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Transfer of Personal Driving Styles to Autonomous Vehicles

Silviu BUTNARIU
Transilvania University of Brasov

Florin GIRBACIA
Transilvania University of Brasov

Csaba ANTONYA
Transilvania University of Brasov

Abstract: This paper presents a learning model that can be implemented on autonomous vehicles, using a dedicated software platform, based on physics, which can also be used to track the behavior of components and subsystems of the vehicle. In order to prepare the data for entering the software platform, data (position, orientation, acceleration, instantaneous speed) were recorded from a vehicle driven by several drivers on a previously established route. By processing the data, a driving style was established based on the average values recorded, for each subject who participated in the experimental tests. A virtual environment was created to correspond to the real route in which an autonomous vehicle was modeled and the data on the previously established driving style (instantaneous speeds vs. positions) were transferred. Following the running in the virtual environment and the registration of the data about the behavior of the vehicle on the established route, the data obtained by the classical method and the virtual simulation were compared. Thus, corrections can be made on the speed profile implemented for the autonomous vehicle, in order to comply with the limits imposed by the use of this vehicle with passengers: speed limits, longitudinal and lateral acceleration limits, braking limits.

Keywords: Autonomous vehicle, Driving style, Driver behavior, Simulation.

Introduction

Lately, there have been very intense researches on the autonomous driving of vehicles, which led to an important change in the role of the driver, who goes from an active role to a passive one. These changes imply a new paradigm of the driver-vehicle interaction, the connection between these two elements being modified. On the other hand, the passengers of a car do not have to be additionally stressed if they use autonomous driving, they will have to feel comfortable while driving, as in the case of driving.

Therefore, a large part of the concerns in this field is directed towards the transfer of the driver's knowledge, style and abilities, optimized, if possible, to the autonomous driving system. Several elements have been identified that are measurable and that can define a driver's driving style: acceleration / braking and cornering / trajectory followed in curves. These parameters are measurable; they can be recorded while driving a classic car. Autonomous vehicles require an improved understanding of human driver behavior. This is necessary not only to ensure safe and adequate performance, but also to adapt to the needs of the drivers, enhance their acceptability and, ultimately, meet the preferences of drivers in a safe environment. Therefore, it is essential to recognize the driving style (DS) and deduce the driver's intention for the integration and development of these systems (Martinez, 2018).

State of the Art

In the literature, there have appeared, in the last years, a whole series of researches in the field of autonomous management. Some of this research focuses on a basic question: Is it possible to model an automated and customized driving style based on manual driving? In other words, a passenger will accept to use an autonomous vehicle only if he trusts the automated system and his experience will generate feelings of comfort for you (Sherer e al., 2015; Shi et al., 2015).

In recent years, studies have been conducted on algorithms characterization and recognition of driving styles, with a special focus on machine learning approaches by identifying measurable parameters that contribute to the perceived comfort of the passenger, their recording, processing, analysis and interpretation (Martinez et al., 2018).

Thus, in (Sherer et al., 2015), based on a driving simulation study, the acceleration and braking parameters were studied, as well as the longitudinal control, after which experimental tests were performed on a special track. One conclusion of this experiment was that the longitudinal control of the vehicle has a great impact on the comfort perceived by the subject.

In Van Li et al. (2013), studies were performed using the smartphone, more precisely the inertial sensors mounted on the phone, to record data on braking and turning, by segmenting and classifying driving events. In (Shi et al., 2015) a quantitative assessment of driving styles is proposed using personalized modeling of the driver, based on an algorithm with neural networks. It starts from the test data from the real environment of the vehicle and the road over which a standard driving cycle is tested in order to normalize the driving behavior and based on the analysis of the energy spectral density on the normalized behavior, an aggressiveness index is proposed to Quantitatively evaluate driving styles, which can be used to detect abnormal driving behavior.

In Shinar et al. (2011) a unified model for studying the driver's behavior is proposed, which combines aspects of his driving activity, respectively information about what he does but also the reason for performing a certain maneuver. The tests were performed on a single test driver and the vehicle and the environment have parameters with fixed values. The proposed model is used to evaluate new technologies taking into account the skills and style of a driver.

Other authors have studied particular aspects of activity management, for example, the transition on the railway level. They have tested 24 subjects who crossed a level crossing with passive protection and one with active light signal protection (Grippenkoven et al., 2016). Deficient behavior could be determined in the case of visual detection of a train approaching the level crossing. Several techniques for detecting drowsiness and distraction have been studied in recent years, and some of these techniques have been adopted and implemented by major car companies. In this study (Kaplan et al., 2015), the driver monitoring techniques were carefully examined and the pros and cons were presented, based on several classifiers: characteristics used, classification methods, accuracy rates, system parameters, and environmental details.

McDonald et al. (2019), proposes a review of articles studying automatic vehicle pickup and driver modeling to identify the factors that influence the driving style and their impact on automatic pickup performance. Relevant models for braking and steering operations were studied. Several factors have been identified that influence pick-up time and post-pickup control. It was found that drivers respond similarly between manual emergencies and automatic pick-ups, albeit with a delay.

Another level of research in the field is proposed in (Zhu et al., 2018), where the planning of autonomous leadership is done through the method of deep learning with reinforcement (deep RL - reinforcement learning). The aim is to obtain an optimal policy or a car tracking model, which can be continuously updated, which is intended to operate in a human-like manner, at least in aspects: speed, the relative speed between vehicles in a column, the distance between vehicles, and the acceleration of a vehicle.

In Martinez et al. (2018), an attempt was made to define the concept of "leadership style", taking into account the multitude of researchers studying this area. It was concluded that this is a complex concept, influenced by a very large number of factors that complicate its description, which led to the emergence of many terms, which usually do not have an agreed definition. The driving event is generally understood as maneuvers that occur during driving activity, such as acceleration, deceleration, turning and lane change, which can be used to identify the DS (Martinez et al., 2018).

About Driving Styles, Driver Behavior

Driver behavior can be modeled in one of two approaches (Shinar et al., 2011):

(i) "descriptive" models describing driving activity in terms of what the driver is doing
(ii) "functional" models that seek to explain why the driver behaves as he behaves and how drivers' performance is predicted in demanding and routine situations.

Demanding situations determine peak performance capabilities, and routine situations determine typical behavior (not necessarily the best). It seems that the optimal approach could be a hybrid of several types of models, extracting the most useful features of each (Shinar et al., 2011).

Development of Working Methodology

About Simcenter Prescan

PreScan is a simulation platform based on the laws of physics for the development of Advanced Driver Assistance Systems - ADAS and which can incorporate and use dedicated sensors: GPS, radar, LiDAR, video camera. At the same time, this software platform is used for the design / evaluation of vehicle-vehicle (V2V) and vehicle-infrastructure (V2I), controller (MIL) communication applications in real-time testing with software-in-the-loop (SIL) systems and hardware-in-the-loop (HIL). For calculations, PreScan uses the facilities of Matlab & Simulink (Mathworks, 2021).

In the process of validating the reliability of Advanced Driver Assistance Systems (ADAS), as well as the safety and automatic functionality of an autonomous vehicle, it is necessary to test a very large number of scenarios to cover many of the possible circumstances. Of course, this is very difficult to do with physical / real tests, so virtual simulation is a welcome solution. To perform this type of simulation, it is necessary to use a software platform based on the laws of physics (Siemens, 2021).

Thus, this platform can run various scenarios based on five steps:

(i) a real-world traffic scenario is created using elements from the software database (infrastructure elements, light sources, actors, roads, etc.);
(ii) various types of sensors are introduced;
(iii) the interaction between the vehicle and the environment is tested;
(iv) an interface is used for control systems, data processing, sensor fusion, decision, control;
(v) and various scenarios are run by modifying the input data (roads, sensors, algorithms, etc.).

This software can validate autonomous vehicle systems: emergency braking (AEBS), lane departure warning (LDW), traffic sign recognition (TSR), lane change assistance system (LCAS), etc. At the same time, HMI human-machine interface systems can be designed by using a loop driver and checking the hardware components of the ECU.

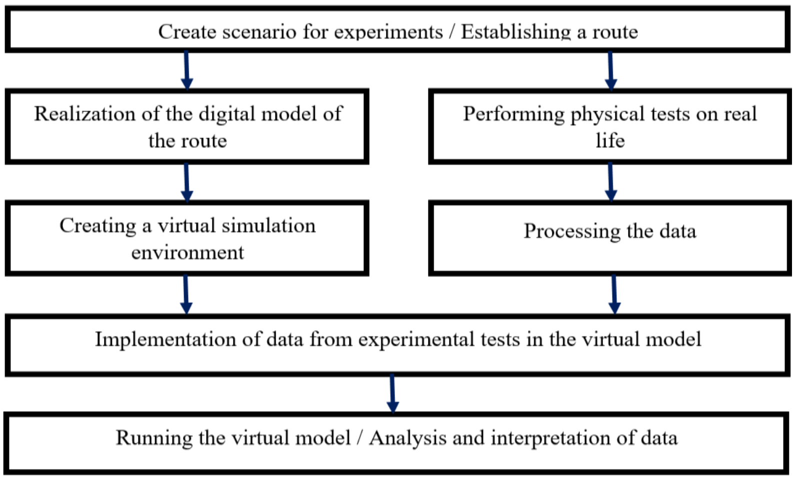


Figure 1. The scenario of experiments

Proposed Working Method

In order to achieve the objectives stated above, a method is proposed that includes the following main steps (Figure 1), including establishing a route, a circuit dedicated to motor vehicles on which practical tests can be performed, realization of the digital model of the route, at 1: 1 scale, proposing a physical testing scenario on the chosen route, performing physical tests and recording data on driving style, processing the data collected during the tests, creating a virtual simulation environment in the PreScan software, based on the proposed route, implementation of data from experimental tests in the virtual model, running the virtual model and recording the data, analysis and interpretation of data obtained from virtual simulation.

Digital Model of the Route

It was decided to use a route around the Research and Development Institute of the Transilvania University of Brasov, with a length of approximately 950 m, insignificant level difference, with a series of turns and speed alignments. In Figure 2, a is presented the area of the Institute, with the route around the buildings, from the *Google Maps* application (https://www.google.ro/maps/@45.6694209,25.5501715,447m/data=!3m1!1e3). In order to digitize the route, a free software application *OpenStreetMap* was used, available on the website https://www.openstreetmap.org/#map=18/45.66934/25.54988 (Figure 2,b). The procedure for obtaining a digitized route in file.osm file (Open Street Map) involves an automatic export of all streets in a selected window and then finishing the results, deleting streets that do not interest us and repairing incomplete ones. Thus, a path is obtained in an .osm file that can be further used in other software applications (Figure 2,c). The route was slightly modified, the lower right part not being accessible by car, creating a small connection segment (Figure 2, d).

a. b. c. d.

Figure 2. Digital model of the route

Creating A Virtual Simulation Environment

Figure 3. The virtual environment

Based on the digital path obtained using the procedure explained above, a virtual environment is created for simulation in the Simcenter PreScan software program. Besides the digitized route, which is the most important element, the environment can include other details: buildings, vegetation, traffic signs, other vehicles, pedestrians, etc (Figure 3).

Each element of the virtual environment can be customized, configured according to the needs of the experiment. Of course, an important actor is the vehicle on which the simulations will be made. For example, speed can be limited on a route segment. For a vehicle, the operating characteristics but also the number, type and characteristics of the sensors with which it is equipped can be configured.

Conducting Physical Tests

In order to record various characteristics of the personal driving style of the vehicles, experiments were performed using the track around the Research-Development Institute in Brasov, using two cars with different technical characteristics and two drivers (Mercedes GLC - 2018, Renault Laguna -2013). The data was recorded by the sensors of some mobile phones (Samsung Galaxy S20 and Xiaomi Redmi Note 10 Pro), mounted on the same plane support to simultaneously record the same data, using Matlab software (https://www.mathworks.com/). Two tests were performed for each driver and each car. The data recorded on the phone, in .csv files for each sensor, were taken on a personal computer where they were processed using the same program, Matlab. The recording settings sensors were: acceleration, magnetic field, orientation, angular velocity, position. Sensor recordings were made at different frequencies. If for accelerations, the reading frequency was 100 Hz, for position recording with the GPS sensor, the frequency was much lower, only 10 Hz.

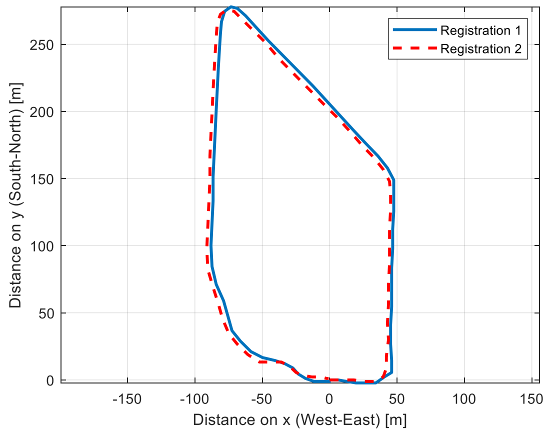


Figure 4. Car position registration

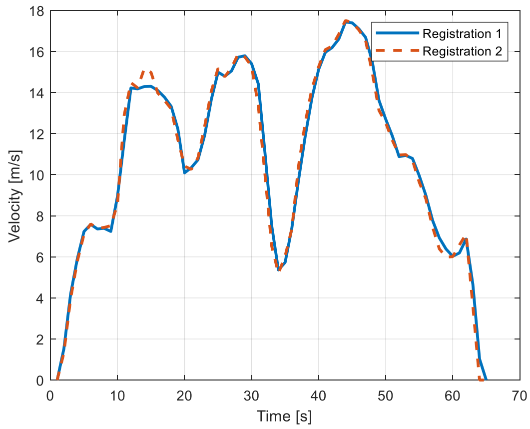


Figure 5. Speed variation

Because recordings of several sensors were made, the data fusion method was used in the data processing stage. The following figures show some of the results obtained: the variation of the position, in X and Y coordination, based on GPS measures (Figure 4) and the variation of the speed depending on the time during operation for the two cars (Figure 5).

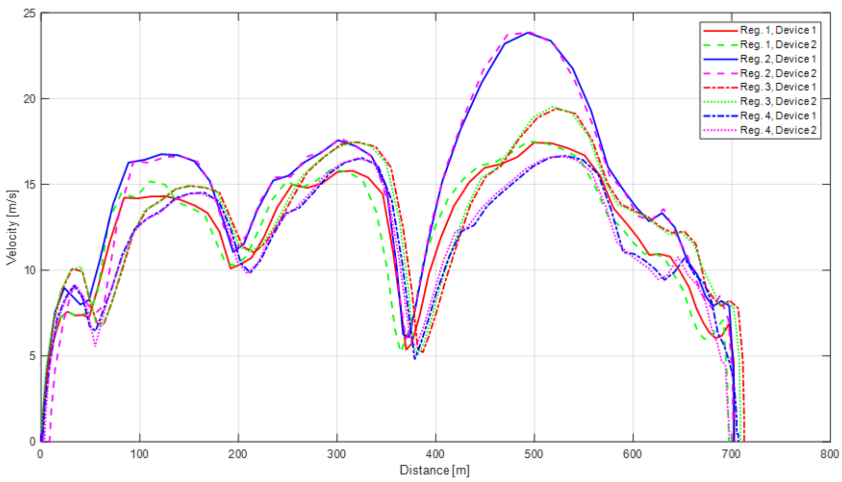
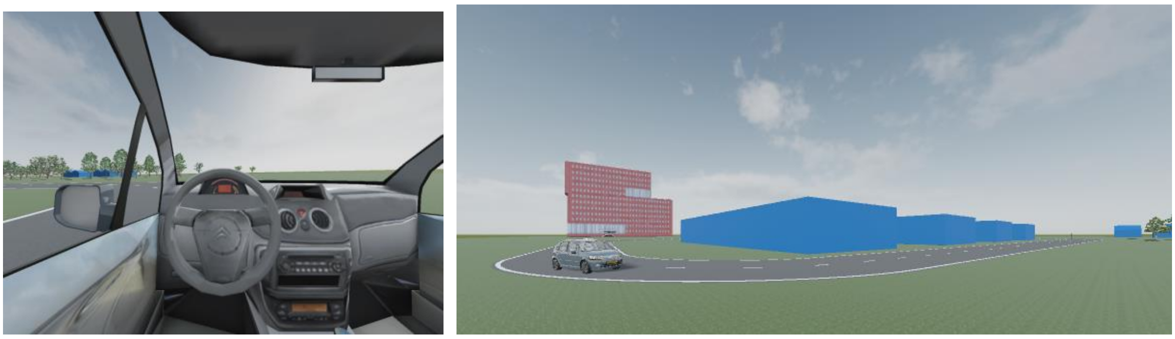


Figure 6. Instantaneous speed depending on the total distance traveled

Following the fusion of the data obtained by the sensors and the calculation of the instantaneous speed according to the position of the car, the graph below was made, where on the X-axis is found the total distance traveled by the car since the beginning of the experiment (Figure 6). In this graph, there are 8 curves performed in the experimental tests, which represent 4 runs on the chosen route registered with 2 devices. The curves marked with Reg.1 and Reg.4 belong to Subject no. 1, and those with Reg.2 and Reg.3 correspond to the actions of the Subject no. 2. There is some difference between the driving styles of the two drivers. One of them runs at a higher speed accelerating and decelerating in force, having a sportier style (Figure 6, Reg. 2). The other driver involved in the tests, runs at lower speeds, this requiring fewer spectacular accelerations and braking (Figure 6, Reg. 4).

Simulation of Driving in The Virtual Environment

First, the route in the virtual environment was compared with the route obtained from the physical tests, based on the measurements with GPS sensors and some small differences were repaired. Thus, following the measurements, a route of length between 697 ... 714 m was obtained. The route in the virtual environment, which corresponds in shape to the real route, has a total length of 704.39 m. The route was divided into several segments, each with different geometric characteristics (straight lines, curves of different radius sizes, in both directions). In order to simulate, the data regarding the speeds of the vehicles, recorded during the tests, on various segments of the route were used for the configuration of the autonomous vehicle introduced as an actor in the virtual environment (Figure 6, Reg.1, Device 1). For testing, a car from the software library was used (Citroen C3 Hatchback), capable of being configured within very wide limits (Figure 7). After configuring the system based on the scenario proposed at the beginning, the application is saved in PreScan and then transferred to be processed in Matlab / Simulink.



a. b.

Figure 7. Actors in Prescan: Citroen C3 Hatchback (a. cockpit view during simulation; b. view from a fixed point outside the route)

After running the Simulink model, various results can be obtained, depending on the input data and the test objectives: data on vehicle dynamics, data on the operation of certain subsystems (throttle pedal, brake, wheel direction, etc.).

Results and Conclusion

The present simulation aimed at the operation of an autonomous vehicle to which an individualized data set was transferred, which contains a series of speed recordings along an established route. After a first simulation, the behavior of the vehicle in operation can be observed, especially in the case of very small radius curve segments where it is possible not to follow the imposed trajectory due to high speeds. In this way, corrections can be made on the speed profile implemented for the autonomous vehicle, in order to respect some limits imposed by its use with passengers: speed limits, longitudinal and transversal acceleration limits, braking limits.

Figure 8 shows the variation of the speed of the autonomous vehicle as a function of time after running the scenario in the virtual environment. A comparison can be made with the input data, presented in Figure 5, Reg. 1, Device 1, continuous red line. There is a small difference between these two curves. These differences can come from various constants that can be set at the beginning of the simulation (environmental characteristics: air pressure, temperature; interaction between the vehicle and the road: friction coefficient; constructive characteristics of the vehicle).

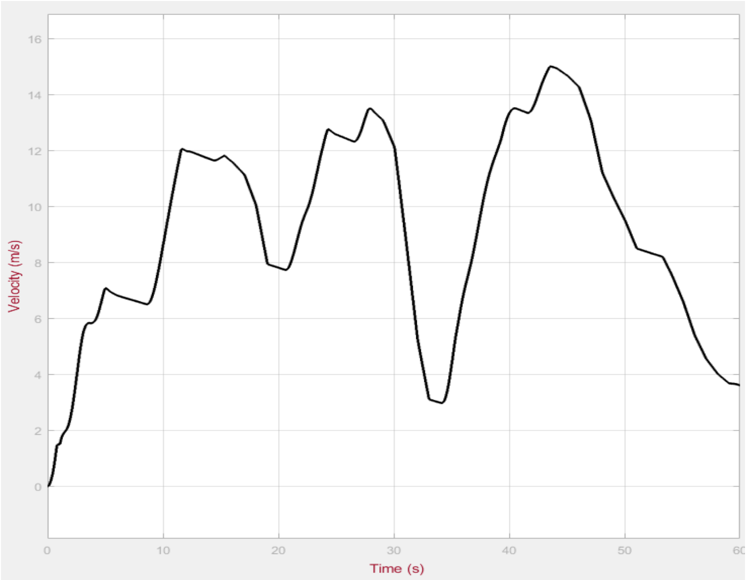


Figure 8. Results: vehicle speed variation

The proposed method can be used for programming and virtual testing of autonomous vehicles using driving styles recorded on various routes with classic vehicles. Passengers included in these field-tests can participate by answering various questionnaires that aim to identify the limit values of accelerations, decelerations, speeds, lateral accelerations. For example, in the case of bus public transport, they travel on urban roads, which are usually not designed to be used at high speeds. Therefore, although there are commonly accepted limit standards or values for speeds and accelerations, a real test is required for various route segments in order to establish adequate driving styles and accepted by passengers.

With the proposed virtual simulation, there will be no need for real tests, all changes can be made in the software program and the results obtained are accessed, verified, processed and discussed immediately. Thus, segments with a strong effect on passengers can be eliminated, passages between different speed values can be smoothed, and accelerations can be limited.

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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Author Information

Silviu BUTNARIU
Transilvania University of Brasov
29 Eroilor Blvd., RO-500036, Brasov, Romania

Florin GIRBACIA
Transilvania University of Brasov
29 Eroilor Blvd., RO-500036, Brasov, Romania

Csaba ANTONYA
Transilvania University of Brasov
29 Eroilor Blvd., RO-500036, Brasov, Romania
Contact e-mail: *antonya@unitbv.ro*

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