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Advanced Traffic Simulation Framework for Networked Driving Simulators

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Abstract: Simulating surrounding vehicles in a driving simulator is essential for drivers to experience realistic traffic situations. However, simulating traffic several miles ahead or behind a driving simulator vehicle is not efficient. This paper presents the concept and structure of a traffic simulation framework for an environment of networked driving simulators. The framework enables users to select a target simulator vehicle and generate traffic only in its neighborhood. The other participating drivers are considered, so that they experience realistic traffic behaviour as well. The developed framework has been validated with a demonstrator to graphically observe the interaction of the generated traffic.

Keywords: Vehicle simulators, Driver models, Road traffic, Distributed simulation, Training

1. INTRODUCTION

Driving is one of the most popular daily activities that people perform. Nevertheless, it is a complex and relatively dangerous activity. Drivers have to interact with different vehicle systems, like, e.g., intelligent transportation systems, advanced driver assistance systems (ADAS), and in-vehicle information systems (Pauzie (1994)). These systems influence drivers' behaviour and their ability to handle traffic situations.

Automotive manufacturers and suppliers focus on overcoming new technological challenges and addressing acceptance aspects for connected vehicles (Lu et al. (2014)) and future ADAS. From a technology-driven perspective, these systems must be evaluated regarding their functionality, robustness, and interoperability with systems provided by different manufacturers. From the human factor point of view, it is important to study the impact of these systems on drivers and their cooperative behaviour (Mayenobe et al. (2004)). Further, drivers must learn how to use these systems and not to overestimate their capabilities in order to achieve safe traffic flow.

In this regard, driving simulation and traffic simulation are used in the automotive field. In driving simulation, a participant controls a virtual vehicle in a simulated environment. In traffic simulation, driver models are used to investigate aspects related to a whole traffic system. Driving simulation and traffic simulation are used together to create scenarios that involve human-driven and programmed vehicles (Punzo and Ciuffo (2010)). However, this provides only an approximation of the level of uncertainty and unpredictability encountered when multiple human drivers are operating in the same environment, i.e., as the case in real-world traffic situations (Muehlbacher (2015)). In other words, individual simulators serve only as isolated solutions, which enable research, development, and drivers training in repetitive and predefined scenarios. They lack realism and multi-interactivity required for future automotive applications.

In networked driving simulation, different human-driven vehicles in a distributed simulation environment can participate and interact within a common traffic scenario (Oeltze and Schießl (2015)). The ability to create a virtual driving environment simultaneously accessed by two or more human drivers allows a much closer approximation of reality, with its attendant risks and uncertainty. Networked driving simulation can be used for future research and development areas, which serve automotive applications involving connectivity and interaction. Examples for these applications are: development of connected vehicle systems (Tideman and van Noort (2013)), conjoint training of drivers (Kandhai et al. (2011)), and investigations of drivers' cooperative behaviour (Mayenobe et al. (2004)).

Simulating surrounding vehicles in a driving simulator is essential to let simulator drivers experience realistic traffic situations (Punzo and Ciuffo (2010)). The characteristics of surrounding traffic influence the driver's behaviour, and hence, the ability to drive the vehicle. However, simulating traffic several miles ahead or behind the driving simulator vehicle is not efficient from a computational point of view. Previous approaches have been developed to efficiently generate traffic vehicles for a single driving simulator (Olstam and Lundgren (2008)). This paper presents the concept of a traffic simulation framework for networked driving simulators. The developed framework allows users, i.e., operators or developers, to select a target simulator vehicle and generate traffic with realistic interactions only in its neighbourhood. In other words, traffic vehicles are generated only within sight distance or area of interest of the target driving simulator vehicle. The other participating human drivers are considered, so that they experience realistic traffic behaviour as well. The main objective is to simulate traffic vehicles and to let all simulator drivers

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undergo realistic behaviour at the same time. Moreover, users are able to vary the speed and density of the generated traffic during simulation runtime as desired. The developed framework has been tested with a demonstrator to observe the interaction of the generated traffic.

This paper is structured as follows: Section 2 presents related work in the field of traffic simulation for driving simulators. Section 3 introduces the concept and structure of the developed traffic simulation framework. Section 4 describes the design and functionality of each subsystem. The validation of the framework is discussed in Section 5. Finally, Section 6 presents potential future work for the developed framework.

2. RELATED WORK

According to literature review, there is a lot of research work in the field of traffic simulation for driving simulators. For example, a symbolic vision model for traffic simulation is presented in (Espie and Auberlet (2007)). This model allows each traffic vehicle to observe various elements of its environment, like, e.g., other traffic vehicles, road signs, lane markings, etc. Hence, each traffic object can adjust its behaviour based on the traffic situation as well as the perceived road environment. An approach using Hierarchical Concurrent State Machines (HCSM) is introduced in (Bonakdarian et al. (1998)). This model allows each traffic vehicle to check the situation, and hence, to automatically switch between different decisions, like, e.g., lane tracking or change, object following, traffic collision avoidance, static object collision avoidance, etc. A model for traffic simulation that utilizes a fuzzy logic approach is presented in (Wright et al. (2002)). By introducing a degree of indeterminism, this model mimics the behaviour of a typical human driver. To reduce computation effort, a concept for traffic vehicles simulation in a specified candidate area is introduced in (Olstam (2003)). A comprehensive survey for previous traffic simulation approaches is presented in (Olstam (2005a)).

SUMO from DLR Institute of Transportation Systems is an open and flexible suite for modelling traffic systems including road vehicles and pedestrians (Behrisch et al. (2011)). To simulate surrounding traffic for driving simulators, there are several commercial tools in the market. For instance, ASM Traffic from dSPACE is a framework consisting of Simulink models to simulate road traffic (Amelunxen (2015)). The model simulates one test vehicle and up to 15 independent traffic vehicles and it can be utilized for interactive driving simulations. The ASM traffic editor enables users to define different traffic scenarios through its graphical user interface. IPGTraffic from IPG Automotive provides models to represent the interactions of traffic vehicles for driving simulators (Miquet et al. (2010)). Unlimited number of traffic objects can be created, where maneuvers can be assigned to each traffic object individually. One problem with most commercial solutions is that they simulate an entire geographic area. For wide areas or long roads, many traffic vehicles have to be simulated, especially when running long driving simulator experiments. This may introduce challenges regarding the required computation capacity. Therefore, some commercial solutions define a simulation area around the driving simulator vehicle, where traffic objects are generated. For example, v-TRAFFIC from VIRES Simulation Technology is a traffic and scenario simulation engine that can be used with driving simulators to simulate surrounding traffic objects (Neumann-Cosel et al. (2009)). Principally, there is no limit for the number of traffic objects that can be created. Moreover, v-TRAFFIC utilizes a simulation area/window concept to reduce computation effort.

Despite promising work in the research and commercial fields, there is still no traffic simulation model that can be used efficiently when multiple driving simulators are connected in the same virtual environment. Previous work and existing solutions consider only setups consisting of one driving simulator. This paper presents a concept of a traffic simulation framework that considers a driving simulation setup, where multiple human drivers interact together in the same virtual scenario. The following section introduces the concept and the structure of the developed traffic simulation framework.

3. CONCEPT AND STRUCTURE OF THE TRAFFIC SIMULATION FRAMEWORK

A crucial difference between traffic simulation for driving simulators and other purposes of traffic simulation is that one of the vehicles is controlled by a human driver. Consequently, traffic vehicles have not only to react to each other, but also to the behaviour of the simulator driver. The developed traffic simulation framework in this work considers networked driving simulation setups. That is, the generated traffic vehicles are shared among multiple human drivers that interact within the same virtual scenario. Fig. 1 shows the structure of the developed traffic simulation framework along with the main building blocks of the overall simulation environment.

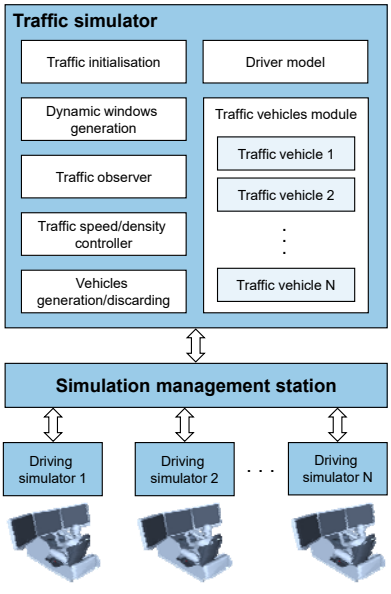

Fig. 1: The developed traffic simulation framework and its relation with the networked driving simulation environment.