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Orchestration of driving simulator scenarios based on dynamic actor preparation and automated action planning

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ABSTRACT

In driving simulation, a scenario includes definitions of the road environment, the traffic situation, simulated vehicles' interactions with the participant's vehicle and measurements that need to be collected. The scenarios need to be designed in such a way that the research questions to be studied can be answered, which commonly imply exposing the participant for a couple of predefined specific situations that has to be both realistic and repeatable. This article presents an integrated algorithm based on Dynamic Actor Preparation and Automated Action Planning to control autonomous simulated vehicles in the simulation in order to generate predefined situations. This algorithm is thus able to plan driving actions for autonomous vehicles based on specific tasks with relevant contextual information as well as handling longitudinal transportation of simulated vehicles based on the contextual information in an automated manner. The conducted experiment shows that the algorithm is able to guarantee repeatability under autonomous traffic flow. The presented algorithm can benefit not only the driving simulation community, but also relevant areas, such as autonomous vehicle and in-vehicle device design by providing them with an algorithm for target pursue and driving task accomplishment, which can be used to design a human-vehicle cooperation system in the coming era of autonomous driving.

1. Introduction

A driving simulator is a tool for imitating real vehicle driving. Instead of driving on a real road the drive takes place in a virtual world. The driver interface may include a real vehicle cabin or consist of a simpler driver interface with only a steering wheel and pedals. Driving simulators are mainly used to study driving behaviour in different driving contexts, i.e. different combinations of road environment, vehicle characteristic, support system(s), weather condition, etc. Compared to other tools for studying driving behaviour, as field trials and test tracks, driving simulators offer:

(1) a risk-free environment;
(2) the possibility to study hazardous situations not easily investigated in the real world;

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(3) the possibility to study new support systems, road environments, etc.
(4) repeatable and consistent scenarios.

The scenario is the key to provide a pre-defined environment that experimenters need a participant to experience. It includes definitions of the road environment, the traffic situation, simulated vehicles' interactions with the participant's vehicle[1] and measurements that need to be collected. Choreography of scenarios, plays an important role in driving simulation. In general, the scenarios need to be designed in such a way that the research questions to be studied can be answered. This commonly imply exposing the participant for a couple of predefined specific situations which has to be both realistic and repeatable.

Realism in driving simulators is related to the creation of an illusion of real driving (Olstam et al., 2011). Good realism in a driving simulator imply that the human participants make similar decisions in the driving simulator as they would in real driving. For the surrounding traffic point of view, realism imply requirements of adopting sufficient realistic driving behaviour models for the surrounding vehicles, as Papelis and Ahmad (2001) makes the following conclusion with respect to realism in driving simulators: "*In our experience with research studies in high-fidelity simulators, users generally focus their evaluation of the model realism towards the richness of the behaviors, not their fidelity.*"

Repeatability means that the essential conditions in a scenario should be repeatable in each trial (Fisher et al., 2010). The balance between realism and repeatability is difficult and depend on the requirements of the scenario, which often includes high requirements on repeatability for statistical power in the result analysis. As a result, behaviours of each simulated vehicle are more or less always strictly controlled in order to guarantee repeatability However, even for a strictly pre-defined scenario, unexpected movements of participants' vehicle (the simulator driver) due to driver variability may interrupt some of the pre-defined interactions. In addition strictly controlled surrounding vehicles may behave less realistic in some situations.

This article presents an approach for combining repeatability and realism of driving simulator experiments by orchestrating scenarios with autonomous surrounding vehicles. It utilises an active planning methodology to minimise the options of human participation during simulator driving in order to create desired context for experiments and cope with driver variability. The work presented in this article is a further development of the scenario orchestration framework named SOAV (Xiong et al., 2012). The framework is enhanced by adding an algorithm for dynamic actor preparation based on the algorithm in Olstam et al. (2011). The enhanced version makes it possible to engage the participant's vehicle actively based on pre-defined tasks and rich behaviours in order to create desired situations for interactions. The ability to create repeatable scenarios is demonstrated by applying the revised framework to a two lane motorway scenario including a braking lead car and an passing lane platoon that keep the participant vehicle from changing lane.

The paper is organised as follows. Section 2 gives an overview of related work on orchestration of driving simulator scenarios. The revised algorithm is presented in Section 3. The numerical results are presented in Section 4 and the Section 5 ends the paper with concluding remarks and future research needs.

2. Related work

In driving simulation, orchestration of scenarios has been a focus of research since the mid 1990s regarding how scenarios can be described and how to use those descriptions (e.g., Cremer et al. (1995)). Generally speaking, the scenario orchestration shares the same idea: have a human experiment designer describe every aspect of the scenario, and then author the scenario to relevant simulated vehicles. This process can define the rules or sequence of actions that the simulated vehicles should follow before or when the scenario is exposed to human participants.

In general, three questions need to be answered in order to orchestrate a particular scenario:

(1) Which simulated vehicles should be involved in the scenario?
(2) How will those simulated vehicles be prepared?
(3) How can the scenario be produced?

These three questions can be answered in a single framework or algorithm as discussed in Wassink et al. (2005). However, the framework in Wassink et al. (2005) considered a driving education application in which scenarios and events can be launched in a random order, which is commonly not allowed in research applications. Furthermore, Wassink et al. (2005) do not include any details regarding the underlying algorithms. More common is that researchers put a focus on answering each question with separate algorithms as listed below.

Question one can be called *the actor management problem*. Simulated vehicles can be pre-defined and fully described beforehand (e.g., Wolffelaar et al. (1999)). However, some existing methodologies can recruit simulated vehicles for interactions in real-time. For instance, Kearney et al. (1999) developed a state machine-based scenario orchestration language that does not require specification of the simulated vehicles to be involved in an interaction beforehand, which implies that recruitment can be done online. In Olstam et al. (2011), an actor management algorithm was developed by considering the average speeds of simulated vehicles needed to reach the proposed location for interactions. The simulated vehicle with the least conspicuous speed trajectory was assigned to interact with the participant.

[1] In this research, only one participant or participant's vehicle (simulator) is included in a particular scenario.