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Multi-agent based modeling and simulation of microscopic traffic in virtual reality system

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ABSTRACT

Traffic simulation in virtual reality system plays an important part in the research of microscopic traffic behavior, but developing the traffic simulation is a difficult work because of its inherent complexity. This article focuses on the modeling and simulation of microscopic traffic behavior in virtual reality system using multi-agent technology, a hierarchical modular modeling methodology and distributed simulation. Besides, the dynamic features of the real world have been considered in the simulation system in order to improve the microscopic traffic analysis. First, the multi-agent based system framework is designed and analyzed. Then, the environment agent and the intelligent vehicle agent are presented for the simulation of interaction between vehicles and environment, especially the road geometry and wind affect on the vehicle. Finally, the application results are presented to show the feasibility of the proposed method.

1. Introduction

Transportation research and development are no longer a field dominated by civil, mechanical, operation research, and other traditional engineering and management disciplines [1], but it is an interdisciplinary field. The development of Intelligent Transportation System (ITS) and Automated Highway System (AHS) requires extensive testing, verification and evaluation of new traffic concepts. Computer simulation is widely used in the design and test of intelligent vehicles, to complement experimental results as well as to analyze different control algorithms in different traffic situations and environment, where realistic experimental tests with real vehicles would be difficult to accomplish due to hardware, vehicle availability, safety and reproducibility problems [2].

Traffic simulation provides a flexible, effective and safe way to research innovative concepts and applications. Several traffic simulation tools have been developed, such as AIMSUN, VISSIM, and MITSIM. The primary areas of application for AIMSUN are offline traffic engineering and more recently, online (real-time) traffic management decision support. In either case, the use of AIMSUN or AIMSUN Online aims to provide solutions to short and medium term planning and operational problems [3]. VISSIM is a microscopic, behavior-based multi-purpose traffic simulation to analyze and optimize traffic flows. It offers a wide variety of urban and highway applications, integrating public and private transportation [4]. The MITSIM model has been used to evaluate aspects of the traffic control system of the Central Artery/Tunnel project in Boston [5]. Little attention has been paid on system modeling and formal specification of traffic simulation, which results in a gap between the

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system modeling at the design stage and the implementation at the application stage. Developing traffic simulation system is a difficult work because of its inherent complexity, such as the interaction between vehicle and environment, the communication among the softwares, the development of different simulation models and the design of all kinds of simulation applications. Therefore, it is necessary to structure the complex system into relatively independent modules, which can realize making simulation system easy to be built and maintained. In this way, this gap could be decreased.

Virtual Reality (VR) technology is increasingly being used in transportation visualization [6], traffic simulation systems [7] and driving simulators [8]. In [9,10], we presented the intelligent vehicle simulation platforms that combine VR and ITS/AHS. The development of Multi-Agent System (MAS) brings a new idea to go deep into recognizing the modeling and simulation of intelligent traffic system. MAS provides a suitable way to model and simulate traffic systems since they offer an intuitive way to describe every autonomous entity on the individual level. MAS has been used in collaborative driving [11,12], agent-based driver behavior modeling [13,14] and multi-agent based microscopic traffic simulation [15,16].

Inspired by the existing studies mentioned above, a modular application software, Virtual Reality Intelligent Simulation System of Vehicles (VR-ISSV) has been developed, combining traditional ITS with VR and MAS to systematically investigate the modeling method of vehicle simulation system. We are interested in two aspects that are important for virtual reality traffic simulation system: the first one is to structure the complex system into relatively independent modules, which can realize making simulation system easy to be built and maintained; the second one is that not only the visualization of traffic simulation will be realized in this paper, but also the complicated and dynamic features (such as road geometry and wind) of real world will be involved in the virtual reality traffic simulation system.

The aim of this paper is to present a system framework for traffic simulation within virtual reality systems. The focus is on a systematic modular approach for the traffic simulation, which makes it is possible to structure the simulation system into different types of agents and to use geometry data from a geographical database. This paper proposes a method to research the microscopic behavior in virtual reality system and to realize the verification of the vehicle controller in microscopic behaviors. Microscopic traffic models study traffic phenomena by taking each individual vehicle as a starting point and analyzing how it interacts with the other vehicles [5]. In this paper, the microscopic traffic behavior focuses on the individual vehicle behavior and how the vehicle interacts with the environment and the other vehicles. With this method, the microscopic traffic behavior could be realized in the virtual reality system with the consideration of the influence of road and wind on the vehicle.

The main application of the system is the evaluation of the microscopic traffic behaviors and the vehicle control algorithms involving the environment. The system is capable of realizing the simulations of the traffic behavior in a virtual environment, which can be modeled as closely as possible to the real situation so as to avoid certain dangers and simultaneously reduce the cost and shorten the development time. Some situations with bad road condition or abominable environment could be proposed to be carried out in this system which can provide a complex natural environment. In this way, some existing control algorithms can be tested or simulated and more appropriate intelligent control system can be designed to promote the development of ITS field. VR-ISSV could assist the user in preparing the simulation of different traffic situations, designing the control algorithms in different environment. A preliminary version of this research appears in [17].

The following parts of this article are organized as follows. Section 2 presents the multi-agent based framework modeling for VR-ISSV and gives some formal definitions. In Section 3, the modeling of synthetic natural environment agent is presented, the interaction between the environment and the vehicles are analyzed. Section 4 focuses on the modeling of intelligent vehicle agent, vehicle dynamic model and fuzzy vehicle controllers considering the road geometry and the wind are presented. Section 5 shows the application cases used in the microscopic behavior simulation of traffic safety and analyzes the advantages of multi-agent based VR-ISSV. Section 6 concludes the paper finally.

2. System framework design

2.1. Multi-agent based framework for VR-ISSV

Based on multi-agent technology, VR-ISSV can be modeled as four layers hierarchical framework shown in Fig. 1, which consists of hardware, network and operating system layer; visualization management layer; multi-agent layer; human–machine interface layer.

Hardware, network and operating system layer provides the supporting technology of the system running, which includes the visualization rendering subsystem (*i.e.* the graphics accelerator hardware and the software development library such as OpenGL and DirectX), the vehicle dynamic model and the control model subsystem (Matlab/Simulink), the distributed network communication environment, the operation system and the model database storing Digital Elevation Model (DEM), 3D models, etc.

Visualization management layer is responsible for managing the 3D model, organizing and driving the 3D scenes, and calculating physical properties, such as the collision detection and the scenario-based event management.

Multi-agent layer includes entity agents, environment agent and service agents. This layer reflects the intelligence, the reconfigurability, the reusability and the scalability of VR-ISSV.