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Traffic situation visualization based on video composition

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ABSTRACT

Vehicle detectors (VDs) are usually distributed in a road network to detect macroscopic traffic situations. These detectors provide global information such as vehicle flows, average speed, and road occupancy. Given that the collected statistic data are difficult for citizens to interpret, we visualize the data by providing users with realistic traffic videos. To achieve this aim, our system collects the surveillance videos and VD data that represent the traffic situation of a position. It then builds the connection between these two types of data. Considering the distribution of VDs is much denser than that of surveillance cameras, for those road segments with a VD but without a surveillance camera, one can utilize our system to synthesize videos for visually depicting the traffic situations over there. That is, we estimate vehicle flows from a video and apply the regression model to build the mapping between the flows and VD data. After that, given by a VD dataset, our system retrieves videos that match the VD data and seamlessly composes them to synthesize a traffic video. The evaluations and the experimental results demonstrate the feasibility of our system.

1. Introduction

Vehicle detectors are usually distributed in-road to acquire spatiotemporal traffic statistic. The detectors record the number and the average speed of vehicles that pass within a time span. These data are important for city planners and traffic controllers [1] because the data depict overview and details of traffic situations over time. However, interpreting traffic statistic demands expertise and is not suitable for general populations. For example, the same driving speed in a countryside and an urban city could have very different experience because of light and heavy traffic densities. Providing users with a number of vehicles that pass is also unintuitive because it depends on the number of lanes on the road. Moreover, a light traffic flow may indicate few vehicles on the road or a serious traffic jam, which easily induces misleading. Accordingly, providing an interface for general users to realize traffic situations is essential.

Since transmitting videos captured from road surveillance cameras consumes expensive load, simulation techniques are presented for traffic visualization. The methods estimate velocity and density fields over the road network, followed by applying an agent-based traffic simulator to create 3D animations. They enjoy the visualization from various viewpoints and even allow users to observe traffic from a driver's perspective. However, a simulator cannot always realize the real traffic flows because driving behaviors are often different in countries and regions (Fig. 1), not to mention other conditions such as weather, rush hours, and holidays. To overcome this problem, we present an example-based system that visualizes traffic situations by synthesizing road surveillance videos.

Our goal is to visualize statistic VD data using real world materials. Specifically, we find a road segment where VD and surveillance camera are both available and extract the relations between them. For the place with a VD but without cameras, we synthesize a streaming video by composing the video clips in our database to visualize its traffic situations over time. The main advantage of this framework is generality. While a simulation technique is insufficient to create an animation that satisfies all driving behaviors, our system does not have this problem because they are already provided by road surveillance videos. Note that this framework also consumes light data transmission load because example videos are collected in advance. Only statistic VD data are transmitted when the traffic flows of a road segment are visualized.

The problems of traffic visualization in our framework are video retrieval and seamless composition. Considering the traffic situation of a video is unclear, to obtain the information, we seed particles on the video and track their motions. The number and speed of these particles that go outside the video coordinate or gather at the vanish point are recorded. After that, we compute a regression model to map the VD data and the particle flows so as

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Fig. 1. Left and right show traffic jams occur at different regions. Left: all vehicles are in lane and no drivers attempt to violate traffic rules. Right: vehicles cross lanes wantonly and make the traffic even worse. Simulation methods are difficult to reconstruct all types of traffic flows.

to retrieve proper videos for composition when a macroscopic traffic statistic of another place is given. To prevent artifacts of video transition, we overlap consecutive videos by a number of frames and compute a surface that passes through pixels with the least distortion. Specifically, pixels on this surface should have small color variations and zero motions to avoid discontinuity artifacts and suddenly appearing or disappearing vehicles. We also apply the Poisson blending to smooth the difference of illumination conditions in videos for achieving high visual quality.

Our method synthesizes a streaming video to visualize the traffic situations of a place over time. This example-based framework can realize the traffic flows consistent with the sparse VD data at different regions. The main advantage of this framework is generality, which is able to visualize different traffic situations derived from driving behaviors, weathers, etc. We show the experimental results in Figs. 6, 7, and in the accompanying video to demonstrate the feasibility of our technique.

2. Related work

Traffic visualization: Visualizing traffic information is essential to city planners and traffic controllers. Many on-line services such as SigAlert and Google Maps depict the conditions of a traffic network by colorization. The abstracted visual means look clean and neat but lack details for understanding dynamic vehicle flows. Therefore, Walton et al. [2] projected live traffic videos onto maps to provide such information. However, the method consumes heavy transmission load when too many traffic videos are displayed at a time. Another approach to achieve the aim is traffic simulation [3–10]. The methods first estimate the full traffic state based on the sparse VD sensing data, followed by simulating the dynamics of all individual vehicles to create animations. These simulation techniques enjoy various viewpoints when visualizing traffic situations. But they are insufficient to simulate all kinds of vehicle kinematics and dynamics due to unknown driving behaviors in different regions. As a result, we attempt to visualize traffic situations by composing road surveillance videos. This example-based approach achieves more accurate visualization because various vehicle kinematics and dynamics are already provided by road surveillance videos.

Video textures: Video textures [11,12] are commonly used to generate an infinite length video based on a finite video clip. The technique changes the order of video frames that are unnoticeable to viewers and plays the video forever. Considering that two video frames with very similar content is difficult to obtain, to prevent discontinuity artifacts, Kwatra et al. [13] overlapped a number of frames and computed a surface to transit one video to another seamlessly. Besides the videos with a fixed viewpoint, Agarwala et al. [14] captured videos using a panning camera and synthesized panoramic video textures to enhance visual experience. Later, Couture et al. [15] extended the panoramic video textures to a stereo version. Our streaming traffic video synthesis is inspired by these works. However, all previous methods consider local color gradients during composition. Foreground objects with large motions may suddenly appear or disappear when videos are composed by these methods.

Poisson blending: Many image and video editing techniques apply Poisson blending to smooth boundary artifacts when visual media are composed. This operation performs in the gradient field of an image and has attracted significant attention in research works [16–19]. Our system also applies this operation to smooth discontinuity artifacts when transiting one video to another. Given that Poisson blending requires solving a large linear system, which consumes expensive computational cost, there were also techniques presented to improve its performance [20–23].

3. Algorithm

Our goal is to visualize traffic statistic using videos captured by road surveillance cameras. To achieve the aim, the first step is to build the relations between traffic statistic and videos. We search for places where VD and surveillance camera are both available, and then compute a regression model to map the detected number of vehicles and average speed to the particle flows in a video. Specifically, our system cuts a streaming road surveillance video into short clips, with each clip containing one minute, because each VD returns a traffic statistic every one minute. Because of different natures of traffic statistic and videos, we extract vehicle flows from the video and train a regression model to link these two data. This objective is achieved by computing optical flows from each video, which roughly represent the traffic flows because surveillance cameras have fixed viewpoints and most moving objects can be considered vehicles. Accordingly, given by traffic statistic at another place, our system is able to retrieve proper videos from the database and compose them together for traffic situation visualization.

Our system composes one-minute videos to a streaming video for visualizing the traffic situation of a place with a VD but without a surveillance camera. To prevent discontinuity artifacts, we reserve a number of frames at the two ends of each one-minute