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A discounted recursive logit model for dynamic gridlock network analysis

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A R T I C L E I N F O

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A B S T R A C T

Emerging sensing technologies such as probe vehicles equipped with Global Positioning System (GPS) devices on board provide us real-time vehicle trajectories. They are helpful for the understanding of the cases that are significant but difficult to observe because of the infrequency, such as gridlock networks. On the premise of this type of emerging technology, this paper propose a sequential route choice model that describes route choice behavior, both in ordinary networks, where drivers acquire spatial knowledge of networks through their experiences, and in extraordinary networks, which are situations that drivers rarely experience, and applicable to real-time traffic simulations. In extraordinary networks, drivers do not have any experience or appropriate information. In such a context, drivers have little spatial knowledge of networks and choose routes based on dynamic decision making, which is sequential and somewhat forward-looking. In order to model these decision-making dynamics, we propose a discounted recursive logit model, which is a sequential route choice model with the discount factor of expected future utility. Through illustrative examples, we show that the discount factor reflects drivers' decision-making dynamics, and myopic decisions can confound the network congestion level. We also estimate the parameters of the proposed model using a probe taxis' trajectory data collected on March 4, 2011 and on March 11, 2011, when the Great East Japan Earthquake occurred in the Tokyo Metropolitan area. The results show that the discount factor has a lower value in gridlock networks than in ordinary networks.

1. Introduction

A gridlock network is an extraordinary situation that drivers do not usually experience, unlike congestion due to accidents, construction, rush hour, and special events. In gridlock networks, drivers cannot make global decisions for their route choice because of which they travel in confusion. These extraordinary route choice mechanisms may confound the network situation. Therefore, technologies to observe and analyze these behaviors are needed.

The mainstream method of traffic congestion control is the crossing or area control (e.g., Daganzo, 2007; Geroliminis and Daganzo, 2008) that is based on traditional vehicle detection sensors, but this method cannot deal with network-based congestion spread, which is critical in dealing with gridlock networks. On the other hand, emerging sensor technologies such as probe vehicles equipped with global positioning system (GPS) devices are helpful to understand the infrequent but significant behavior of each vehicle in gridlock networks. Using certain type of vehicles as probe vehicles, such as taxis or buses, has increased the monitoring

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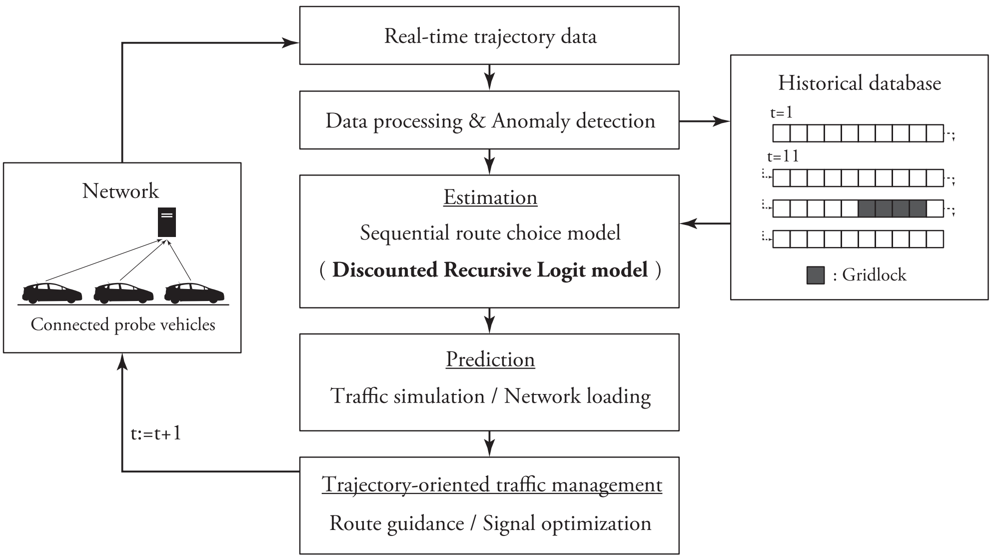

Fig. 1. Framework of trajectory-oriented gridlock network management.

capability (Dailey and Cathey, 2002). This emerging sensor technique is now ubiquitous and provides real-time information of vehicle trajectories, which has been opening up possibility of network analysis and management (e.g., Feng et al., 2014; Kim and Mahmassani, 2015; Yang et al., 2017).

In this paper, on the premise of this type of emerging technology, we aim at developing a sequential route choice model applicable to a trajectory-oriented framework for gridlock network analysis and management (Fig. 1). The management method is based on traffic simulations using trajectories from real-time and ubiquitous technologies in contrast to the previous route choice models that require the choice set generation (e.g., Bekhor et al., 2006) and the information regarding entire trips, including origin and destination for estimating parameters. Herein, we propose a sequential route choice model that does not require the information of entire trips to estimate parameters. Using the model, in the framework of Fig. 1, the parameter estimation is implemented at each time period, because we assume that not only network situations but also behavioral preferences can change at different time periods.

In a route choice modeling context, it is assumed that drivers usually acquire spatial knowledge of networks through direct environmental experiences (Gale et al., 1990). Most of previous route choice models assume this type of travelers, that is, they postulate that drivers have global spatial cognition to accurately evaluate the path utilities of all alternatives. Contrary to such a daily route choice model, in extraordinary situations such as natural hazards or urban gridlocks, drivers' route choice behavior has distinctive features. They are non-habitual situations where drivers' have no experience. Moreover, drivers cannot gain appropriate information because of network disarray, as a result, they have little spatial knowledge of networks. In such a situation, drivers cannot evaluate the path utilities accurately, but they rather appraise close or visible spaces with the larger weight than distant spaces. Route choice decisions become sequential and somewhat forward-looking.

This study aims at developing a route choice model, which describes both route choice behavior in ordinary networks and gridlock networks, and focuses on the decision-making dynamics in sequential route choice models. Existing sequential route choice models (e.g., Baillon and Cominetti, 2008; Fosgerau et al., 2013) formulate route choice behavior based on sequential link choices conveniently; however, they do not discuss the serializability of decisions and result in the equivalent path probability to the path-based MNL model. To the contrary, we deal with the decision-making dynamics of drivers, which mean that the decisions at possible future states affect the decision at the current state. For this reason, we apply the concept of a discount factor in the dynamic discrete choice model (Rust, 1987) and formulate a sequential route choice model with it. Note that we model the dynamics of decisions as the mechanism of route choice behavior, as opposed to dealing with the route switching/adaptation behavior in time-dependent networks as previous dynamic route choice models do: therefore, the targets are different from each other. It is possible to combine both the dynamics of decisions and networks; however, in this study we concentrate on the former and assume a static and deterministic network to clarify the impact of decision-making dynamics in route choice models.

We also estimate parameters of the route choice model as a disaggregate discrete choice model, rather than macroscopic analyses of extraordinary networks (Daganzo, 2007; Mahmassani et al., 2013). Real-time parameter estimation and traffic simulations are significant for gridlock network management; however, path-based route choice models require the information on entire paths of trips and choice set generations. On the other hand, sequential route choice models require the information of only link transitions and the destination, for parameter estimation, and these are applicable to emerging real-time sensing technologies. Moreover, we focus on the change of route choice mechanisms in each network condition and compare the estimation results among multiple time periods over two very different days (ordinary/extraordinary) using probe-vehicle data. One of the days is that of the Great East Japan Earthquake.

The contributions of this paper are summarized as follows. This paper first gives the spatial interpretation to the discount factor of