Human Factors in Intelligent Vehicles

INTELLIGENT vehicle (IV) technologies have experienced a great improvement in the last couple of decades, turning vehicles into more interactive counterparts in transportation and mobility systems. However, the impact of such technologies on traffic awareness for the driver and driver's behavior toward improving driving performance and reducing road accidents still demands appropriate methods and tools. Whereas the feasibility of incorporating new technology-driven functionality to vehicles has played a central role in the automotive design, safety issues related to interaction with the new in-vehicle systems have not always been taken into consideration. Additionally, other aspects are equally important and need to be analyzed, such as the impact technologies that support specific driving functions play on the overall driving task, as well as their impact on the overall performance of transportation systems. In addition to current industrial achievements that feature today's vehicles with a number of important driving assistance systems, the perspective of autonomous driving vehicles populating the urban environment poses even more challenging issues. Therefore, the information and functionalities that rely on new ways of communication have to be presented in a nonintrusive way, complying with specific design requirements. A system that guarantees efficiency of use, comfort, and user satisfaction can contribute to a more conscious driving behavior that would directly result from the adoption of state-of-the-art IV technologies.

This present Special Issue of IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS aims to present issues related to the analysis of human factors in the design and evaluation of IV technologies, in a wide spectrum of applications and in different dimensions. It builds upon a proper environment to disseminate knowledge and motivate interactions among the technical and scientific communities, practitioners, and students, allowing for state-of-the-art concepts to be devised, tested, and evaluated. A total of 26 quality contributions reporting on original research of different fields related to human factors were received for potential publication in this Special Issue on Human Factors in Intelligent Vehicles. Thirteen of these manuscripts were accepted and included in this special issue.

The paper coauthored by a number of researchers from Simon Fraser University in Canada entitled "Detection of Intoxicated Drivers Using an Online System Identification of Steering Behavior" elaborates on a novel method to detect intoxicated driving and lays a foundation that can be implemented in future cars to derive personalized models of the drivers and to detect other reckless driving styles. The authors showed the autoregressive noise integration moving average with exogenous input (ARIMAX) model to be the most appropriate to describe the steering behavior of drivers being the positions of the model poles a good indicator for an intoxicated driving behavior.

The paper entitled "Study on Emergency Avoidance Braking for the Automatic Platooning of Trucks," coauthored by researchers from University of Tokyo in Japan, presents a detailed experimental study on emergency braking to avoid rear-end collisions during automatic platooning of trucks. Their approach uses an advanced driving simulator system and an actual vehicle. The experimental results indicated 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 to be higher than the one for the preceding truck.

The paper coauthored by several researchers from Technische Universität München in Germany entitled "Impact of In-Vehicle Displays Location Preferences on Drivers' Performance and Gaze" addresses the effects of the integration of technologies, in an automotive context, that can be currently found in other mobile environments such as smart phones and tablets. The authors analyzed differential preferences for the layout of DIS and ADAS compared with existing approaches through a card-sorting experiment. Additionally, they validated their data through the study of drivers' performance and gaze with the preferred locations for in-vehicle information. Results showed that the time the drivers needed to find the conveyed information in the preferred layout was within the recommended time of the NHTSA guidelines. As for the integration of mobile applications and social media in a vehicular context, results also showed that it was not deemed necessary by the drivers.

A methodology to assess electric vehicle exterior sounds is discussed in the paper entitled "Toward a Methodology for Assessing Electric Vehicle Exterior Sounds" by researchers from University of Warwick and Heriot-Watt University, in Edinburgh, U.K. The authors examine automotive exterior sound evaluation methods in the context of experimental design and cognitive psychology and propose a methodology for conducting evaluations of electric vehicle's exterior sounds, testing its detectability and emotional evaluation. They recruited 31 test subjects to evaluate 15 exterior sounds for an electric car in a virtual environment of a town's T-junction and recorded the detection time of the sound, as well as related pleasantness and powerfulness. They showed that, overall, the proposed methodology increased the realistic context and experimental control combining two competing elements necessary for assessing electric vehicle exterior sounds, namely, pedestrian safety and impressions of the vehicle brand.

Emotions have also been the topic of research of a further manuscript from various researchers from University of

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Veracruz in Mexico, Universidad Politécnica de Cataluña in Spain, and Jaguar Land Rover in the U.K., entitled "Developing a Body Sensor Network to Detect Emotions During Driving." In-vehicle integration of heterogeneous body sensors with vehicular ad hoc networks poses a challenge, particularly for the detection of human behavioral states that may impair driving. However, emerging applications using body sensor networks (BSNs) constitute a new trend in car safety. Therefore, the authors propose a detector of human emotions that could be related to traffic accidents. They present an exploratory study demonstrating the feasibility of detecting one emotional state in real time using a BSN. Based on these results, they propose the 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 while guaranteeing better security measures for the car driver.

The paper coauthored by researchers from the Electronics and Telecommunications Research Institute, Daejeon, Korea, entitled "A Validation Study on a Subjective Driving-Workload Prediction Tool" offers a variety of methods to measure driver's workload that includes driver's characteristics and attitudes. To this aim, they developed a subjective driving-workload prediction tool (DWPT) that has been validated through three subfactors, namely the situational inadaptability, the risk-taking personality, and the interpersonal inadaptability. To this end, the authors conducted a driving simulator experiment to study subjects' driving behaviors with several driving tasks. Thirty male drivers participated in the 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 such as the operation of the indicator/steering/gas pedal and attention gaze behaviors. In particular, two subfactors, namely 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 DWPT could be used to predict the drivers' subjective driving workload instead of measuring the driving performance or self-reporting questionnaire.

A further paper from the Electronics and Telecommunications Research Institute, Daejeon, Korea, in collaboration with Chungnam National University, analyzed electroencephalogram (EEG) data collected through an urban road driving test in order to measure and quantify driving workload. In their paper "Driver Workload Characteristics Analysis Using EEG Data from Urban Road," the authors overcome large deviations of EEG values among drivers using EEG variation rates instead of raw EEG values. They extracted five kinds of behavior sections from the data, namely left-turn section, right-turn section, rapid-acceleration section, rapid-deceleration section, and lane-change section. Afterward, the authors selected a reference section for each of these behavior sections and compared EEG values from the behavior sections to those from the reference sections to calculate the EEG variation rates and perform a statistical analysis. Cognitive characteristics of driving workload caused by drivers' behavior in the vehicle information system (VIS) are explained for a safer driving behavior.

The paper coauthored by researchers from Universidad Rey Juan Carlos, Madrid, Spain, entitled "Subjective Traffic Safety Experts' Knowledge for Driving Risk Definition" presents a novel system for the detection of driving risk situations based on the combination of the knowledge acquired from traffic safety experts. A complete methodology to generate a driving risk reference signal was developed within the work and later tested within a set of driving sessions in a very realistic truck simulator, in which several measures and visual information from the vehicle, driver, and road were collected. The authors designed two kinds of experiments, namely controlled driving sessions (in which several risk situations were induced) and natural driving sessions (in which no risk situations were induced and a natural driving behavior was expected). A group of traffic safety experts from Royal Automobile Club of Spain evaluated the driving risk in each simulated session, and the information was used to develop a methodology to combine their conclusions. The risks detected with the proposed methodology were then analyzed to determine the most common human factors related with the generation of driving risk situations.

The manuscript entitled "Driver Monitoring Based on Low-Cost 3-D Sensor," coauthored by several researchers from Universidad Carlos III, Madrid, Spain, provides a solution for driver monitoring and event detection based on 3-D information from a range camera. The system combines 2-D and 3-D techniques to provide head pose estimation and the identification of regions of interest. Based on the captured cloud of 3-D points from the sensor and analyzing the 2-D projection, points corresponding to the head are determined and extracted for further analysis. Later, head pose estimation with 3 degrees of freedom (Euler angles) is estimated based on the iterative closest point algorithm. Finally, relevant regions of the face are identified and used for further analysis, e.g., event detection and behavior analysis. The resulting application is a 3-D driver monitoring system, based on low-cost sensors. It represents an interesting tool for human factors research, allowing automatic study of specific factors and the detection of special event related to the driver, e.g., driver drowsiness, inattention, or head pose.

Driver identity is addressed in the paper entitled "Toward Privacy Protecting Safety Systems for Naturalistic Driving Videos" by researchers from University of California at San Diego. They argue that a common pool of naturalistic driving data is necessary to develop and compare algorithms that infer driver behavior to improve driving safety but naturalistic driving data, such as video sequences of looking at the driver, cause concern for privacy of individual drivers. Therefore, in this study, they implement a specific de-identification filter on video sequences of looking at the driver from naturalistic on-road driving and present novel findings on the effect of face recognition and driver gaze zone estimation. This approach protects the identity of the driver and preserves driver behavior (e.g., eye gaze, head pose, and hand activity). Moreover, driver gaze estimation is of particular interest because it is a good indicator of driver's visual attention and a good predictor of driver's intent. Interestingly, the same facial features that are explicitly or implicitly used for gaze estimation play a key role in recognizing a person's identity.

In their paper "The Effect of Using an In-Vehicle Smart Driving Aid on Real-World Driver Performance," researchers from University of Warwick and MIRA Ltd., in the U.K., devised a smart driving system to provide both safety and fuel efficiency driving advice in real time in the vehicle. The authors evaluated their system in real world, carrying out on-road driving trials to see if any measurable beneficial changes in driving performance would be observed. Two conditions were particularly investigated, i.e., one without any smart driving feedback offered and another with advice being presented to the driver via a smart phone in the vehicle. Their findings demonstrated that the in-vehicle smart driving system conceived with drivers' information requirements in mind could lead to significant improvements in driving behaviors in real-world settings.

Researchers from Nagasaki University, Mazda Motors Company, and Hiroshima University, in Japan, presented an experimental study on human mechanical impedance properties (HMIPs) of the arms measured in the steering operations according to the angle of a steering wheel and the steering torque. Based on their empirical HMIP data and findings, the authors devised a novel method for designing adaptive steering control systems, as reported in their paper "Vehicle Active Steering Control System Based on Human Mechanical Impedance Properties of the Arms." Their approach was then demonstrated via a set of double-lane-change tests with several subjects using the originally developed stationary driving simulator and the 4-DOF driving simulator with a movable cockpit.

Finally, the paper entitled "Haptic Steering Support for Driving Near the Vehicle's Handling Limits: Test-track Case," coauthored by researchers from Volvo Cars Company, Sweden, Cranfield University, U.K., and Delft University, The Netherlands, reports on the development of a hepatic steering support system when driving near the vehicle's handling limits. The authors aim to promote driver's perception of the vehicle's behavior and handling capacity by providing haptic cues on the steering wheel. Their hepatic support near limit (HSNL) approach has been evaluated in a test track where 17 test subjects drove a vehicle equipped with a steering system that is able to provide variable steering feedback torque. Their findings suggest that hepatic support can reduce driver's mental and physical demands with no effect on their driving performance.

We conclude with a word of appreciation to all authors that have submitted their contributions to this Special Issue on Human Factors in Intelligent Vehicles, with novel visions, outstanding research, and significant results. The papers included in this issue resulted from laborious and time-consuming work of many anonymous reviewers that have contributed with their expertise, suggestions, and recommendations, to whom we are greatly indebted. We hope that the readers will enjoy this special issue as much as we did, and both the scientific community and practitioners will find its content stimulating and somehow useful to further promote and develop the field.

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Dr. Rossetti is an active member of IEEE, ACM, APPIA, and AISTI. He has been engaged as member of technical committees and as co-organizer of many scientific events and served as Reviewer for journals such as IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS (ITS), *Transportation Research Part C*, *Journal of the American Society of Civil Engineering*, *Transactions of SCS International*, and *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*. He was a member of the IEEE ITS Society's Board of Governors during the term 2011–2013 and he is the chair of the society's Technical Activities Committee on ATS and Simulation. He is an Associate Editor of IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, the ITS Department Editor of *IEEE Intelligent Systems Magazine*, and a member of the Steering Committee of IEEE Smart Cities Initiative.