16 INSIDE THE COCKPIT OF THE SEMI-AUTONOMOUS CARS OF TOMORROW

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ABSTRACT

Simulations play a crucial role to investigate hazardous situations that are impossible to test in real-life conditions without endangering the user's safety. This paper presents a simulator of conditionally automated cars aiming at enhancing the driver safety and driving comfort. In addition, thanks to the simulator's highly repeatability, integrated sensors and controlled conditions we collected valuable scientific data, which is otherwise very difficult to gather.

KEYWORDS

AR/VR simulator, conditionally automated vehicles, psychophysiological signals acquisition and processing, evaluation framework.

CONTEXT

The main goal of the "Ad Vitam" project is to study how to design human-car interfaces, which will be operated at different levels of attention (focused, peripheral and implicit interaction) [1] in shared control driving to keep the driver in the loop, at the optimum cognitive load.

This paper describes the work carried out to design and improve an evaluation framework (e.g., driving scenarios) for conditionally automated vehicles. In particular, it focuses on the simulator used as a platform to design and evaluate novel conceptual interfaces. In fact, the simulator does not only represent a driver inside the cockpit of a semi-autonomous vehicle, it also enables the acquisition of indicators from the driver, metrics representing the driving performances and statistics from the environment surrounding the vehicle. The simulator has been developed to investigate hazardous situations that are impossible to test in real-life conditions without endangering the user's safety.

TARGETED ISSUES

There are still many road accidents each year, with an annual number of 1.35 million deaths in 2018 [2]. The development of autonomous vehicles wants to improve traffic safety and driving experience by reducing road accidents, making traffic easier, reducing pollution and assisting the driver in the various driving tasks. Transition to fully autonomous vehicles will not be immediate. We can expect to see a transition from vehicles with little or no automation (level 1 or 2) to conditionally automated vehicles (level 3 to 4) before seeing fully automated solutions (level 5) [3]. In conditionally automated cars, the automated system and the driver share the car control, with only one of them being responsible for driving, depending on the situation. Specifically, the car remains in control 1) until it encounters a situation it cannot handle, or 2) if the driver wants to regain control.

This take-over maneuver is a critical situation and could endanger the driver's life and his surroundings if it is not correctly and timely communicated and executed [4].

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PROPOSED SOLUTION

In our study we propose to consider the driver's psychophysiological state in order to provide a suitable feedback. For instance, a tired, sleepy driver will require a different take-over request (TOR) from a driver that is just looking at social media on the smartphone.

Nevertheless, in order to validate our approach and design suitable Human Vehicle Interfaces (HVIs), we need to investigate hazardous situations and get signals from the driver and the environment. To do so, we created a simulator representing the car cockpit.

The simulator has physical components (seats, seat belts, steering wheel, pedals, etc.) and augmented/virtual elements that can be presented to the user via a VR headset or a large screen where the driving simulation software is displayed. We also installed a small screen behind the steering wheel in order to display the vehicle's dashboard with speed indicator, lap indicator and autonomous system status (ON/OFF or TOR).

For the driving simulation, we used the GENIVI open source software, developed by a consortium of several companies, including some car manufacturers. It is developed under Unity and it uses some scripts in C#. This simulator allows a better graphic rendering and a higher level of immersion compared to other simulator programs that we tested. Moreover, it already has an Autopilot function implemented in one of the three proposed scenarios.

RELEVANT INNOVATION

Since the adoption of this simulator, we profoundly modified the GENIVI software to suit our project needs. Our software solution proposes 2 types of scenarios:

- Rural environment: the rural environment models Yosemite National Park where a 20-minute autonomous driving is available. It is also possible to trigger some obstacles such as falling trees, bears, rockslide, etc. We implemented the most important factors that a restrain the proper functioning of autonomous systems as identified here [5]. These limitations are sloping road, adverse weather (heavy rain), fading lane marking, stationary obstacle (rock on the left lane) and a mobile obstacle crossing the road (deer) which leads to a takeover request.
- Urban environment: the urban environment model is San Francisco. The scene has many intersections and the autonomous traffic is already implemented. It is also possible to trigger some obstacles such as pedestrians, dogs, stationary cars on the lane, etc. The main improvements are the autopilot implementation and some limitations addition (unclear lane markings, external human factors such as pedestrians and bicycles, construction zones, ...) in the scene.

PROJECT OUTCOMES & RESULTS

The current simulator version provides information on the car and its surrounding environment, including indicators of the driving quality. Sensors are integrated to obtain psychophysiological signals from the user in the cockpit. This includes electrodermal activity (EDA), heart rate and heart rate variability (computed from ECG) and respiratory rate.

The hardware is hackable and multiple add-ons have been tested (such as a haptic seat or a smart seat belt enriched with sensors).

Multiple experiments were conducted to validate the simulator quality. In one experiment, 90 participants were enrolled: half of them had to perform a cognitive loading secondary task while the car was driving in conditional automation during 20 minutes (the control group had no secondary task to perform). 6 take-over requests were triggered to each driver. In such situations, participants' ECG, EDA and respiration rate were collected. First results show that the learning system has 97% of accuracy to classify drivers that performed the secondary task for 20 minutes. The takeover situation data, used to classify drivers' situational awareness, are currently being analyzed.

CONCLUSION

Simulations play a crucial role to investigate hazardous situations that are impossible to test in real-life conditions without endangering the user's safety. In addition, highly repeatability and controlled conditions allow to get scientifically solid evidence that is otherwise very difficult to reach. In this paper, we presented a simulated cockpit of a semi-autonomous vehicle, conceived to be an evaluation framework to study critical, possibly life-threatening conditions.

PERSPECTIVES & NEEDS

We are developing multimodal solutions to trigger and display TOR. An AI module is also in development, the goal being to select the best modality combination in real time and according to the environmental, car and driver state.

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