Yisheng Lv, Editor

Chair for Intelligent Transportation Systems–Sustainable Transport Logistics 4.0

EDITOR'S NOTE

Please send your proposal on profiling research activities of your or other ITS research groups and labs for the "ITS Research Labs" column to Yisheng Lv at yisheng.lv@ia.ac.cn.

The Chair for Intelligent Transportation Systems (ITS)–Sustainable Transport Logistics 4.0 at Johannes Kepler University Linz (JKU) is a new unit with in-depth knowledge and practical experience in the core areas of intelligent technologies in vehicular environments (information communication technology, data analysis, and smart mobility) and extensive relevant experience in research related to mobile sensors that support automated, cooperative, and connected transport (Figure 1). Sponsored by the Republic of Austria Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation, and Technology; Austrian Research Promotion Agency (FFG); Austrian Post; University of Applied Sciences Technikum Wien; and IAV Automotive Engineering, in Germany, and IAV S.A.S.U., in France, the team at the JKU–ITS aims at providing transport solutions that have a small environmental impact by using sensor and communication technologies for data exchanges among vehicles, infrastructure, and people.

Existing and emerging transportation challenges that are tailored to the needs of users are investigated through relationships between the elements of networked systems, while taking into account human behavior. The research is very collaborative and interdisciplinary, and it is supported by strong ties to an international network and relevant partners from public services, government agencies, and industry. It aims at adapting technology to the needs of users, with the help of computational tools to compile and analyze real-time data so that the efficiency of transport services and mobility can be optimized for clients and service providers. The activities of the JKU–ITS are focused on thematic networks around transportation, as discussed in the following.

Human Factors and Interaction With Intelligent Vehicles

The adoption of autonomous vehicles (AVs) will depend on the public's trust in the technology. To establish that trust, it is important to understand the actions of different road users and their reactions to self-driving cars and trucks [1]. AVs are expected to display human-like behavior, at least to the extent that their decisions can be intuitively understood by other road users. If this is not the case, the coexistence of manually controlled and autonomous cars and trucks in a mixed environment might negatively affect

QUICK FACTS

Lab name: Chair ITS-Sustainable Transport Logistics 4.0.

Affiliation: Johannes Kepler University Linz, Austria

Website: https://www.jku.at/its/

Established: 2018

Research focus: Human factors, mobile robotics, autonomous driving, cooperative systems, sustainable transportation, and virtual and mixed reality

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road user interactions and jeopardize safety. The team at the JKU–ITS investigates algorithms that are capable of analyzing and reproducing human decision-making processes to determine the level of cooperation between vehicles in several scenarios [2] (Figure 2). The interaction of road users with intelligent vehicle technologies, detailing interaction design concepts and metrics while focusing on road safety, is also the subject of research [3]. For example, during conditional automation, a timely response from a driver during a take-over request in the event of an unexpected situation is crucial to ensure road safety. To this end, the effect of nondriving tasks in a real-world environment is assessed, taking into account a driver's state and the environment [4], [5].

Driver–Pedestrian Interaction

Rapid advances in driver assistance technology will lead to the integration of fully automated cars and trucks that will interact with other road users. The team at the JKU–ITS developed a framework for estimating the intentions of pedestrians waiting to cross a street, with the aim of reducing the uncertainty that the lack of eye contact between road users creates. The framework was deployed in a real vehicle and tested in three experimental cases that showed a variety of communication messages to pedestrians in a shared-space scenario [6], [7]. The team investigated the automatic analysis of pedestrian body language and determined behavioral patterns, thereby enabling the assessment of the impact of the coexistence of AVs and other road users on general road safety in a shared space for vulnerable road users (VRUs) and vehicles [8]. The perception of a road situation as safe in an environment that potentially influences well-being is also a topic of research that makes it possible to determine several levels of trust, uncertainty, and fear [9]. Research is performed by combining data from field and simulation test results [10] (Figure 3).

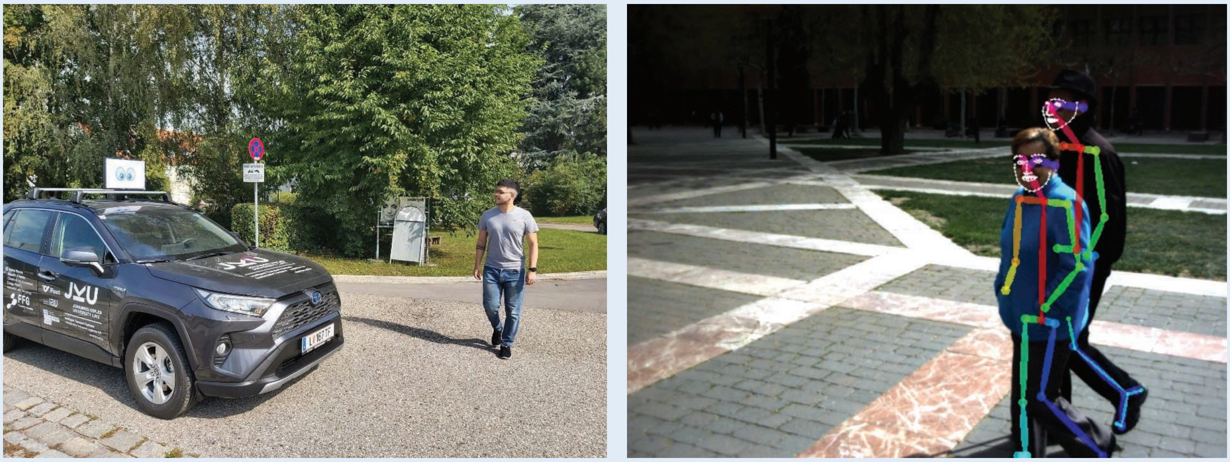
Automated Connected Transportation

Data transfers between vehicles and other road users and infrastructure enable the development of new applications for increasing the safety and efficiency of transport networks and highway utilization. This can minimize the impact that traffic has on carbon emissions and fuel consumption. In recent years, significant

FIG 1 The JKU Science Park (Source: Herta Hurnhaus; used with permission.)

(a) (b)

FIG 2 Field tests with an JKU–ITS automated vehicle at the Driving Technology Center at Österreichische Automobil-, Motorrad- und Touring Club, Marchtrenk, Austria. (a) A driver performing a non-driving-related task (NDRT) during a real-world evaluation of the impact of automated driving system technology on driver gaze behavior, reaction time, and trust. (Source: Cristina Olaverri-Monreal; used with permission.) (b) The team at JKU-ITS during the field test. (Source: Stefan Neubauer; used with permission.)

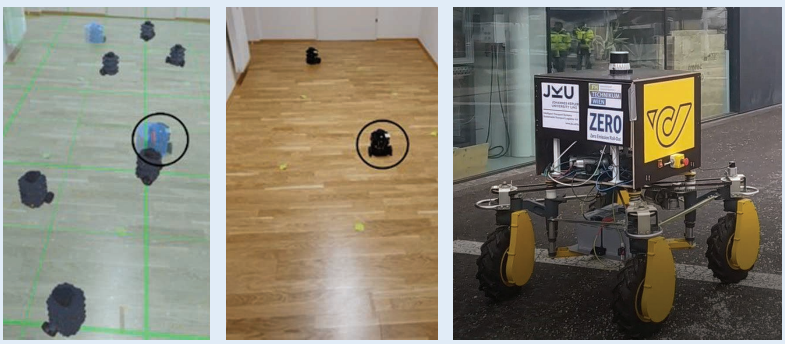


(a) (b)

FIG 3 (a) A JKU–ITS Research vehicle with automated capabilities during a field test. (b) The identification of pedestrian poses for further classification. (Source: Walter Morales; used with permission.)

attention has been paid to the implementation of cooperative driving by means of the integration of advanced driver assistance systems (ADASs) and vehicle-to-vehicle (V2V) communication, which has led to a wide range of applications that have the potential to enhance road safety and prevent traffic accidents. The effects on safety for roads with a variety of penetration rates of ADAS- and V2V-equipped vehicles is also a major subject of study [11].

In the context of ITS and the delivery of goods, the team investigates new approaches to cope with challenges that last-mile delivery entails, such as navigation in urban environments. Case studies for autonomous logistics systems based on standardized autonomous transport boxes [12] and autonomous delivery robots can help overcome these difficulties. Accordingly, simulation-based techniques that rely on mixed reality with Robot Operating System (ROS)-based robots using Unity are being investigated [13]. Through these approaches, more realistic and reliable simulations can be obtained (see Figures 4 and 5).



(a) (b) (c)

FIG 4 (a) A mixed reality view with virtual and real robots (in blue). (Source: Yuzhou Liu; used with permission.) (b) A real-world view in which the virtual robots are not visible. (Source: Yuzhou Liu; used with permission.) (c) A delivery robot during a field test on the JKU campus. (Source: Cristina Olaverri-Monreal; used with permission.)

Machine Learning Solutions for Automated Driving Behavior

Solutions for inferring information acquired from sensors in a real-world environment and using the information to train models capable of mimicking human behavior are a focus of our research on machine learning using convolutional neural networks [14]. Additional methods for modeling car-following behavior are also explored [15]. Furthermore, the need for explainable machine learning solutions for safety-critical systems motivates the research into algorithms for motion models and image processing. To identify unknown behaviors and causes that lead to particular predictions by artificial neuronal networks, approaches relying on Gaussian processes are investigated [16]. Nonparametric and nonlinear methods for image processing using Gaussian process latent variable models for street sign feature extraction are also considered [17], [18].

Simulation Platforms

In-vehicle applications that are based on vehicle-to-everything (V2X) communication and automated technologies need to be evaluated under lab-controlled conditions before field tests are performed. The JKU–ITS

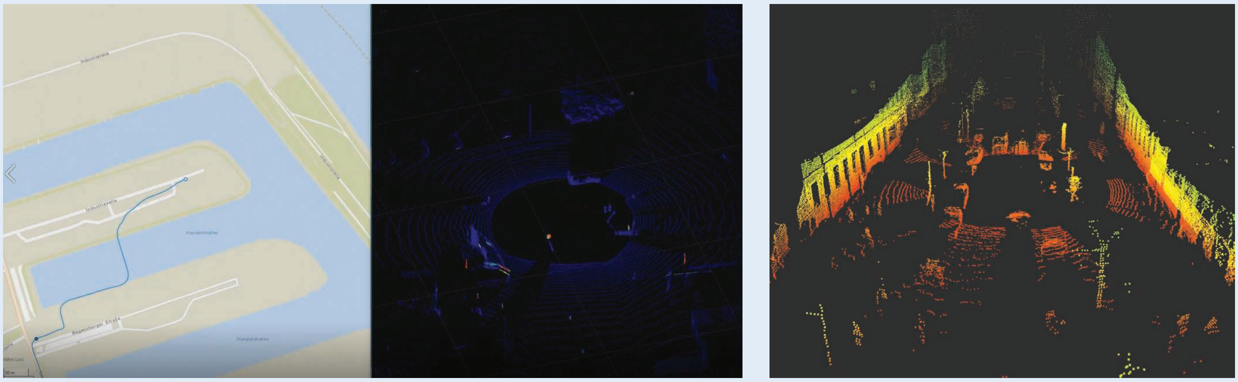


FIG 5 (a) GPS localization (left) with a corresponding 3D map position created at the Linz harbor. (b) A 3D map created during a trip from Inzersdorf to Vienna. (Source: Georg Novotny; used with permission.)

team is continuously developing the flexible, modular 3DCoAutoSim: Simulator for Cooperative ADAS and Automated Vehicles simulation tool and tailoring it to the specific requirements for investigating the effect of automation and V2X communication on drivers (Figures 6 and 7). The simulation platform is linked to the Simulation of Urban Mobility (SUMO) package for micro traffic emulations and connected to ROS for architecture management and nodes handling [19]. The Traffic Control Interface as a Service library was implemented to perform the interaction between a driver-controlled vehicle and SUMO [20]. Research into VRUs has additionally been performed through pedestrian-to-vehicle and vehicle-to-pedestrian communication in a simulated 3D environment [21].

Travel Behavior and Driving Performance

The acquisition of vehicular data for the evaluation of traffic conditions, travel times, and driving performance provides the basis for modeling traffic situations and assessing environmental impacts (congestion and traffic flow). The information extracted through onboard diagnostic devices located in vehicles and through alternative, low-cost, ubiquitous, custom-built mobile applications is used to determine traffic flow patterns through localization data, speed, directions of travel, and time [22]. Accurate travel time prediction is also a fundamental topic of current research. We examine methods, including linear regression models and tree-based ensembles such as random forest, bagging, and boosting, that enable delivery time predictions by conducting extensive experiments that consider a variety of scenarios [23].

Digital and Sustainable Transportation

A further field of research addresses computational tools for the improvement of traffic flow and general transport efficiency. We aim at contributing to emissions reductions and improved sustainability. For example, the team at the JKU–ITS studies electric vehicles as a key alternative for improving energy efficiency and reducing carbon dioxide emissions in the traffic sector, and it performs real-world

FIG 6 The driving simulator framework at the JKU–ITS. (Source: Cristina Olaverri-Monreal; used with permission.)

evaluations in terms of energy consumption and range [24]. Approaches to reduce urban traffic are also investigated by relying on cooperative approaches among different logistics companies, such as sharing and pooling resources for bundling deliveries in the same zone [25], relying on shared distribution centers [26], and using environmentally friendly transport modes.

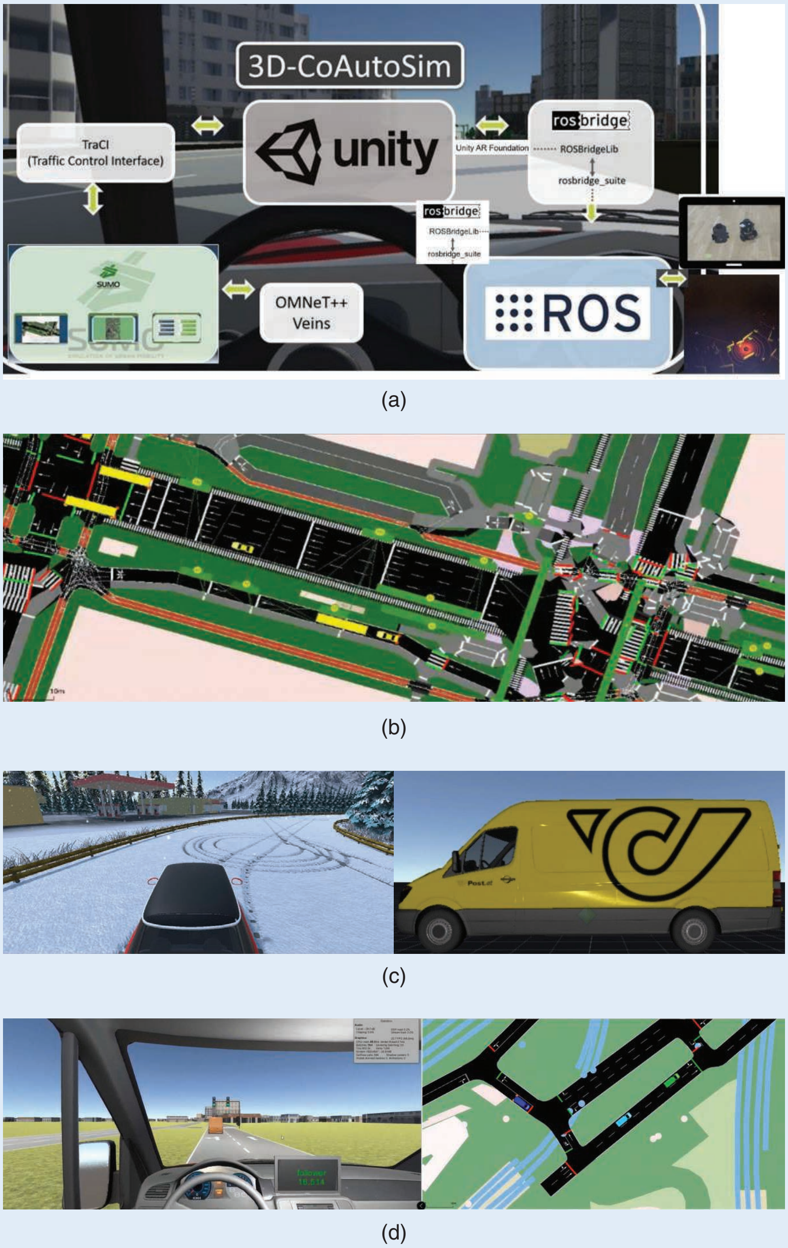


FIG 7 The modular components and software platform of the 3DCoAutoSim simulator at the JKU–ITS. (a) Modular components of the 3DCoAutoSim simulator platform at the JKU-ITS. (Source: Cristina Olaverri-Monreal; used with permission.) (b) A screenshot of a section of Vienna simulated in the simulator of urban mobility (SUMO). (Source: Aso Validi; used with permission.) (c) A snow scenario and van for the Austrian Post simulated in the game engine Unity 3D. (Source: Yuzhou Liu; used with permission.) (d) A screenshot of the driver-centric scenario (left) and traffic simulated scenario (right) to study connected vehicles in platooning mode. (Sources: Nikita Smirnov, Yuzhou Liu, and Aso Validi; used with permission.)

Ongoing Research Projects

Since its creation in 2018, the team at the JKU–ITS has conducted research in multimodal mobility systems that involve different kinds of vehicles in urban and rural areas, including those intended for the transport of goods. Combining transport systems engineering and approaches from the human and social sciences and from natural science and economics, the JKU–ITS partners with sponsors to respond to societal trends for future transport demands. To address these topics, the JKU–ITS has acquired funding as a partner in national and international consortia to contribute to research projects funded by the FFG. One such project, Zero Emission Roll-Out, demonstrates a use case with different types of electric temperature-controlled vehicles in Vienna, focusing on digitalization and automation in transport and their socioeconomic relevance and impact on sustainable development. A further project, ADaptive and Autonomous Data Performance Connectivity and Decentralized Transport Decision-Making Network (ADAPT), which is being developed in cooperation with the Chinese Academy of Sciences Institute of Automation, relies on block chain solutions and develops an adaptive and autonomous decision-making network to support the delivery of protective materials during the COVID-19 pandemic.

The funding of these applied research projects has been made possible thanks to the strong partnership between the JKU–ITS and industry. Finally, and importantly, the excellence of the JKU–ITS in fundamental research has been acknowledged through recent funding from the Austrian Science Fund for basic research in the Interaction of Autonomous and Manually Controlled Vehicles project, which aims at reducing the uncertainty that might jeopardize road safety when AVs interact with driver-controlled vehicles. Regarding projects that aim to provide education, the JKU–ITS has acquired funding with other partners to implement the FFG Qualifizierungsnetz–Digitalisierung und eCommerce in einer nachhaltigen Güterlogistik (DeNaLog) project that provides 16 freight logistics companies with relevant knowledge and know-how from research and case studies in the topics of traffic, smart and green logistics, ADASs, and autonomous driving, among others.

Future Directions

Building on its prior research activities, the JKU–ITS continues to apply technologies that pertain to the field of ITS, such as cooperative, connected ADASs and automated technologies to find solutions for more sustainable, efficient, and environmentally friendly transport. Additionally, real-world evaluation of the impact that automated and autonomous cars and trucks and mobile robots have on road users is being carried out and explored as the most appropriate interaction paradigms are developed.

About the Author

Prof. Cristina Olaverri-Monreal is with Johannes Kepler University Linz, Austria. She is also the 2021 ITSS President Elect.

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