node degree and duration of communication). While existing research on these relations has mainly focused on simulation work or on the free-flow regime of traffic, we discuss these relations for both free-flow and congested traffic and provide an analytical framework for the computation of relevant networking parameters. We also discuss some results and analyze their impact on vehicular communications.
datasets. Specifically, the use of RADAR and speed data types of data are extracted from these naturalistic driving studies, and provides some examples of how common codes key aspects of how such studies are designed and description of driver distraction into a deeper understanding of driver behavior and, as datasets are expanded to include diverse populations, they will help researchers and automotive engineers in developing novel ways to mitigate and prevent vehicular crashes and their consequences.

9:50-11:00  ThB1.28
**Driver Route Choice Behavior: Experiences, Perceptions, and Choices**, pp. 1195-1200
Tawfik, Aly M. Virginia Tech.
Rakha, Hesham A. Virginia Tech.
Miller, Shadeequa Univ. of Wisconsin-Madison
Within the context of transportation modeling, driver route choice is typically captured using mathematical programming approaches, which assume that drivers, in attempting to minimize some objective function, have full knowledge of the transportation network state. Typically, drivers are assumed to either minimize their travel time (user equilibrium) or minimize the total system travel time (system optimum). Given the dynamic and stochastic nature of the transportation system, the assumption of a driver’s perfect knowledge is at best questionable. While it is well documented in psychological sciences that humans tend to minimize their cognitive efforts and follow simple heuristics to reach their decisions, especially under uncertainty and time constraints, current models assume that drivers have perfect or close to perfect knowledge of their choice set, as well as the travel characteristics associated with each of the choice elements. Only a few of the many route choice models that are described in the literature are based on observed human behavior. With this in mind the research presented in this paper monitors and analyzes actual human route choice behavior. It compares actual drivers experiences, perceptions and choices, and demonstrates that (a) drivers perceptions are significantly different from their actual experiences, and that drivers’ choices are better explained by their perceptions than their experiences; (b) drivers perceive travel speeds better than travel times; (c) perceived travel speeds seem to influence route choice more than perceived travel times, and (d) drivers’ route choice behavior differs across different driver groups.

9:50-11:00  ThB1.29
**Extracting Information from Continuous Naturalistic Driving Data: Sample Applications**, pp. 1201-1208
Perez, Miguel Virginia Tech. Transportation Inst.
Doerzaph, Zachary Virginia Tech. Transportation Inst.
Gaylord, Clark Virginia Tech. Transportation Inst.
Hankey, Jonathan Virginia Tech. Transportation Inst.
The technology and tools used for naturalistic driving data collection have evolved greatly in recent years. Data collection efforts that required a trunk full of equipment and days of installation can now be achieved with data acquisition systems that are about the size of a deck of cards and can be installed in minutes. This evolution has made possible large-scale driving data collection efforts, such as the upcoming Second Safety Highway Research Program Naturalistic Driving Study (SHRP2 NDS). Data from naturalistic studies allow for an unparalleled breadth and depth of driver behavior analysis that goes beyond the quantification and description of driver distraction into a deeper understanding of how drivers interact with their vehicles. This paper describes key aspects of how such studies are designed and executed, and provides some examples of how common types of data are extracted from these naturalistic driving datasets. Specifically, the use of RADAR and speed data are discussed in detail. In addition, a sample architecture for the storage of and access to these vast quantities of driving data and video is provided. Naturalistic driving data have allowed for a transformation in the understanding of driver behavior and, as datasets are expanded to include diverse populations, they will help researchers and automotive engineers in developing novel ways to mitigate and prevent vehicular crashes and their consequences.

9:50-11:00  ThB1.30
**Experimental Study of 802.11 Based Networking for Vehicular Management and Safety**, pp. 1209-1213
Dailey, Daniel J.Univ. of Washington
This paper focuses on the experimental aspect of short range communication between a moving vehicle and a stationary receiver. The accumulated measurements of signal to noise ratio fit a single line of site model rather well with the implication that the communications channel will function best as the distance between the radios is reduced. However, measurements of both bandwidth and packet loss suggest that when the vehicle passes nearby the stationary receiver at approximately the planned speeds (10 or 20 MPH) that the communication channel throughput is reduced.

9:50-11:00  ThB1.31
**How to Conduct a Car? a Design Example for Maneuver Based Driver-Vehicle Interaction**, pp. 1214-1221
Kauer, MichaeleTech. Univ. Darmstadt
Schreiber, Michael TU Darmstadt
Bruder, Ralph Techn. Univ. Darmstadt
Conduct-by-Wire is a vehicle guidance paradigm, which investigates the possibility of controlling an automobile by maneuver commands. The focus of this paper is to show one possible interaction strategy for maneuver-based vehicle guidance between driver and vehicle by means of discrete maneuvers. Therefore, the paper starts with a short introduction to the advantages of maneuver-based vehicle guidance and proceeds to the current design option for maneuver-based driver-vehicle interaction chosen by the TU Darmstadt. This includes the presentation of the user interface as well as the basic assumptions for maneuver-based interaction. This paper is finished by a specific example for the maneuver “Lane Change right”, which includes system behavior, as well as, information displaying and some restricting facts which are presented together with possible countermeasures.

9:50-11:00  ThB1.32
**A Vehicular Filter Suitable for Co-Operative Automotive Safety Applications**, pp. 1222-1227
Lytrivis, Panagiotis Inst. of Comm. & Comp. Syst.
Tsogas, Manolis Inst. of Communication and Computer Systems
Thomaidis, Georgios Inst. of Comm. and Comp. Syst.
Amelis, Angelos Inst. of Communications and Computer Systems
Experimental Study of 802.11 Based Networking for Vehicular Management and Safety, pp. 1209-1213
Dailey, Daniel J.Univ. of Washington
This paper focuses on the experimental aspect of short range communication between a moving vehicle and a stationary receiver. The accumulated measurements of signal to noise ratio fit a single line of site model rather well with the implication that the communications channel will function best as the distance between the radios is reduced. However, measurements of both bandwidth and packet loss suggest that when the vehicle passes nearby the stationary receiver at approximately the planned speeds (10 or 20 MPH) that the communication channel throughput is reduced.

9:50-11:00  ThB1.33
**Perceptions, and Choices**
**Driver Route Choice Behavior**: pp. 1195-1200
Tawfik, Aly M. Virginia Tech.
Rakha, Hesham A. Virginia Tech.
Miller, Shadeequa Univ. of Wisconsin-Madison
Within the context of transportation modeling, driver route choice is typically captured using mathematical programming approaches, which assume that drivers, in attempting to minimize some objective function, have full knowledge of the transportation network state. Typically, drivers are assumed to either minimize their travel time (user equilibrium) or minimize the total system travel time (system optimum). Given the dynamic and stochastic nature of the transportation system, the assumption of a driver’s perfect knowledge is at best questionable. While it is well documented in psychological sciences that humans tend to minimize their cognitive efforts and follow simple heuristics to reach their decisions, especially under uncertainty and time constraints, current models assume that drivers have perfect or close to perfect knowledge of their choice set, as well as the travel characteristics associated with each of the choice elements. Only a few of the many route choice models that are described in the literature are based on observed human behavior. With this in mind the research presented in this paper monitors and analyzes actual human route choice behavior. It compares actual drivers experiences, perceptions and choices, and demonstrates that (a) drivers perceptions are significantly different from their actual experiences, and that drivers’ choices are better explained by their perceptions than their experiences; (b) drivers perceive travel speeds better than travel times; (c) perceived travel speeds seem to influence route choice more than perceived travel times, and (d) drivers’ route choice behavior differs across different driver groups.
exploiting the co-operation among vehicles to enhance road safety, efficiency and comfort. In vehicular ad hoc networks, especially in safety related applications, accuracy of the information exchanged through the wireless network, such as position and velocity of each vehicle, is crucial. For this reason a robust and accurate vehicular filter which also reduces measurements' noise is needed. The extended Kalman filter is used as standard technique for performing recursive nonlinear estimation. However, it provides only an approximation to optimal nonlinear estimation. In order to avoid sub-optimal performance an enhanced unscented Kalman filter is used. The enhancement is that a combination of different motion models is exploited, leading to a more accurate modeling of the vehicle's movement. For this combination the curvature of the road from a digital map and the yaw rate and acceleration values from the vehicle are taken into consideration. The performance of the proposed unscented filter is proven to be superior compared to the performance of both the extended Kalman filter and the simple unscented filter which takes into account only a specific motion model.

**ThC1 Room T1**

**Active and Passive Safety** (Regular Session)

Chair: Eskandarian, Azim  George Washington Univ.

11:00-11:20  ThC1.1  
**Complexity Reduction Using the Random Forest Classifier in a Collision Detection Algorithm**, pp. 1228-1235

Lauer, Christoph  Univ. Erlangen Nuremberg  Botsch, Michael  AUDI AG  

Advanced proactive safety applications are considered a promising approach to increase the effectiveness of already highly optimized vehicular safety systems. Detecting an unavoidable crash situation before the actual collision is of utmost importance and requires an effective real-time implementation. In this paper a collision detection algorithm based on the curvilinear-motion model for trajectory estimation is presented. The algorithm takes into account the EGOvehicle's driving state and the high-level representation of surrounding objects. Next the presented approach is evaluated from a real-time perspective by applying static code analysis to a reference implementation of the algorithm. The results suggest the application of further optimization techniques as the computational complexity does not allow an effective real-time behavior. In order to guarantee both real-time constraints and effective collision detection a novel method for the pre-selection of potential collision opponents based on the Random Forest classifier is employed. The combination of efficient preselection and the proposed collision detection algorithm leads to a highly effective context interpretation that does not neglect the tight economic constraints.

11:20-11:40  ThC1.2  

Sathyanarayana, Amardeep  Univ. of Texas at Dallas  Boyraz, Pinar  Univ. of Texas at Dallas  Purohit, Zelam  Univ. of Texas at Dallas  Lubag, Rosarita  Univ. of Texas at Dallas  Hansen, John  Univ. of Texas at Dallas  

Increasing stress levels in drivers, along with their ability to multi task with infotainment systems cause the drivers to deviate their attention from the primary task of driving. With the rapid advancements in technology, along with the development of infotainment systems, much emphasis is being given to occupant safety. Modern vehicles are equipped with many sensors and ECUs (Embedded Control Units) and CAN-bus (Controller Area Network) plays a significant role in handling the entire communication between the sensors, ECUs and actuators. Most of the mechanical links are replaced by intelligent processing units (ECU) which take in signals from the sensors and provide measurements for proper functioning of engine and vehicle functionalities along with several active safety systems such as Anti-lock Brake System and Electronic Stability program. Current active safety systems utilize the vehicle dynamics (using signals on CAN-bus) but are unaware of context and driver status, and do not adapt to the changing mental and physical conditions of the driver. The traditional engine and active safety systems use a very small time window (t<2sec) of the CAN-bus to operate. On the contrary, the implementation of driver adaptive and context aware systems require longer time windows and different methods for analysis. The long-term history and trends in the CAN-bus signals contain important information on driving patterns and driver characteristics. In this paper, a summary of systems that can be built on this type of analysis is presented. The CAN-bus signals are acquired and analyzed to recognize driving sub-tasks, maneuvers and routes. Driver inattention is assessed and we present an overall system which acquires, analyses and warns the driver in real time.

11:40-12:00  ThC1.3  
**Left behind Occupant Recognition in Parked Cars Based on Acceleration and Pressure Information Using K-Nearest-Neighbor Classification**, pp. 1242-1247

Fischer, Christian  Univ. of Wuppertal  Tibken, Bernd  Univ. of Wuppertal  Fischer, Thomas  Delphi Delco Europe GmbH  

One of the major causes of lethal or serious injuries to children in non-traffic accidents with cars is founded on the unattended left behind of them in parked cars. Therefore, Delphi’s safety division is interested in the development of a low cost left behind occupant recognition, so that since 2008 different approaches for a reliable detection system are evaluated. One of them is based on high sensitive analogue accelerometers that monitor vibrations occurring at the car chassis. The investigations show a recognizable signal produced by human beings seated in a parked car which provides enough information to determine the occupancy state of a car. The presented contribution describes the additional use of a second sensor (pressure signal) input to improve the classification reliability by fusing the information of both sensing elements. This is illustrated at the k-Nearest-Neighbor algorithm as preferred classifier.
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