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An advanced traveler navigation system adapted to route choice preferences of the individual users

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ABSTRACT

The majority of existing navigation systems only account for a single aspect of the route choice, like travel time or distance, in finding the optimal route for the trips in the network. In this research, we first identify a range of diverse factors that travelers take into account in their route choice decision in the network. A stated preference survey is conducted to show the heterogeneity in the preferences of users and its dependence to the purpose of the trips over the weekdays and weekends. Interestingly, results of the survey show that road safety is the most influential factor in the route choice decision of the average participants over weekends, exceeding even the travel time, and participants give more importance to the scenic quality of the routes for their weekend trips in comparison to their weekday trips. The results of the second part of the survey also indicate that in 27% of the cases participants choose routes other than the ones suggested by navigation systems, and 33% of the times that they take the suggested routes, they modify these routes according to their own preferences. The partial inability of existing navigation systems to suggest the routes that match the preferences of users can be attributed to ignoring (1) the diversity in influential factors and (2) the heterogeneity in preferences of the users by these systems. We propose a dynamic mixed logit route choice model to include the effects of information and learning to estimate parameters of a multivariable utility function for individual users based on their own historical route choice data over time. Finally, we present the concept of a smart navigation system that can gather the required information from real-time and online sources to suggest the routes that best match the users' own preferences.

Introduction

Navigation systems play an important role in assisting users to choose routes by providing a variety of information regarding the properties of their routes in the transportation network. Widespread usage of the navigation systems on

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smartphones that are connected to the internet has made it possible to collect and analyze GPS probe data from users to provide real-time estimates of the performance of the transportation network. Such real-time feedback from the navigation systems to the users can lend insight towards choosing the routes that best match their own preferences.

Rational travelers seek the route with the minimum generalized cost for their trip in the transportation network. In that sense, they compare the available routes based on their previous experiences as well as the real-time information they receive from their navigation systems. They eventually choose the route that best matches their own preferences to keep the cost of their trips minimized in the network. The reality is that there is a heterogeneity associated with preferences of the travelers in choosing their routes in the network, and non-identical travelers may consider several different factors with different levels of importance in their route choice decision-making procedure. Moreover, the preferences of the user may also vary with the purpose or nature of the trips even for an identical traveler. As a result, it would be of great value for navigation systems to account for both (1) the diversity in route choice characteristics and (2) the heterogeneity in preferences of the users to suggest the most efficient routes to them.

In general, navigation systems are able to collect GPS probe data from users in the network. Having the probe data in the network has made it possible to estimate the real-time performance measures of the network. Travel time is one of the primary performance measures of the transportation network that users take into account in their route choice decision-making procedure. However, there are other factors that users consider in choosing their routes as well (e.g., safety, fuel consumption, and pavement quality), and these factors have different relative importance among the heterogeneous users in different trips. The majority of existing navigation systems focus on a single factor and ignore the heterogeneity that exists in route choice preferences among users. Consequently, they are only able to suggest routes with the minimum expected travel times or distances as the most efficient routes. They may also have a few capabilities for including constraints like avoiding tolls or highways, but these limited flexibilities are not sufficient to account for the heterogeneity in the preferences of users.

In this paper, we propose a concept for a smart navigation system that considers a diverse range of factors in comparing the routes, while it can adapt itself to the route choice preferences of the heterogeneous users. First, we identify the factors that can affect the route choice behavior of the travelers in the network. Then, we combine these influential factors in a multivariable utility function to account for the diversity of characteristics in the route choice behavior of users.

To demonstrate the heterogeneity in preferences of users, we include an analysis on the results of a stated preference (SP) survey regarding the relative importance of the influential factors in the route choice decision making procedure of the users. The results of the second part of the survey also indicate the partial inability of existing navigation systems to suggest routes that meet users' needs. To resolve this problem, we propose a dynamic mixed logit model to capture the effects of information and learning on individual route choice decisions of heterogeneous users by simultaneously accounting for unobserved heterogeneity and the correlation between individual decisions over time. The proposed model is then calibrated using the maximum simulated likelihood estimation method in an experiment conducted on a synthetic dataset generated for this purpose. In practice, the historical route choice record of the individuals on the navigation system can be used to estimate the parameters of the choice model.

To account for the variation of preferences of an individual user in different trips with different purposes, we consider a new feature for navigation systems that allows users define different purposes for their trips purposes (e.g., work, shopping, and leisure trips). To this end, the dynamic model needs to be tailored to each user based on the historical travel data for each trip purpose. The proposed smart navigation system combines the information from real-time and online data sources with a dynamically calibrated route choice model to suggest routes to users that match their preferences.

Problem definition

Travelers tend to minimize the cost of their trips by choosing the route with the lowest general cost in the transportation network (van Vuren and van Vliet, 1992). Conventional traffic assignment models simplify the route choice problem by assuming the travel time is the only important factor that homogenous users take into account in their route choice decision making procedure. In that case, the cumulative result of the individual decisions leads to the user equilibrium condition in which no one can improve his or her travel time by switching to another route. In the user equilibrium, all the used route between each origin-destination pair will have identical travel times while routes with longer travel times will be left unused (Wardrop, 1952). In reality, however, research shows that travelers also consider factors other than the duration of their trips in their route choice decision-making procedure (Golledge and Stimson, 1997). Moreover, relative importance of these factors depends on preferences of travelers as well as the purpose of their trips (Beckmann et al., 1956). A comprehensive study on a GPS dataset from households in Lexington, Kentucky, shows that different drivers choose different routes for traveling between very similar origins and destinations. These route choices are often quite different from the shortest paths between the origins and destinations (Jan et al., 1725). This result implies that heterogeneous travelers with different trip purposes have different measures for choosing the routes with lowest generalized cost for traveling between an origin-destination pair.

There are a variety of different factors in a network that can affect decisions of the travelers in choosing their routes (Bovy and Stein, 1990). Research shows that travelers generally consider factors like expected travel time and its variability (Chen and Zhou, 2010; Wu and Nie, 2011; Levinson and Zhu, 2013; Shahabi et al., 2013; Wang et al., 2014; Amirgholy and

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