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Video-based personalized traffic learning ☆

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ABSTRACT

We present a video-based approach to learn the specific driving characteristics of drivers in the video for advanced traffic control. Each vehicle's specific driving characteristics are calculated with an offline learning process. Given each vehicle's initial status and the personalized parameters as input, our approach can vividly reproduce the traffic flow in the sample video with a high accuracy. The learned characteristics can also be applied to any agent-based traffic simulation systems. We then introduce a new traffic animation method that attempts to animate each vehicle with its real driving habits and show its adaptation to the surrounding traffic situation. Our results are compared to existing traffic animation methods to demonstrate the effectiveness of our presented approach.

1. Introduction

With the popularity of vehicles and the dramatically increasing demand on transportation, road transport has brought about more and more serious negative effects—traffic congestion, traffic accident, and environmental pollution. Traffic management has been a global challenge with its direct impact on economy, environment, and energy. Meanwhile, traffic simulation has found its wide use in computer animation, computer game, and virtual reality [1,2]. Some methods try to simulate each vehicle's behaviors while others aim to capture high-level flow appearance. However, the simulated results usually do not correlate to each driver's personalized driving behavior. Moreover, with better vehicle detection and tracking technology and more software tools for viewing road network, such as OpenStreetMap and GPS, there is a growing need to present realistic traffic scenarios in a virtual environment based on real-world vehicle trajectory data.

In the real world, drivers' driving behaviors vary significantly depending on time, place, personality trait, and many other social factors. These variations in driving behaviors are often characterized by observable factors such as driver's speed choice, gap acceptance, preferred rate of acceleration or deceleration, environmental adaptation factor, and so on. Estimating such characteristics is an important task if we want to reconstruct the traffic flow correlating to an input real traffic. However, existing traffic simulators set these parameters as random values around the average of empirical values, which are hard to reflect drivers' personalized driving behaviors in a specific environment. Moreover, little attention has been paid to this problem in existing traffic simulation methods.

In this paper, we propose a data-driven method to simulate virtual traffic flows that exhibit driving behaviors imitating real traffic flows. We record the motion of vehicles from an aerial view using a camcorder, extract the two-dimensional moving strategies of each vehicle in the video, and then learn the specific driving characteristics from the observed trajectories.

Learning driving behavior from videos is a challenging problem because the motion of each driver is influenced by not only the local road traffic condition, but also the driver's personality and social factors, which cannot be directly seen in the captured video. We choose a short clip from the

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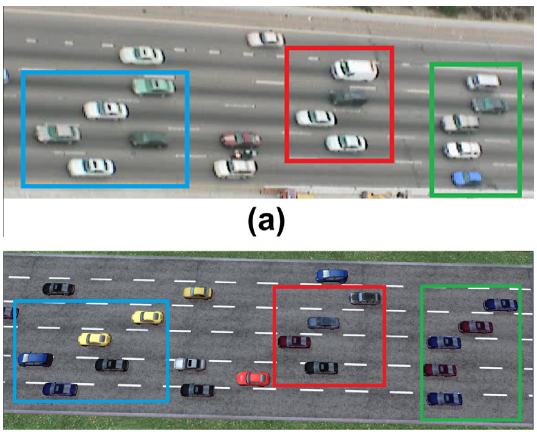
input video as the learning sample, and use a microscopic traffic model to approximate each vehicle's behavior. Since 1940s, lots of traffic simulation models have been proposed, tested and evaluated for calibration. Among them, the intelligent driver model (IDM) [3] was proven to be one of the best approximation models and it conforms to our daily driving habits. The intelligent driver model with memory (IDMM) [4] is an expansion of IDM which introduces memory effects to describe drivers' adaption to the congested traffic. In this work, we revise the original IDMM model to describe the adaptation of drivers to the surrounding traffic situation (not limited to congested traffic).

We present a mapping between the low-level IDMM parameters and high-level driving characteristics. Inspired by the theory on the car-following model calibration [3], we utilize a nonlinear optimization scheme to compute each vehicle's optimal parameter set of IDMM. Different from previous model calibration methods, we develop an adaptive genetic algorithm to better fit for traffic animation.

The main contribution of the paper is that we introduce a novel method to estimate vehicles' personalized driving characteristics based on training data from an input video. These parameters are then employed to reconstruct the traffic flow conforming to the video. We also present a new traffic animation method using IDMM to show drivers' adaptation to the surrounding traffic situation. In addition, we propose an offline learning approach combining IDMM with an adaptive genetic algorithm, which outperforms existing methods for model calibration. Our approach can reproduce new traffic scenarios exhibiting similar driving behaviors with the sample video. Fig. 1 shows a reconstructed scenario using our method.

The rest of the paper is organized as follows. Section 2 describes the related work on traffic animation and model calibration. Section 3 presents an overview of our approach. Sections4 and 5 give a detailed description of the algorithm. The performance analysis and simulation results are shown in Section 6. Finally, we conclude the paper and discuss the future work in Section 7.



(a)

(b)

Fig. 1. One frame in the traffic sample video (a) and our reconstruction result (b).

2. Related work

In this section, we give a brief review of prior work in traffic animation and crowd behavior learning. Model calibrations and genetic algorithms are also reviewed as they will be employed in our framework.

2.1. Traffic animation and crowd behavior learning

The growing ubiquity of vehicle traffic in everyday life has attracted considerable interest in traffic behavior modeling and traffic visualization techniques. In computer graphics, much of the research on traffic has focused on two hot topics: the classical problem of traffic simulation, and traffic reconstruction [1]. The classical problem of traffic simulation is mainly about traffic behavior model. Given a road network, a proposed behavior model, and initial car states, how does the traffic evolve? In general, there are two popular classes of traffic simulation techniques: the continuum-based macroscopic and agent-based microscopic techniques.

In macroscopic simulation, traffic is treated as a kind of continuum whose evolution in time is described by partial differential equations. A famous macroscopic model was developed by Lighthill, Whitham and Richards in 1955 [5] called LWR model. It can fully describe the basic traffic-related phenomena: traffic jams and evacuation. In the 1970s, Payne [6] and Whitham [7] introduced the momentum conservation equation to the original LWR model and simulated some more complicated cases using their PW model. This model was further revised by Aw, Rascle [8] and Zhang [9] to eliminate the nonphysical behavior, referred as ARZ model. In computer graphics, Sewall [10] extended the ARZ model to correctly handle lane changes, merges, and traffic behaviors due to changes in speed limit.

The agent-based microscopic methods treat each vehicle as a discrete autonomous agent with specific rules governing their behavior. Gerlough [11] summarized a set of car-following rules in his dissertation about traffic simulation in 1955. Through a variety of expansion, it has formed some new models, such as the optimal velocity model [12], the intelligent driving model (IDM) [13], and the intelligent driving model with memory [4]. In computer graphics, Shen et al. [14] proposed a new agent-based model by combining IDM with a flexible lane-changing model mainly for vivid traffic animation purpose. Sewall et al. [2] presented a hybrid traffic model integrating continuum and agent-based methods for large-scale traffic animation.

In this paper, we focus on the efficient traffic reconstruction with realistic and various driving characteristics extracted from real-world discrete spatio-temporal data. The aim is to approximate the real-world data as much as possible, and finally reproduce the real-world traffic scenarios. Compared to the classical problems of traffic simulation, this topic is less studied. Sewall et al. [1] presented a novel concept of *Virtualized Traffic*, in which traffic is reconstructed from discrete data obtained by sensors placed alongside the road. Their approach can reconstruct plausible trajectories for each car using priority-based motion