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Editorial

Autonomous Vehicles Technological Trends

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1. Introduction

Twenty years ago, only the most adventurous scientist might have been in the position of dreaming up such a dramatic change for the automotive industry, where fossil fuels are in a position of being banned and vehicles are driverless. Some of the current scientist still consider that the change is developing too fast and that there is going to be a lack of sustainability. Yet, the current selection of papers proves the contrary, that there is knowledge, there is direction, and there is desire for these technologies to be adopted and implemented by the industry. We have in the current selection of papers a crystalized vision where various fields of industry support each other with the clear scope of setting the tone and tuning the rhythm to the development of the most advanced vehicles on the market. Presented in this Special Issue is the ECU, the live traffic interaction, the regulatory basis, pedestrian detection, interior design, trends in the automotive development or software development, or safety features and special maneuvers; all these topics are presented in a mature way with a robust scientific description of the trends and the directions that are mandatory to be adopted for the successful implementation of these vehicles. The selection criteria for the papers had a goal of implementing a referee that was in the position of supporting the scientific world by offering mature solutions at a minimum level of TLR 4 to validate the provided information in the said articles. The Editors hope that this first collection of papers will represent just the beginning of a continuous process that, 20 years from now, will provide scientists with a red line to detect how autonomous vehicles have developed, entered the market, and how they started to represent a safe, reliable, and efficient mean of transport for the future.

2. Short Presentation of the Papers

Ayres et al. [1] presented the vehicle-embedded system, also known as the electronic control unit (ECU), which has transformed the humble motorcar, making it more efficient, environmentally friendly, and safer, but has also led to a system which is highly dependent on software. As new technologies and features are included with each new vehicle model, the increased reliance on software will no doubt continue. It is an undeniable fact that all software contains bugs, errors, and potential vulnerabilities which, when discovered, must be addressed in a timely manner, primarily through patching and updates, to preserve vehicle and occupant safety and integrity. However, current automotive software updating practices are ad hoc at best and often follow the same inefficient fix mechanisms associated with a physical component failure of return or recall. Increasing vehicle connectivity heralds the potential for over the air (OtA) software updates, but rigid ECU hardware design does not often facilitate or enable OtA updating. To address the associated issues regarding automotive ECU-based software updates, a new approach in how automotive software is deployed to the ECU is required. This paper presents how lightweight virtualization technologies known as containers can promote efficient automotive ECU software updates. ECU functional software can be deployed to a container built from an associated image.

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Container images promote efficiency in download size and times through layer sharing, similar to ECU difference or delta flashing. Through containers, connectivity and OtA future software updates can be completed without inconveniences to the consumer or incurring an expense to the manufacturer. This paper has been selected as a Feature Paper.

Ji et al. [2] presented the lane-merging strategy for self-driving cars in dense traffic using the Stackelberg game approach. From the perspective of the self-driving car, in order to make sufficient space to merge into the next lane, a self-driving car should interact with the vehicles in the next lane. In heavy traffic, where the possible actions of the vehicle are pretty limited, it is possible to conjecture the driving intentions of the vehicles from their behaviors. For example, by observing the speed changes of the human driver in the next lane, the self-driving car can estimate its driving intention in real time, much in the same way as a human driver. We use the principle of Stackelberg competition to make the optimal decision for the self-driving car based on the predicted reaction of the interacting vehicles in the next lane. In this way, according to the traffic circumstances, a self-driving car can decide whether to merge or not. In addition, by limiting the number of interacting vehicles, the computational burden is manageable enough to be implemented in production vehicles. We verify the efficiency of the proposed method through case studies for different test scenarios, and the test results show that our approach is closer to the human-like decision-making strategy compared to the conventional rule-based method.

Alves et al. [3] presented that environmental concern regularly leads to the study and improvement of manufacturing processes and the development of new industrial products. The purpose of this work is to optimize the amount of injected plastic and reduce the number of parts used in the production of entrance panels to control features inside the car cabin. It focuses on a particular case study, namely the control of opening and closing windows and rotation of the rear-view mirrors of a car, maintaining all of the functionality, and introducing a futuristic and appealing design in line with new autonomous driving vehicles. For this purpose, distinct low-cost touch sensor technologies were evaluated and the performance of several types of sensors that were integrated with plastic polymers of a distinct thickness was analyzed. Discrete sensors coupled to the plastic part were tested and integrated in the injected plastic procedure. In the former, sensitivity tests were performed to find the maximum plastic thickness detectable by the different sensors. For the latter, experiments were carried out on the sensors subject to a very high pressure and temperature inside the molds—the two most relevant characteristics of industrial plastic injection in this context—and functional results were observed later. We conclude that, by changing the way the user interacts with the car cabin, the replacement of conventional mechanical buttons—composed of dozens of parts—by a component consisting of a single plastic part that is associated with conventional low-cost electronics allows for the control of a more diversified set of features, including many that are not yet usual in the interior of automobiles today, but that will eventually be required in the near future of autonomous driving, in which the user will interact less with driving and more with other people or services around her/him, namely of the multimedia type. Additionally, the economic factor was considered, namely regarding the cost of the new technology as well as its manufacturing, replacement, and subsequent recycling processes.

Mounsey et al. [4] presented that pedestrian detection is at the core of autonomous road vehicle navigation systems as they allow a vehicle to understand where potential hazards lie in the surrounding area and enable it to act in such a way which avoids traffic accidents, which may result in individuals being harmed. In this work, a review of convolutional neural networks (CNNs) to tackle pedestrian detection is presented. We further present models based on CNNs and transfer learning. The CNN model with the VGG-16 architecture is further optimized using the transfer learning approach. This paper demonstrates that the use of image augmentation on training data can yield varying results. In addition, a pre-processing system that can be used to prepare 3D spatial data obtained via LiDAR sensors is proposed. This pre-processing system is able to identify candidate regions that can be put forward for classification, whether that be 3D classification or a combination of 2D and 3D classifications via sensor fusion. We proposed a number of models based on transfer learning and convolutional neural networks and achieved over 98% accuracy with the adaptive transfer learning model.

Custódio et al. [5] presented the current design paradigm of car cabin components which assumes that seats are aligned with the driving direction. All passengers are aligned with the driver that, until recently, was the only element in charge of controlling the vehicle. The new paradigm of self-driving cars eliminates several of those requirements, releasing the driver from control duties and creating new opportunities for entertaining the passengers during the trip. This creates the need for controlling functionalities that must be closer to each user, namely on the seat. This work proposes the use of low-cost capacitive touch sensors for controlling car functions, multimedia controls, seat orientation, door windows, and others. In the current work, we have reached a proof of concept that is functional, as shown for several cabin functionalities. The proposed concept can be adopted by current car manufacturers without changing the automobile construction pipeline. It is flexible and can adopt a variety of new functionalities, mostly software-based, added by the manufacturer, or customized by the end-user. Moreover, the newly proposed technology uses a smaller number of plastic parts for producing the component, which implies savings in terms of production costs and energy, while increasing the life cycle of the component.

Marques et al. [6] presented how with the current technological transformation in the automotive industry, autonomous vehicles are getting closer to the Society of Automotive Engineers (SAE) automation level 5. This level corresponds to the full vehicle automation, where the driving system autonomously monitors and navigates the environment. With SAE-level 5, the concept of a shared autonomous vehicle (SAV) will soon become a reality and mainstream. The main purpose of an SAV is to allow unrelated passengers to share an autonomous vehicle without a driver/moderator inside the shared space. However, to ensure their safety and well-being until they reach their final destination, the active monitoring of all passengers is required. In this context, this article presents a microphone-based sensor system that is able to localize sound events inside an SAV. The solution is composed of a micro-electro-mechanical system (MEMS) microphone array with a circular geometry connected to an embedded processing platform that resorts to field-programmable gate array (FPGA) technology to successfully process in the hardware the sound localization algorithms. This paper has been selected as a Feature Paper.

Abdeen et al. [7] presented that the traffic management challenges in peak seasons for popular destinations such as Madinah city have accelerated the need for and introduction of autonomous vehicles and vehicular ad hoc networks (VANETs) to assist in the communication and alleviation of traffic congestions. The primary goal of this study is to evaluate the performance of communication routing protocols in VANETs between autonomous and human-driven vehicles in Madinah city in varying traffic conditions. A simulation of assorted traffic distributions and densities were modeled in an extracted map of Madinah city and then tested in two application scenarios with three ad hoc routing protocols using a combination of traffic and network simulation tools working in tandem. The results measured for the average trip time show that opting for a fully autonomous vehicle scenario reduces the trip time of vehicles by approximately 7.1% in high traffic densities and that the reactive ad hoc routing protocols induce the least delay for network packets to reach neighboring VANET vehicles. From these observations, it can be asserted that autonomous vehicles provide a significant reduction in travel time and that either of the two reactive ad hoc routing protocols could be implemented for the VANET implementation in Madinah city. Furthermore, we perform an ANOVA test to examine the effects of the factors that are considered in our study on the variation in the results.

Ren et al. [8] proposed a novel deep reinforcement learning (DRL) method for optimal path planning for mobile robots using dynamic programming (DP)-based data collection. The proposed method can overcome the slow learning process and improve the quality of the training data inherently in DRL algorithms. The main idea of our approach is as follows. First, we mapped the dynamic programming method to typical optimal path planning problems for mobile robots and created a new efficient DP-based method to find an exact, analytical, optimal solution for the path planning problem. Then, we used high-quality training data gathered using the DP method for DRL, which greatly improves the training data quality and learning efficiency. Next, we established a two-stage reinforcement learning method where, prior to the DRL, we employed extreme learning machines (ELM) to initialize the parameters of actor and critic neural networks to a near-optimal solution in order to significantly improve the learning performance. Finally, we illustrated our method using some typical path planning tasks. The experimental results show that our DRL method can converge much easier and faster than other methods. The resulting action neural network is able to successfully guide robots from any start position in the environment to the goal position while following the optimal path and avoiding collision with obstacles.

Son et al. [9] presented that the concern over safety features in autonomous vehicles is increasing due to the rapid development and increasing use of autonomous driving technology. The safety evaluations performed for an autonomous driving system cannot depend only on existing safety verification methods due to the lack of scenario reproducibility and the dynamic characteristics of the vehicle. Vehicle-in-the-loop simulation (VILS) utilizes both real vehicles and virtual simulations for the driving environment to overcome these drawbacks and is a suitable candidate for ensuring reproducibility. However, there may be differences between the behavior of the vehicle in the VILS and vehicle tests due to the implementation level of the virtual environment. This study proposes a novel VILS system that displays consistency with the vehicle tests. The proposed VILS system comprises virtual road generation, synchronization, virtual traffic manager generation, and perception sensor modeling, and implements a virtual driving environment similar to the vehicle test environment. Additionally, the effectiveness of the proposed VILS system and its consistency with the vehicle test is demonstrated using various verification methods. The proposed VILS system can be applied to various speeds, road types, and surrounding environments.

Ortega et al. [10] presented the overtaking maneuver, that consists of passing another vehicle traveling on the same trajectory but at a slower speed. Overtaking is considered one of the most dangerous, delicate, and complex maneuvers performed by a vehicle, as it requires a quick assessment of the distance and speed of the vehicle to be overtaken, and also the estimation of the available space for the maneuver. In particular, most drivers have difficulty overtaking a vehicle in the presence of oncoming vehicles in other trajectories. To solve these overtaking problems, this article proposes a method of performing safe, autonomous vehicle maneuvers through the PreScan simulation program. In this environment, the overtaking maneuver scenario (OMS) is composed of highway infrastructure, vehicles, and sensors. The proposed OMS is based on the solution of minimizing the risks of collision in the presence of any oncoming vehicle during the overtaking maneuver. It is proven that the overtaking maneuver of an autonomous vehicle is safe to perform through the use of advanced driver-assistance systems (ADAS) such as adaptive cruise control (ACC) and technology-independent sensors (TIS) that detect the driving environment of the maneuver.

Luna-Álvarez et al. [11] presented how in the self-driving vehicles domain, steering control is a process that transforms the information obtained from sensors into commands that steer the vehicle on the road and avoid obstacles. Although a greater number of sensors improves perception and increase control precision, it also increases the computational cost and the number of processes. To reduce the cost and allow data fusion and vehicle control as a single process, this research proposes a data fusion approach by formulating a neurofuzzy aggregation deep learning layer; this approach integrates aggregation using fuzzy measures μ as fuzzy synaptic weights, hidden state using the Choquet fuzzy integral, and a fuzzy backpropagation algorithm, creating data processing from different sources. In addition, implementing a previous approach, a self-driving neural model is proposed based on the aggregation of a steering control model and another for obstacle detection. This was tested in an ROS simulation environment and in a scale prototype. Experimentation showed that the proposed approach generates an average autonomy of 95% and improves driving smoothness by 9% compared to other state-of-the-art methods.

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