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Research paper

Virtual traffic simulation with neural network learned mobility model

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A B S T R A C T

Virtual traffic simulation plays an important role in easing traffic congestion and reducing traffic pollution. As the transportation network expands, the former rule-based mobility models showed several limitations in producing convincing virtual vehicles. A more realistic model with example-based method is in demand. In this paper, a neural network is employed with carefully selected traffic trajectory data. The virtual vehicle production is driven by the proposed mobility model and organized by a specified structure. Then, the virtual traffic simulation could be given for an indicated scenario.

1. Introductions

Researches on intelligent transportation system (ITS) has gained great amount of attentions recent years. Thanks to the rapid development of computer techniques in both software and hardware, ITS goes one step further from the ideal model to reality. ITS can be broadly defined as collective application of advanced technologies, such as communications, sensors, and computing, to the transportation systems, in order to supply real-time information to improve safety, efficiency and comforts, at the same time reduce the impact to environment.

As can be found among previous work on ITS, it covers a broad range of research interests and multiple kinds of problems should be faced. For example, the routing or communication problems of the network focus on the network or its communication protocols for either vehicle-to-vehicle communication or vehicle-to-infrastructure communication [1]. Game theory is also employed in dealing with the traffic light management and organization problems [2] in order to ease traffic congestion. Besides, Liu and Kamel [3] provides a platoon control method to adjust the speed of vehicles so as to fulfill the blind crossing of an intersection. There are also other interests such as length estimation problem of the waiting platoon, co-operative traffic monitoring problem, etc. All these research on ITS are committed to improve road safety, relieve traffic congestion and comfort driving experience [4].

In this paper, we focus on another aspect, in which the simulation of virtual traffic situations has been taken into consideration. The simulation refers to produce virtual, reliable, and realistic vehicular flow. This kind of vehicular flow has a critical use in predicting, pre-casting and simulating a certain traffic situation for the specified transportation scenario. The simulation aims to build up a bridge between the two kinds of view of daily traffic: the macroscopic traffic and the microscopic traffic. Changes in microscopic traffic could be easily shown when some macro managements are taken. Thus, it could help to ease the congestion and reduce the pollution, in alternative way.

It also has an essential application in traffic design or traffic control for either daily life traffic or special events traffic. For example, the EURO Cup 2016 held in France brings up large amount of traffic for the host cities, and causes changes for daily traffic. At the same time, a specified, well-rounded parking and traffic control plan would be in need, which is very much based on the incoming and out-coming vehicular flows. However, since the event is not a normal action for city traffic, little previous traffic data can be used as references. Organizing exercises of large scale real traffic can solve the problem, however, with a huge expense and can still be inefficient. Thus, the virtual vehicular flow is essential to simulate the certain scenario.

Previous work has combined conventional traffic motion model with virtual reality technique, and produced a traffic simulator for driving exercises [5]. The virtual traffic system could be represented as an autonomous agent system in most existing research of traffic simulation. Similar with crowd simulation system, according to elaboration on [6], a well-rounded agent system could be built in three layers: the action selection layer, the steering layer and the locomotion layer.

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In this paper, we mainly focus on an enhanced vehicular mobility model using a neural network based method to produce more realistic virtual traffic vehicle flows. The proposed method may also consider the interactions among vehicles, that although every vehicle makes its decision individually, it also considers the relative information from the adjacent vehicles. Neural network is used to learn the hidden spatial-temporal relationships among vehicles. The learned mobility model would help in providing the traffic simulation locally, which indicates that we can synthesize and generate virtual trajectories for each single vehicle agent in a traffic system. The produced simulation would be more realistic than the one produced by conventional ones. And we also implemented a specified structure to organize and manage the virtual vehicles. The presentation by far is realized by employing a traffic simulator SUMO. With the limitations of time, construction of this platform is the only concern in this paper. Further applications could be executed by relying on the built platform. And that would be discussed later.

The rest of this paper is organized as follows: Section 2 introduces the related works of our research including the existing mobility models and previous applications of neural network in traffic simulation. Section 3 defines the facing problem that why our method produces better vehicular flows than the conventional methods. The method descriptions are presented in Section 4 and corresponding validations and experiments are shown in Section 5. A section on discussion is given in Section 6 and the conclusions are given in Section 7.

2. Related works

2.1. Mobility model

As for the major concern of this paper, vehicle model or literally mobility model would be involved in simulating virtual traffic. These models are proposed in Mobility ad Hoc Network (MANET) and in Vehicular ad Hoc Network (VANET) as well. The adjustments are necessary due to the fundamental differences between the two networks. Mobility model is designed to describe how vehicles behave in road, how their location, velocity and acceleration change over time. A realistic model is an essential component to predict the following behavior of the vehicles. Similarly, the mobility models have been built both in macroscopic level, in which the researchers focus on the movement of relative to a particular area including the cell change rate, handover traffic and blocking probability, etc., and in microscopic level that would be mainly described below. According to the classification of [7], these mobility models could be grouped in different categories.

For example the most frequently used random waypoint model (RWP) [8] could be categorized as a random model along with the random walk model and random direction model. In RWP, destinations are randomly chosen and vehicles move toward the destination at a uniform speed. After reaching a destination, another destination is chosen at random to continue the loop. Several drawbacks and limitations exist in the RWP. The corresponding remedies also lead to further categories of the mobility models.

Since some extreme behaviors including a sudden stop or sharp turn may frequently happen in a random model, memories of previous actions are held and considered in creating further movement of the mobile entity. It's called the mobility model with temporal dependency. Differs from the basic RWP, in which mobile entities make decisions independently, communications and collaboration among multiple entities could also be added into mobility models. The mobility model with spatial dependency is capable in describing complex relationship such as leader-follower. And mobility model with geographic restriction could also make the entities or the vehicles comply with certain traffic rules. However, these models are mostly rule-based models that directly use equations to describe the restrictions on the mobile entity.

On the contrary, instead of using exactly dynamics or physics equations, the mobile entity could also move under control of the motion patterns drawn from the real-world data. It is obvious that it is inappropriate to directly use the real-world data itself. The reasons could be concluded as the three below:

1. Insufficient data: The absence of data on some time periods, some intersections and sections exists. The surveillance camera may not be plated anywhere and be turned on anytime.
2. Special events: There are no existing data in help of prediction and analysis the traffic situation for event such as EURO Cup 2016. The surveillance camera recorded data are usually traffic situation in normal life, which is not instructive in large scale events like this.
3. Inefficiency: It is inefficient in using such a large amount of real-world data. According to the traffic data from Next Generation Simulation (NGSIM) [9,10], a highway surveillance camera may record 10,000 frames of data in a time period of 15 minutes, which includes more than 1 million queries in database (for comparison, the Microsoft EXCEL can only contain about a million queries in a single sheet). Any searching from data in this scale can never be efficient.

Thanks to the computer learning algorithms that provide us a black box, and allow us to ignore the detail inside, yet be capable in extracting the features to represent the given data, example-based mobility models could be proposed.

2.2. Neural network

Artificial neural network is a computational approach which is based on a loosely modeling on the way how real neural network solves problems. As the elaboration of [11], a neural network model could be efficiently used in applications such as clustering, estimating of statistical distributions, compression and filtering. Meanwhile it is also capable in applications such as regression analysis, prediction and modeling.

As for the existing work in relevant domain, Yu and Chen [12] used a three layer simple neural network model with back propagation algorithm to prediction the traffic. Due to the limitation of computational capability, the proposed network is quite simple in his modeling that the traffic quantity of a time period is chosen as the only feature focused during the prediction.

Recently, the network grows much bigger and more complex. Jiang and Fei [13] proposed a two-level vehicle speed prediction system for highways based on neural network and hidden Markov model. In this system, the under simulated road has been divided into several segments. The traffic speed of certain road segments on certain time stamp is predicted by neural network with the information of neighbor segments using historical data. Differently, Ma et al.[14] presented a long short-term memory neural network to predict speed using microwave detector data. To validate the effectiveness of the proposed method, one month traffic data with the updating frequency of two minutes from two sites in Beijing expressway were collected. Comparisons with other method such as SVM have also been made on the same dataset.

Despite the diversity of using neural network in solve traffic prediction problem, there is one essential difference that all these prediction systems focus on the overall speed prediction, which is from the macroscopic-level modeling. Individual behaviors have not been considered in their methods. As for the simulation in microscopic level, Lerner et al.[15] presented an example-based simulation technique, however for the human crowds. Xia and Kamel [16] used neural network with reverse reinforcement