Coupled simulator for research on the interaction between pedestrians and (automated) vehicles

Pavlo Bazilinskyy*, Lars Kooijman*, Dimitra Dodou, Joost de Winter

Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, Delft, the Netherlands, {p.bazilinskyy, d.dodou, j.c.f.dewinter}@tudelft.nl

Abstract *– Driving simulators are valuable tools for human factors research on automated driving and traffic safety. We present an open-source coupled simulator developed in Unity. The simulator supports input from head-mounted displays, motion suits, and game controllers. The results of a demo experiment on the interaction between a passenger in an automated car equipped with an external human-machine interface, a driver of a manual car, and a pedestrian show that the coupled simulator is a promising tool for human factors research.*

Keywords: *coupled simulator, automated driving, virtual reality, open-source software.*

Introduction

Traffic in the coming decades will be mixed, with manual vehicles, automated vehicles (AVs), and pedestrians sharing the roads. Understanding the interaction between humans inside and outside of AVs is important, for example, in cases of automated evasive steering [Kal18] and take-over requests for pedestrians stepping onto the road [DeW16]. [Boe15] argued that driving simulators can be used to study such interactions, and that to achieve this, "it is necessary that walking and cycling humans (not just models) can move around in today's driving simulators and encounter manual and autonomously driven vehicles." In this paper, we present an open-source coupled simulator that facilitates research on interactions between pedestrians and humans inside manual cars and AVs. A disadvantage of many driving simulators is that they tend to be expensive. Game development platforms offer reasonable levels of realism and possibilities for interaction between multiple agents. The coupled simulator was developed using the game engine Unity.

Design of the simulator

The simulator supports day and night-time settings (see Fig. 1 for the night mode). The environment offers a model of a city centre consisting of a road network with ten intersections with traffic lights and 34 zebra crossings. Traffic lights can be pre-programmed or programmed to respond to road users. Parked cars, advertisements, and other static objects are placed throughout the city. Cars can be controlled by human drivers, or be pre-programmed to follow a trajectory and respond to other road users. The advertisements are also programmable and can be used as visual distractions.

The simulator supports a keyboard and a gaming steering wheel as input sources for drivers of manual cars, a keyboard for passengers of AVs to control an external Human-Machine Interface (eHMI), and a motion suit for pedestrians. The output sources are head-mounted displays and computer screens.

Figure 1: Night mode of the coupled simulator.

Design of demo experiment

In a demo experiment, we tested a setup with three participants: a pedestrian (PED), a passenger in an AV with an eHMI (PAV), and a driver in a manual car (DM). Fig. 2 shows the virtual world, as seen by the three participants. The PED was standing on a sidewalk in front of a zebra crossing at a T-section. The DM approached the T-section from the street facing the PED and turned right to cross the zebra crossing. Simultaneously, from the left of the PED, the AV approached at a speed of 30 km/h. The initiation of the motion of the AV was triggered based on the location of the DM. The information displayed on the eHMI was either none or "WALK" or "DON'T WALK" (Fig. 3) and could be activated by the PAV.

* Joint first authors.

Figure 2: Scenario as seen by the participants. Top row: recordings from cameras aimed at the passenger in the AV, the driver in a manual car, and the pedestrian, respectively. Bottom row: Screenshots of the corresponding participants' views.

Participants had specific roles. PED was informed that the cars he would encounter were either AVs with eHMIs or manually driven vehicles. He was instructed to cross the road when he felt that it was safe enough to do so. The DM was instructed to violate the traffic rules and to not stop in front of the zebra crossing. The PAV was instructed to switch on the eHMI as soon as the AV started braking or when the DM violated the traffic rules.

Figure 3: View of the AV from the pedestrian's perspective.

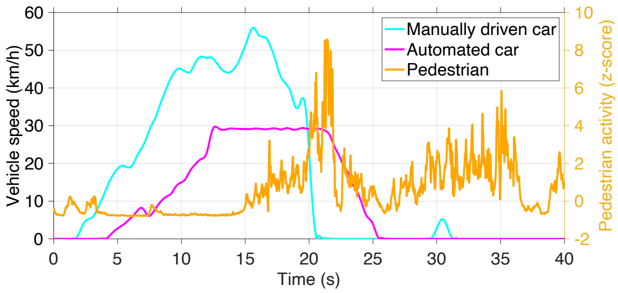

Figure 4: Agent speed/activity as a function of elapsed time.

Results and conclusions

Figure 4 shows the speed of the AV, the speed of the manual car, and a measure of movement activity of the PED in one of the tested scenarios. Here, we used a multivariate analysis to extract a total movement activity score of the PED.

The coupled simulator is made available open-source to facilitate the advancement of human factors research in interactions between pedestrians and (automated) vehicles. Our demo indicates the potential of the simulator for investigating human participants' response in dangerous situations. We used standard middle-range gaming PCs, which illustrates the potential of deploying the simulator in any laboratory or even a home setting.

Supplementary material

Synchronised video of the three participants and recordings of their screens: https://youtu.be/W2VWLYnTYrM

Open-source code of the simulator: https://github.com/bazilinskyy/coupled-sim

Data and MATLAB code used for the analysis:

http://doi.org/10.4121/uuid:63072181-e9fb-4221-91e6-ba836ae3190c

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