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RESEARCH PAPER

Route Choice Behavior Model with Guidance Information

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Abstract: Using modeling and simulation methods, the driver's route choice behavior under guidance information is explored based on the combination of the decision field theory (DFT) and Bayesian theory. First, based on the Bayesian theory, a road condition dynamic updating model is presented in light of the guidance information and the driver's previous travel experiences. Then, the route choice behavior model under guidance information is formed by the fusion of the process-oriented vehicle dynamic route choice model and the road condition dynamic updating model. The developed model describes a driver's propensity to comply with received guidance information in terms of the interaction between perceived unreliability of the information, his previous travel experiences, preference for different road alternatives, decision-making speed/quality, and route selection criteria. The simulation results show that the combination of the DFT and Bayesian theory can effectively explain the driver's travel dynamics behavior.

Key Words: urban traffic; driver's route choice behavior; decision field theory; bayesian theory; guidance information

1 Introduction

The essence of guidance information service is to guide drivers' route choice behaviors by providing appropriate traffic information so that they choose routes as expected by the traffic management. With the ever changing technology of such provision, the effect, as well as mechanism of action, of guidance information on the above behaviors has become an urgent problem that should be addressed in the field of transport research. Most of the existing studies have been based on the Expected Utility Theory[1]; whereas others are carried out based on the Prospect Theory and Random Utility Theory[2], as well as fuzzy logic or heuristic theory. AL-DEEK et al proposed a framework for evaluating the effect of Advanced Traffic Information System (ATIS) on travelers' behaviors[3]; Wahle *et al*. described driver-vehicle units as agents, and studied the impact of different traffic information on the agents' travel behaviors using simulations[4]; Ben-Elia and Shiftan established a learning-based model of route choice behavior under real-time information using prospect theory and random utility theory[2]; Lu proposed models of drivers' response behaviors under guidance condition by using the Game Theory in this field[5]; Stern and Richardson believed that the decision field theory (DFT) should be the framework for a new research agenda aimed at understanding the motivational and cognitive mechanism of drivers' deliberation process[6].

Although some outcome has been reaped from the research on drivers' route choice behaviors under guidance information, there are still some questions worthy of further study, which are mainly reflected on the following points: (1) it is extremely difficult to strictly describe drivers' route choice behaviors from the aspect of mathematical modeling because the traffic system under guidance information is inherently dynamic, discrete, complex, and uncertain; (2) no research has been carried out on the changing process of drivers' route choice behaviors under guidance information; (3) the current analysis on the drivers' route choice behaviors under guidance information is mainly concentrated on a single factor of travel time, without comprehensive consideration about the interaction among various factors such as drivers' thought, road condition, and guidance information.

The effect of a traffic guidance system ultimately depends on drivers' response on guidance information. The scientificity of the research on drivers' response behaviors immediately affects the design and construction of intelligent traffic guidance systems. Bayesian theory, which has been successfully and practically applied to human's uncertain

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inference, learning, and alteration of experience, is chosen to build a model that describes drivers' prediction, judgment, and dynamic updating of road condition. DFT[7] is used to study drivers' multi-attribute cognition and decision process under guidance information and construct the model of route choice behaviors. Thereby, the model of route choice behaviors under guidance information is obtained to provide theoretical foundation for the reasonable configuration of guidance information and effective utilization of ATIS.

2 A model of prediction, judgment, and dynamic updating of road condition based on Bayesian theory

In view of the fact that drivers will make route choice decisions by first predicting the road condition of traffic network and then updating their prediction according to the real-time information of road condition provided by guidance information as well as their travel experience. During the updating process, there are uncertain factors with respect to guidance information and travel experience. In our model, all kinds of prediction are treated as random variables and updated using the Bayesian method.

The Bayesian theory was proposed by Thomas Bayes in 1763. Its basic principle is to give prior likelihood estimation of a hypothesis and update the likelihood function in the light of new evidence (observed data). The Bayesian analysis method relates the prior probability to the posterior probability of events, and provides a method to calculate the latter from the former. Define $P(B_i)$ as prior probability and $P(A \mid B_i)$ as new additional information obtained from survey, where i=1, 2, ⋯, n. Then, the posterior probability is as follows:

$$P(B_i \mid A) = \frac{P(A \mid B_i)P(B_i)}{\sum_{j=1}^{n} P(A \mid B_j)P(B_j)} \tag{1}$$

Define $P(\pi_k)$ as the probability for a driver to estimate the occurrence of road condition π_k based on his/her previous travel experience; and π^I as the road condition provided by the guidance information. $P(\pi^1 \mid \pi_k)$ is defined as the occurrence probability of road condition π^I provided by the guidance information, as estimated by the driver based on the accuracy of previously provided guidance information. It is the driver's earlier evaluation on the quality of guidance information, that is referred to as the confidence level of the guidance information. According to Bayes' theorem, the occurrence probability of road condition π_k as concluded by the driver after receiving the guidance information should be:

$$P(\pi_k \mid \pi^I) = \frac{P(\pi^I \mid \pi_k) \cdot P(\pi_k)}{\sum_{\pi_j \in \pi} [P(\pi^I \mid \pi_j) \cdot P(\pi_j)]} \tag{2}$$

Thus, a model of prediction, judgment and dynamic updating of road condition is obtained.

3 A DFT-based dynamic route choice model Vehicle class composition identification based

Neuroscientists' recent research on human brain has indicated that the process of human choice is the one in which the stimulation degree of preference to each alternative dynamically accumulates in human brain. With the accumulation and increase of preference state, the first alternative that exceeds the threshold will be chosen[8]. DFT is based on this research result and it approaches human's decision-making process using diffusion models[7]. DFT was initially applied to the study of decision making under uncertainty initially, then to the research of decision-making behaviors such as multi-attribute decisions, multi-alternative choices, and multiple measures of preference[9]. DFT lies on the information processing theory and "approach-avoidance" theory of psychology. As a behavioral decision theory oriented about decision-making process, it dynamically approaches the cognition of human's decision-making process based on psychological rather than economic principles.

3.1 Creating the model

In Ref. [10], we created a DFT-based dynamic route choice model as follows:

$$\tilde{P}(t) = S \cdot \tilde{P}(t-h) + C \cdot A \cdot W(t) + E(t) \tag{3}$$

where $\tilde{P}(t)$ is a preference state vector; each of its coordinate represents the preference state of a route at time t, and measures the driver's preference to the route. The initial preference state $\tilde{P}(0)$ represents the driver's preferences to the routes before choosing any of them. h is any small time increment. $t = l \cdot h$ (l = 1, 2, ⋯).

For the purpose of studying the driver's route choice behaviors under guidance information, the parameters in the model have the following definition and values:

(1) Feedback matrix S:

It indicates the effect of previous preference status on alternative routes (memory effect) and the effect of the alternative routes between one another. Elements on the principal diagonal mean the memory of the previous preference status. Non-diagonal elements indicate the inhibitory effect between competitive routes. In the model, s_{11}=s_{22}=0.98, and s_{12}=s_{21}=−0.03.

(2) Contrast matrix C:

It is used to compare the weighted average of each alternative at time t. In the model,

$$C = \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

(3) Attribute matrix A:

It represents the evaluation on each attribute of an alternative route under different road conditions. Suppose there are two routes L_1 and L_2 from one place to another in the real-world transport of a city, and classify the road condition into three states: normal (N), heavy (H), and very heavy (VH).