Scanning the Issue and Beyond: Parallel Driving With Software Vehicular Robots for Safety and Smartness

First, I would like to thank our Guest Editors Cristina Olaverri-Monreal and Rosaldo J. F. Rossetti for their hard work and great effort for the special issue on "Human Factors in Intelligent Vehicles." The special issue and our white paper on smart grid and intelligent vehicles have reminded me of some old and new works I have conducted more than a decade ago and recently, which are in my thoughts on a new direction for intelligent vehicle research in this issue: parallel driving for safety and smartness. Please check @IEEE-TITS (http://www.weibo.com/u/3967923931) on Weibo (an extended Chinese version of Twitter), https://www.facebook.com/IEEEITS on Facebook, and @IEEEITS (https://twitter.com/IEEEITS) on Twitter for any news regarding IEEE ITSS, IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, and *IEEE Intelligent Transportation Systems* magazine. The three sites are under development and your participation and suggestions are extremely welcome.

SCANNING THE ISSUE

Electrified Vehicles and the Smart Grid: The ITS Perspective

X. Cheng, X. Hu, L. Yang I. Husain, K. Inoue, P. Krein, R. Lefevre, Y. Li, H. Nishi, J. G. Taiber, F.-Y. Wang, Y. Zha, W. Gao, and Z. Li

Vehicle electrification is envisioned to be a significant component of the forthcoming smart grid. Based on the discussion from a series of workshops on smart grid and intelligent vehicles sponsored by IEEE, a smart grid vision of electric vehicles for the next 30 years and beyond is presented from six perspectives pertinent to intelligent transportation systems: vehicles; infrastructure; travelers; systems, operations, and scenarios; communications; social, economic, and political impacts.

Classification of Driving Direction in Traffic Surveillance Using Magnetometers

N. Wahlström, R. Hostettler, F. Gustafsson, and W. Birk

Traffic monitoring using low-cost two-axis magnetometers is considered. We propose a simple algorithm based on a nonlinear transformation of the measurements, which is simple to implement in embedded hardware. A theoretical justification is provided, and the statistical properties of the test statistic are presented in closed form. The method is compared to the standard likelihood ratio test on both simulated data and real data from field tests, where very high detection rates are reported, despite the presence of sensor saturation, measurement noise, and near-field effects of the magnetic field.

Modeling and Detecting Aggressiveness from Driving Signals

A. B. R. González, M. R. Wilby, J. J. Vinagre Díaz, and C. Sánchez Ávila

Driving aggressiveness is modeled as a linear filter operating on external driving signals, such as lateral and longitudinal accelerations, and speed. This model is validated via an experiment conducted under real driving conditions subject to both smooth and aggressive behaviors. The obtained results confirm the validity of the model of aggressiveness. In addition, they show the generality of this model and its applicability to every driving signal, every single driver, and every road type. Finally, we build a classifier that is capable of detecting aggressive behavior from the driving signal with a success rate of up to 92%.

A Novel Electric Vehicle for Smart Indoor Mobility

A G. Bianchessi, C. Ongini, I. Boniolo, G. Alli, C. Spelta, M. Tanelli, and S. M. Savaresi

This paper presents the design of the vehicle platform and of the related control system of an innovative electric vehicle tailored to indoor personal mobility without handle bars. Specifically, the inertial sensors onboard of smart phone allow commanding the vehicle motion, and two metal in-soles equipped with pressure sensors allow gathering the user's weight distribution in real time to issue the steering commands. The work presents all the development phases, characterized by a codesign of the vehicle mechanics and electronic systems that makes the motion control problem more easily manageable than that of comparable existing mobility solutions.

Situational Knowledge Representation for Traffic Observed by a Pavement Vibration Sensor Network

M. Stocker, M. Rönkkö, and M. Kolehmainen

This paper presents and discusses the architecture of a software system that utilizes sensor data, digital signal processing, machine learning, and knowledge representation and reasoning to acquire, represent, and infer knowledge about real-world situations that are observable with a sensor network for traffic control and management. The application of the system to vehicle detection and classification by measuring road-pavement vibration is demonstrated.

B-Planner: Planning Bidirectional Night-Bus Routes Using Large-Scale Taxi GPS Traces

C. Chen, D. Zhang, N. Li, and Z.-H. Zhou

A two-phase approach for bidirectional night-bus route planning is proposed using taxi GPS information. In the first

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phase, a process to cluster "hot" areas with dense passenger pickup/dropoff is proposed, and it is then followed by effective methods to split large "hot" areas into clusters and identify a location in each cluster as a candidate bus stop. In the second phase, given the bus route origin, destination, candidate bus stops, and bus operation time constraints, it derives several effective rules to build the bus route graph and prunes invalid stops and edges iteratively. Based on this graph, a bidirectional probability-based spreading algorithm is developed to generate candidate bus routes automatically for selecting the best bidirectional bus route.

Robust Traffic Sign Recognition Based on Color Global and Local Oriented Edge Magnitude Patterns

X. Yuan, X. Hao, H. Chen, and X. Wei

A novel Color Global and Local Oriented Edge Magnitude Pattern is proposed as a framework to effectively combine color, global spatial structure, global direction structure, and local shape information and balance the two concerns of distinctiveness and robustness for traffic sign recognition. Experiments are performed to validate the effectiveness of the proposed approach with traffic sign recognition systems, and the experimental results are satisfying, even for images containing traffic signs that have been rotated, damaged, altered in color, or undergone affine transformations, or images that were photographed under different weather or illumination conditions.

General Behavior Prediction by a Combination of Scenario-Specific Models

S. Bonnin, T. H. Weisswange, F. Kummert, and J. Schmuedderich

A computational system designed to anticipate other traffic participants' behaviors could assist the driver in decision making, by sending an early warning when a risk of collision is predicted. Existing research in this area usually focuses on only one of two aspects: quality or scope. In general, we see methods targeting broad scope but showing low quality and others having narrow scope but high quality. The goal is to create a system with high quality and high scope. To achieve this, this paper proposes an architecture that combines classifiers to predict behaviors for highway and inner-city scenarios.

On Topology of Sensor Networks Deployed for Multitarget Tracking

Y. Zhu, A. Vikram, and H. Fu

Topologies of sensor networks for tracking multiple targets based on blind source separation (BSS) are proposed. The topology of a wireless sensor network with BSS-based algorithms is critical to tracking performance. First, the topology affects separation performance. Second, the topology determines the accuracy and precision of estimation on the paths taken by targets. Cluster topologies are proposed for BSS-based tracking algorithms. Guidelines on parameter selection for proposed topologies are given here. The proposed cluster topologies are evaluated with extensive experiments. Experiments show that the proposed topologies can significantly improve both the accuracy and the precision of BSS-based tracking algorithms.

Fuel Panics: Insights From Spatial Agent-Based Simulation

E. Upton and W. J. Nuttall

This paper demonstrates that computational agent-based techniques offer a powerful framework for cosimulation of supply chains and consumers under conditions of transient demand. In the case of a fuel panic crisis, it shows that even a highly abstract model can reproduce a range of transient phenomena seen in the real world, and presents a set of practical recommendations for policymakers faced with panic buying.

Earliest Deadline-Based Scheduling to Reduce Urban Traffic Congestion

A. Ahmed, R. Arshad, S. A. Mahmud, G. M. Khan, and H. S. Al-Raweshidy

The evaluation of two scheduling algorithms as adaptive traffic control has been proposed here to reduce unwanted delay by the priority vehicles. One is the earliest deadline first (EDF), while the other is the fixed priority (FP). A comparative study is performed, in which they were compared against a fixed traffic controller. Results reveal that the number of stops, the average delay, and the mean trip time of the priority vehicles are significantly reduced by these algorithms. Furthermore, the overall performance of the EDF is much better than the FP, in terms of improvement in different performance measures for congestion reduction of priority vehicles.

Cooperative Adaptive Cruise Control: Network-Aware Analysis of String Stability

S. Öncü, J. Ploeg, N. van de Wouw, and H. Nijmeijer

A cooperative adaptive cruise control (CACC) system, which regulates intervehicle distances in a vehicle string for achieving improved traffic flow stability and throughput, is studied. The design of a CACC system is approached from a networked control system (NCS) perspective under a NCS modeling framework that incorporates the effect of sample-and-hold and network delays that occur due to wireless communication and sampled-data implementation of the CACC controller over this wireless link. Based on this network-aware modeling approach, a technique to study the so-called string stability property of the string, in which vehicles are interconnected by a vehicle following control law and a constant time headway spacing policy, is developed.

On-Demand Conflict Resolution Procedures for Air-Traffic Intersections

J. D. Yoo and S. Devasia

This paper develops a provably safe on-demand conflict resolution procedure (CRP) for intersecting routes in en route air-traffic control. The present paper removes the inefficiency of always-on CRPs by developing provably safe CRPs that can be activated on demand (when conflicts appear) to accommodate an impending conflict. Conditions are developed to guarantee safety during activation and deactivation of the CRP, and the proposed on-demand approach is illustrated through an example route intersection.

Formal Intent-Based Trajectory Description Languages

G. Frontera, J. A. Besada, A. M. Bernardos, E. Casado, and J. López-Leonés

An improved version of intent-related hierarchy of formal languages for describing aircraft trajectories is presented. These languages allow a complete or partial specification of aircraft trajectories at different levels, and the extension of its features here allows their applicability to define more complex types

of missions. This paper provides a complete description of lexicon, syntax, and graphical representation details for each language and shows their applicability through a set of clarifying examples of flight specifications with different granularity. The versatility and flexibility of described language are demonstrated through a set of scenarios identifying characteristic operational examples.

Dynamic Vehicle Redistribution and Online Price Incentives in Shared Mobility Systems

J. Pfrommer, J. Warrington, G. Schildbach, and M. Morari

A combination of intelligent repositioning decisions and dynamic pricing for the improved operation of shared mobility systems is considered and applied to London's Barclays Cycle Hire scheme. Dynamically varying rewards are computed and offered to customers with the aim of encouraging them to park bicycles at nearby under-used stations, thereby reducing the expected cost of repositioning using dedicated staff. In parallel, the routes that the repositioning staff should take are periodically recomputed. It is shown that it is possible to tradeoff reward payouts to customers against the cost of hiring staff to reposition bicycles.

A Switching Rollover Controller Coupled With Closed-Loop Adaptive Vehicle Parameter Identification

M. Akar and A. D. Dere

A real-time adaptive switching controller is designed to mitigate rollover accidents without reducing the performance of the vehicle. The proposed controller relies on the adaptive identification of vehicle lateral and vertical dynamics parameters, including the center of gravity (CG) height that has a major role in rollover. Least squares and Kalman filtering techniques are employed in order to propose two novel identification algorithms that are robust against speed variations, which can further be coupled effectively with a switching rollover controller while parameter identification is in progress. Extensive simulations are carried out in order to demonstrate the superior performance of the proposed method.

Monocular Road Terrain Detection by Combining Visual and Spatial Information

J. Fritsch, T. Kühnl, and F. Kummert

A new hierarchical two-stage approach for learning the spatial layout of road scenes is introduced. In the first stage, base classifiers analyze the local visual properties of patches extracted from monocular camera images and provide metric confidence maps. The core of the proposed approach is the computation of SPatial RAY (SPRAY) features from each metric confidence map in the second stage. The approach is evaluated by operating at 20 Hz on a graphics processing unit, on a publicly available data set, and its performance on a variety of road types and weather conditions is shown.

Improving Traffic Flow Efficiency by In-Car Advice on Lane, Speed, and Headway

W. J. Schakel and B. van Arem

A new in-car advisory system that gives advice on lane, speed and headway is presented. The system aims at an optimal lane distribution in high flow conditions, decreasing the chance of spillback by advising drivers away from the right lane, and a reduction of the capacity drop by advising drivers to maintain a short headway at the end of congestion. Benefits at both low and high rates are found because only a small redistribution of traffic over the lanes may be required to stabilize flow. The capacity drop is reduced mainly at high rates because it is required that many vehicles accelerate more. The maximum benefit found is a reduction of 49% in travel time delay.

A Proxy-Based Authentication and Billing Scheme With Incentive-Aware Multihop Forwarding for Vehicular Networks

L.-Y. Yeh and Y.-C. Lin

A localized-based authentication and billing scheme is proposed to lessen the long-distance communication overhead for full vehicular ad hoc networks, including the vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) environments. Only a few signatures are used in the first message to ensure the nonrepudiation payment approval. Security analysis and performance evaluation support the proposed scheme, as compared with the conventional public-key-based scheme. Its advantages include the following: 1) mutual authentication and session key agreement; 2) privacy preservation; 3) confidentiality, integrity, free-riding resistance, double-spending avoidance, and nonrepudiation properties; 4) efficient billing and payment clearance.

Smart Public Transit System Using an Energy Storage System and Its Coordination With a Distribution Grid

A. Agrawal, M. Kumar, D. Kumar Prajapati, M. Singh, and P. Kumar

A transportation network based on a supercapacitor-powered electric city bus has been shown to work in harmony with the electric grid. The load profile of the transportation network and the grid are interfaced using a battery-based energy storage system (ESS). The ESSs stabilize the grid at the corresponding node through peak shaving and valley filing during peak and off-peak hours, respectively. The objective is to achieve the required frequency of buses and maintain the grid voltage close to 1 per unit. Increasing penetration of an electric-bus-based transit system will substantially improve the grid operation efficiency and also reduce oil consumption by the transport sector.

Transit Coordination Using Integer-Ratio Headways

D. Tuzun Aksu and U. Akyol

A novel genetic algorithm that creates clusters of routes, whose coordination reduces the transfer time for connecting passengers, is proposed. The objective is to minimize the total system cost, which includes in-vehicle, waiting, and transfer costs for all passengers served by the transit system and the operating cost of all transit vehicles. The experimental study conducted on one transit network from the literature, as well as a new network based on the Istanbul rail system, demonstrates that this approach produces superior results compared to the literature.

Modeling and Nonlinear Adaptive Control for Autonomous Vehicle Overtaking

P. Petrov and F. Nashashibi

A mathematical model and adaptive controller for an autonomous three-phase overtaking without the use of any roadway marking scheme or intervehicle communication are considered. The developed feedback controller requires information for the current relative intervehicle position and

orientation, which is assumed to be available from onboard sensors. The standard robotic nomenclature for translational and rotational displacements and velocities is used for a general kinematic model of the vehicles and relative intervehicle kinematics during the overtaking maneuver. An update control law for the automated overtaking vehicle is designed, which allows tracking the desired trajectories in the presence of unknown velocity of the overtaken vehicle.

A Real-Time Transit Signal Priority Control Model Considering Stochastic Bus Arrival Time

X. Zeng, Y. Zhang, K. N. Balke, and K. Yin

A stochastic mixed-integer nonlinear model (SMINP) is used as the core component of a real-time transit signal priority (TSP) control system. The model adopts a novel approach to capture the impacts of the priority operation to other traffic, by using the deviations of the phase split times from the optimal background split times. Comparison analyses were performed to compare the proposed control model with the state-of-the-practice TSP system [i.e., ring-barrier controller (RBC)-TSP]. The results showed the SMINP has yielded as much as 30% improvement in bus delay, comparing to RBC-TSP, in a single-bus case. In a multiple-bus case, SMINP handles the bus priority request much more effectively under congested traffic conditions.

Comparing Optimal Relocation Operations With Simulated Relocation Policies in One-Way Carsharing Systems

D. Jorge, G. H. A. Correia, and C. Barnhart

Realistic ways to mitigate the imbalance caused by carsharing through relocating vehicles and a new mathematical model to optimize relocation operations with a simulation model for different real-time relocation policies are studied. Both methods were applied to networks of stations in Lisbon, Portugal, and results show significant increases in profit. In the case in which the carsharing system provides maximum coverage of the city area, imbalances in the network resulted in an operating loss of 1160 €/day, when no relocation operations were performed. When relocation policies were applied, however, the simulation results indicate profits of 854 €/day, even with increased costs due to relocations.

Bayesian Road Estimation Using Onboard Sensors

Á. F. García-Fernández, L. Hammarstrand, M. Fatemi, and L. Svensson

An algorithm for estimating the road ahead of a host vehicle based on the measurements from several onboard sensors is described. A novel road model that is able to describe the road ahead with higher accuracy than the usual polynomial model is proposed. A Bayesian fusion system that uses the following information from the surroundings is developed: lane marking measurements obtained by the camera and leading vehicle and stationary object measurements obtained by a radar–camera fusion system. The performance of the fusion algorithm is evaluated in several drive tests. As expected, the more information used, the better the performance is.

An Iranian License Plate Recognition System Based on Color Features

A. H. Ashtari, Md. J. Nordin, and M. Fathy

An Iranian vehicle license plate recognition system based on a new approach for its localization is proposed along with a hybrid classifier that recognizes license plate characters. A modified strip search to localize a standard color-geometric template in Iran and a few European countries is proposed. License plate characters are recognized by a hybrid classifier that comprises a decision tree and a support vector machine with a homogeneous fifth-degree polynomial kernel. The proposed system ensures 96% performance detection rate and 94% recognition rate.

A Simulation Analysis on the Existence of Network Traffic Flow Equilibria

S. Lin, Q.-J. Kong, and Q. Huang

To verify the existence of the equilibria on macroscopic fundamental diagrams (MFDs), microscopic simulations are run for an urban traffic network with various network input traffic flows and traffic signal control strategies. The simulation results show that the traffic network can reach its network flow equilibria if the traffic flows in the network are in the linear region of the MFD, although the network flows are heterogeneous. However, network flow equilibria do not exist for the nonlinear region of the MFD, unless the traffic network flows are homogeneous.

Pedestrian Simultaneous Localization and Mapping in Multistory Buildings Using Inertial Sensors

M. Garcia Puyol, D. Bobkov, P. Robertson, and T. Jost

FootSLAM is extended to multistory buildings following a Bayesian derivation. This approach employs a particle filter and partitions the map space into a grid of adjacent hexagonal prisms with eight faces. The multistory FootSLAM maps are created from three data sets collected in different buildings. Hereby, the user is only carrying a single foot-mounted inertial measurement unit. The resulting maps are strong evidence of the robustness of FootSLAM. This work raises the future possibility of crowdsourced indoor mapping and accurate navigation using other forms of human odometry, e.g., obtained with the low-cost and nonintrusive sensors of a hand-held smartphone.

Parallel Public Transportation System and Its Application in Evaluating Evacuation Plans for Large-Scale Activities

F. Zhu, S. Chen, Z.-H. Mao, and Q. Miao

This paper proposes a method based on ACP (artificial societies, computational experiments, and parallel execution) to build parallel public transportation systems (PPTS). The framework and components of a PPTS are analyzed, and some details for building the PPTS are discussed. One prototype based on intelligent traffic clouds is established. One specific PPTS is developed for the Guangzhou 2010 Asian Games in the case study, and its effectiveness is verified through the evaluation of two evacuation plans for the Asian Games.

SPECIAL ISSUE PAPERS

Detection of Intoxicated Drivers Using Online System Identification of Steering Behavior

M. M. Shirazi and A. B. Rad

A novel method to detect intoxicated driving is presented and lays a foundation for future cars to derive personalized models of the drivers and to detect not only intoxicated driving but also other reckless driving styles. Two hundred sets of

data from various subject drivers were collected in a high-fidelity driving simulator. Lateral preview error and steering wheel angle were considered as input and output of the driver, respectively. Aggressive driving style due to impaired driving leads to migration of dominant poles toward the instability region. A Kalman filter and online identification techniques are used to update the driver model during driving.

Study on Emergency Avoidance Braking for the Automatic Platooning of Trucks

R. Zheng, K. Nakano, S. Yamabe, M. Aki, H. Nakamura, and Y. Suda

An experimental study on emergency braking to avoid rear-end collisions during the automatic platooning of trucks is presented. In particular, with different settings for the mean maximum decelerations of the brake system of the following truck, the stopping gap distances and driver reaction times are analyzed in the driving experiment, using the advanced driving simulator and an actual vehicle. The experimental results indicate that emergency braking is an effective method for avoiding rear-end collision when there is a system failure in the automatic platooning, resulting in the mean maximum deceleration for the following truck being higher than for the preceding truck.

Vehicle Active Steering Control System Based on Human Mechanical Impedance Properties of the Arms

Y. Tanaka, N. Yamada, T. Tsuji, and T. Suetomi

This paper presents the experimental data of human mechanical impedance properties (HMIP) of the arms. The HMIP data show that human stiffness/viscosity has the minimum/maximum value at the neutral angle of the steering wheel in relax and increases/decreases for the amplitude of steering angle and torque, and that the stability of arm motion in handling the steering wheel becomes high around the standard condition. Next, a novel methodology for designing an adaptive steering control system based on HMIP is proposed, and the effectiveness was demonstrated via a set of double-lane-change tests with several subjects.

Impact of In-Vehicle Display Location Preferences on Drivers' Performance and Gaze

C. Olaverri-Monreal, A. E. Hasan, J. Bulut, M. Körber, and K. Bengler

Differential preferences for the layout of advanced driver assistance systems (ADAS) and driver information systems (DIS) are compared to existing ones through a card-sorting experiment. To validate the data, it additionally studies the driver performance and gaze with the preferred locations for in-vehicle information through gaze location and speed metric measurements. Drivers' preferences regarding the functional layout of current DIS and ADAS compared to existing ones did not essentially differ from the layouts that are currently on the market. However, including mobile applications and social media in a vehicular context is not considered necessary.

Haptic Steering Support for Driving Near the Vehicle's Handling Limits: Test-Track Case

D. I. Katzourakis, E. Velenis, E. Holweg, and R. Happee

The goal of this study is to develop and evaluate a haptic steering support when driving near the vehicle's handling limits (HSNL). The support aims to promote the driver's perception of the vehicle's behavior and handling capacity, by providing haptic cues on the steering wheel. The HSNL has been evaluated in a test track, where 17 test subjects drove around a narrow twisting tarmac circuit. The drivers were instructed to achieve maximum velocity through corners, while receiving haptic steering feedback cues related to the vehicle's cornering potentials. The test-track tests led to the conclusion that haptic support reduced drivers' mental and physical demand without affecting their driving performance.

Toward a Methodology for Assessing Electric Vehicle Exterior Sounds

S. Singh, S. R. Payne, and P. A. Jennings

This paper examines automotive exterior sound evaluation methods in the context of experimental design and cognitive psychology. Currently, such evaluations are usually conducted on roads or inside a laboratory, yet a virtual environment provides advantages over both these methods but none of their limitations. A methodology is proposed for conducting evaluations of an electric vehicle's exterior sounds, testing its detectability and emotional evaluation. An experiment indicates that, overall, the proposed methodology increases the realistic context and experimental control than in existing listening evaluations. It benefits by combining two competing elements necessary for assessing electric vehicle exterior sounds, i.e., pedestrian safety and impressions of the vehicle brand.

Effect of Using an In-Vehicle Smart Driving Aid on Real-World Driver Performance

S. A. Birrell, M. Fowkes, and P. A. Jennings

A smart driving system was evaluated in real-world on-road driving trials to see if any measurable beneficial changes in driving performance would be observed. Forty participants drove an instrumented vehicle over a 50-min mixed-route driving scenario. Two conditions were adopted, i.e., one with a control with no smart driving feedback offered and the other with advice being presented to the driver via a smartphone in the vehicle. Key findings from the study showed a 4.1% improvement in fuel efficiency when using the smart driving aid, importantly with no increase in journey time or reduction in average speed.

Toward Privacy-Protecting Safety Systems for Naturalistic Driving Videos

S. Martin, A. Tawari, and M. M. Trivedi

A common pool of naturalistic driving data is necessary to develop and compare algorithms that infer driver behavior, in order to improve driving safety. Naturalistic driving data, such as video sequences of looking at the driver, however, cause concern for privacy of individual drivers. In an ideal situation, a deidentification filter applied to the raw image of looking at the driver would, semantically, protect the identity and preserve the behavior of the driver. This study implements a specific deidentification filter on video sequences of looking at the driver from naturalistic driving and presents novel findings on its effect on face recognition and driver gaze-zone estimation.

Subjective Traffic Safety Experts' Knowledge for Driving-Risk Definition

O. S. Siordia, I. Martín de Diego, C. Conde, E. Cabello

This paper presents a novelty system for the detection of driving risk situations based on the combination of the knowledge acquired from traffic safety experts. Two kinds of experiments were designed: controlled driving sessions and natural driving sessions. A group of traffic safety experts from the Royal Automobile Club of Spain were consulted to evaluate the driving risk in each simulated session. The information acquired from the traffic safety experts was used to develop a methodology to combine their evaluations. The risks detected with the proposed methodology were analyzed to determine the most common human factors related with the generation of driving risk situations.

A Validation Study on a Subjective Driving-Workload Prediction Tool

Y. Hwang, D. Yoon, H. S. Kim, and K.-H. Kim

This study validates a subjective driving-workload prediction tool (DWPT) composed of three subfactors: the situational inadaptability, the risk-taking personality, and the interpersonal inadaptability. Thirty male drivers participated in this study. The analysis results showed that a driver's predicted score of subjective driving-workload had a positive or negative relation to their workload-related driving behaviors. In particular, two subfactors, i.e., the risk-taking personality and the interpersonal inadaptability, were more closely related to their driving behaviors than the total predicted subjective driving-workload and situational inadaptability subfactor. These results suggest that a DWPT could be used to predict the drivers' subjective driving-workload, instead of measuring the driving performance or self-reporting questionnaire.

Driver Workload Characteristics Analysis Using EEG Data from an Urban Road

H. S. Kim, Y. Hwang, D. Yoon, W. Choi, and C. H. Park

Electroencephalogram (EEG) data collected through an urban road driving test are analyzed for driving workloads. Five kinds of behavior sections from the data are extracted, and a reference section is selected for each of these behaviors. EEG values from the behavior sections are compared to those from the reference sections to calculate the EEG variation rates. The analysis results of this paper are being used to explain the cognitive characteristics of a driving workload caused by drivers' behavior in the human–vehicle interface management system, which will provide information for safe driving by taking into account the driving workload.

Developing a Body Sensor Network to Detect Emotions During Driving

G. Rebolledo-Mendez, A. Reyes, S. Paszkowicz, M. C. Domingo, and L. Skrypchuk

A detector of human emotions, of which tiredness and stress could be related to traffic accidents, is proposed. An exploratory study demonstrating the feasibility of detecting one emotional state in real time using a body sensor network is conducted. Based on these results, this paper proposes a middleware architecture that is able to detect emotions that can be communicated via the on-board unit of a vehicle with city emergency services, vehicular ad hoc networks, and roadside units aimed at improving the driver's experience and at guaranteeing better security measures for the car driver.

Driver Monitoring Based on Low-Cost Three-Dimensional Sensors

G. A. Peláez, F. García, A. de la Escalera, and J. M. Armingol

A solution for driver monitoring and event detection based on 3-D information from a range camera is presented. The system combines 2-D and 3-D techniques to provide head pose estimation and regions-of-interest identification. Based on the captured cloud of 3-D points from the sensor and analyzing the 2-D projection, the points corresponding to the head are determined and extracted for further analysis. Later, head pose estimation with three degrees of freedom is estimated. Finally, relevant regions of the face are identified and used for further analysis based on low-cost sensors.

Parallel Driving With Software Robots

Recently, autonomous driving and intelligent vehicles have become hot topics again. However, the reality is that the automobile industry is one of the last few sectors that has not yet been revolutionized by the Internet technology. We do see a lot of guarded gates, roads, and bridges from big automotive corporations and their allies, such as *OnStar, G-BOOK, SYNC+AppLink, iDrive, inkaNet*, as well as *CarPlay, Android Auto, Windows in the Car*, etc., but this is far from the vision of a world of connected vehicles and infrastructures, as least far from the vision outlined in many papers of our special issue and our white paper "*Electrified Vehicles and the Smart Grid: The ITS Perspective*," the first article published in this issue.

In 2003, I wrote a technical report entitled "Parallel Vehicular Services for Intelligent Vehicles: From Real Cars to Artificial Cars" to promote the idea of a distributed framework for control and management of advanced driver assistance systems (ADAS) based on mobile agents that connect cars, homes, offices, and service centers, which was able to conduct various services for operators under the principle of "simple inside vehicles, complex outside vehicles" for design and the implementation of connected vehicular platforms. From there, we proposed and launched the first IEEE International Conference on Vehicular Safety and Electronics in the next two years with Prof. Nanning Zheng (then the President of Xi'an Jiaotong University) in order to promote further research and applications in this direction. The idea was funded partially by China's Ministry of Science and Technology, in 2004, as a key project under its "863 Program," in which we developed a few key technologies and a vehicular application specific operating system (**vASOS**) for real-time embedded software platforms based on OSEK/VDX and OSGi protocols. Since then, parts of the report had been published in journals and conference proceedings, and a number of proposed directions became the topics for Ph.D. dissertations of my graduate students, from 2003 to 2007, and led to a few patents. I had actually stopped working in this area for a few years until three years ago. I was reinvigorated mainly by the significant progress made in autonomous driving by Google and the new publicity brought to the field. Originally, I had thought these leaps would be impossible within the next 50 years due to potential legal hurdles created by lawyers in the United States. With the recent

advances in mobile communication, knowledge automation, robotics, and artificial intelligence techniques (particularly machine learning and natural language processing) as well as the increase in public awareness and excitement on smart cars over Google's autonomous vehicles, I believe we must reevaluate and adjust our own approaches and directions for research and development in intelligent vehicles. To me, now is the time for various smart technologies to begin incorporating into cars and auto service centers. I would like to see technologies in the form of software robots driving and working in parallel with human operators, so that operators can more effectively and easily keep their attention on roads and cars and enjoy a safe, smooth, and smart driving experience.

My original idea was very simple: developing task-specific agents for various driving and maintenance/service functions that can be hosted and executed by simple local but real-time platforms inside a vehicle. These agents could also move to complex remote but powerful environments outside the vehicle, where they can be enhanced in performance through further training and learning with human or computer programs. After reading Christopher Steiner's ***Automate This: How Algorithms Came to Rule Our World*** two years ago, I think now is the perfect time to expand this idea and make those agents smart web surrogates or software robots for both autonomous driving and ADAS. To this end, we need to rethink and redefine many of our current vehicular hardware and software systems, such as ABS, ACC, DSC/TCS/ESP, lane departure warning, pedestrian detection, obstacle avoidance, fatigue detection and warning, smart speed adaptation, etc., viewing them as vehicular robots, making them mobile through networks and able to learn from driver behaviors and local environments by cloud computing. In this way, these systems can be adaptive and refined over time and individually optimized for the best performance. Of course, we need a more open platform and many more specified protocols in order to develop more such software robots to perform diversified tasks: monitor the state of drivers, check the condition of cars, evaluate the safety of environments, and identify the availability of services during driving processes. We also need to establish reputable test beds that can thoroughly evaluate, verify, and certify these vehicular robots, so that people can create, test, and buy them easily with confidence. Of course, security and privacy could still be a big issue for such scenarios of parallel driving.

I believe this is not a dream too far from reality. In fact, this year I have graduated my first Ph.D. in parallel driving research. Although the technical orientation and depth of the dissertation was more basic, this is a good start toward parallel driving with software vehicular robots and achieving safety and smartness in the age of driving in cyberspace.

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