Paper:

Massive Multiagent-Based Urban Traffic Simulation with Fine-Grained Behavior Models

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As it is getting easier to obtain reams of data on human behavior via ubiquitous devices, it is becoming obvious that we must work on two conflicting research directions for realizing multiagent-based social simulations; creating large-scale simulations and elaborating fine-scale human behavior models. The challenge in this paper is to achieve massively urban traffic simulations with fine-grained levels of driving behavior. Toward our objective, we show the design and implementation of a multiagent-based simulation platform, that enables us to execute massive but sophisticated multiagent traffic simulations. We show the capability of the developed platform to reproduce the urban traffic with a social experiment scenario. We investigate its potential to analyze the traffic from both macroscopic and microscopic viewpoints.

Keywords: multiagent-based simulation, traffic simulation, human behavior modeling

1. Introduction

Social mechanism design is such an intractable task due to the complexity of human societies that effective heuristic technologies are being sought widely. Multiagent-based social simulations are increasingly seen as the most attractive approach to creating sophisticated social mechanisms [1, 2]. As fine-scale digital data can now be readily acquired via the latest personal devices, a vast quantity of data on human behavior is being accumulated. This situation suggests that there are two research directions for multiagent-based social simulations; that is, creating large-scale simulations and elaborating human behavior models against the backdrop of the huge amount of data. Although many studies have been conducted on both approaches, the vast majority of them seems to be strongly biased to one viewpoint. Yamamoto and Mizuta proposed a platform for massive agent-based simulations called ZASE [3]. While they showed ZASE can perform well with a large number of agents, they did not show great concern about the details of the behavior models. Murakami et al. proposed a modeling technology based on participatory simulations to construct behavior models that can reproduce human-like behaviors [4]. Although their proposed technology enables the construction of diverse behavior models, they did not execute large-scale simulations with the constructed models. This is because there is a trade-off between the scale of MultiAgent-based Simulations (MASim) and the granularity of behavior models in terms of the computation time. However, thanks to recent advances in computing power, it is becoming possible to conduct massive MASim with fine-grained behavior models. It is the time to combine scale-oriented MASim with model-oriented MASim, both of which have been studied in different threads up to now.

The challenge presented in this paper is to achieve massive urban traffic simulations with fine-grained levels of driving behavior. Traffic is an adequate target for our research because vehicular traffic is a phenomenon that emerges from interaction among a lot of human drivers with diverse driving styles. Toward our objective, we develop a multiagent-based simulation platform that enables us to execute massive MASim. Concretely, there are three issues to be achieved.

1. Development of a scalable MASim platform:
   We need to design and implement a scalable traffic simulation platform that can run citywide traffic simulations with agents controlled by individual driving behavior models.
2. The ability to reproduce "actual" urban traffic:
   To explain different traffic phenomena, we need to confirm that the developed platform can generate reasonable traffic flows.
3. Investigation of the potential to analyze the urban traffic based on both macroscopic/microscopic viewpoints:
   We need to ensure that the developed platform is useful in examining both the macroscopic and microscopic aspects of urban traffic.

2. Massive Traffic Simulation with Fine-Grained Models

2.1. Design of Traffic Simulator

The multiagent-based traffic simulation platform proposed in this paper is implemented as an extension of MATSim (MultiAgent Transport Simulation toolkit) [5].

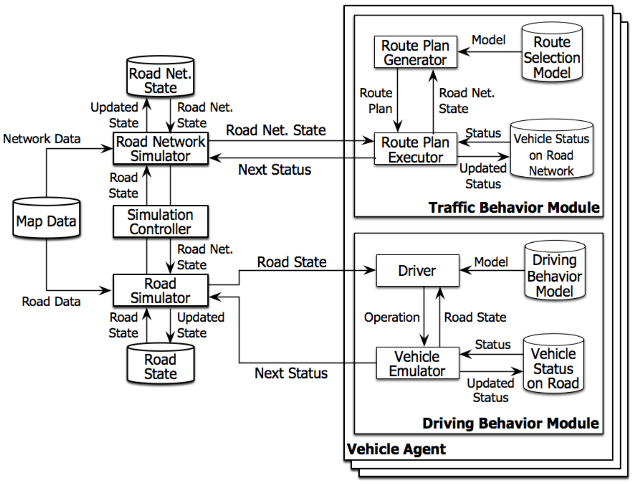

Fig. 1. Traffic simulation platform architecture.

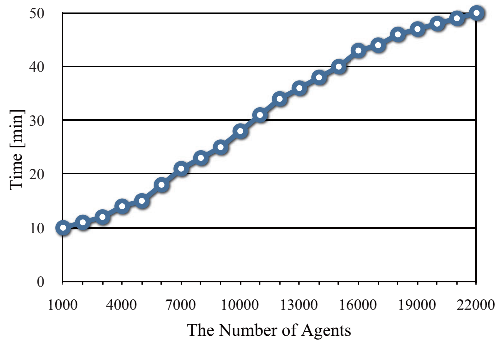

Fig. 2. Computation time.

Although MATSim enables to conduct queue-based massive traffic simulations, it fails to support realistic micro traffic simulations. This is because the details of road structures (e.g., the number of lanes) or surrounding environment including neighboring vehicles cannot be represented so that "driving behaviors" considering such locally available factors cannot be reflected in simulations. In order to achieve traffic simulations with the fine-grained driving behavior models, we designed and implemented a simulation platform shown in **Fig. 1**.

Our simulation platform includes two main simulation modules; *Road Network Simulator* and *Road Simulator*. Road Network Simulator plays the central role on controlling the transition of each vehicle on the extensive road network so that this simulator updates the location of each vehicle, i.e., the current road, on the road network. Road Simulator corresponds to one physical road and manipulates the vehicle agents on it; that is, the simulator requests each agent to execute the calculation required to carry out a simulation. Additionally, this simulator updates the status of each agent, such as its location on the road. During traffic simulations, these two simulators exchange state of vehicles and realize both global traffic phenomena and local traffic behaviors. On the simulation platform, an agent includes a traffic behavior module for route planning and driving behavior module for driving operation. Both modules are assigned models used to determine plans and operations. Currently, we use a common model for planning which calculates the shortest plan based on Dijkstra method. Road Simulator request each agent's driving behavior module to execute a driving operation every 100 msec, then *Driver* sub-module in each agent calculates the next operation based on the assigned driving behavior model. The next speed, velocity, and location are calculated in *Vehicle Emulator* based on the current status stored in *Vehicle Status on Road* DB.

As mentioned above, we extended established traffic simulator, MATSim. Although MATSim enables to represent each agent as a distinct entity, it is unable to explicitly represent the characteristics of agent behaviors. On the other hand, our platform enables to represent distinct unique behaviors of each agent. Thus, our simulator offers a more detailed view of complex traffic phenomena. AVENUE [6] is another traffic simulator which provides the detailed view of the urban traffic flow. AVENUE is based on hybrid block density method which can offer the future of both fluid model and discrete vehicle model. In AVENUE, micro behaviors are decided at the macro level. Namely, the movement of discrete vehicles are controlled by the parameter calculated by the fluid model. Therefore, traffic flows in AVENUE are not generated by the accumulation of diverse local behaviors of agents so that it is not based on pure bottom-up approach. On the contrary, our simulator generates traffic flows through bottom-up calculation based on two discrete models for route planning and reproducing driving behaviors. Thus, we are proposing pure micro traffic simulators with reasonable scalability (see Section 2.2).

2.2. Computational Performance

We show that our simulator has sufficient scalability. In this experiment, we generated 100 ODs by pairing two randomly selected points from 25 main intersections within the heart of Kyoto city (2 km $\times$ 2 km square). For the simplicity, all agents used the same behavior model. The simulation time was 2 hours so some agents could not reach their destination due to congestion. We ran our experiments on a computer with a Core2Duo 2.53 GHz CPU and 3 GB of main memory. As we explained in the previous section, our simulator trades computation time off against an increase in simulation resolution. **Fig. 2** plots the computation time versus the number of agents. As you can recognize, the computation time is directional proportional to the number of agents. In fact, with the largest number of agents (22,000), the computation time is around 50 min. This result means our platform has sufficient scalability for urban traffic simulations with fine-grained behavior models. For example, Geroliminis and Daganzo executed traffic simulations in Yokohama, which is a major Japanese city of the Greater Tokyo Area, with