Route Guidance System Incorporating Travelers Behaviors via Cyber Physical System

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Introduction

Transportation is a key to sustaining economic vitality and ensuring quality of life. With ever-increasing the number of vehicles and vehicle miles traveled, surface transportation system experiences significant side effects. These include annual congestion costs of $100 billion and annual crash costs of over $300 billion, as well as continuously degrading air qualities and serious concerns on climate changes and its consequences [AAA 2011].

Studies have shown that route guidance help mitigate traffic congestions and improve fuel consumption and emissions [Lee and Park 2008, Park and Lee 2009]. However, the impact of route guidance system largely depends on travelers' compliances. Let's assume there is a crash on a freeway segment. If every traveler on the freeway receives and complies the advisory route guidance utilizing a local street, the local street is likely to become the worst route. Thus, it is important to consider market penetration rate of travelers who can receive guidance information, and the compliance rate of travelers.

Motivations

As noted, the performance of the state of the art route guidance system depends on the market penetration rate and compliance rate. Simulation based studies show that the performance under 100% market penetration rate and 100% compliance rate did not perform the best [Lee and Park 2008]. In fact, it became much worse than the base case (i.e., do nothing case). Several studies conducted research to identify an optimum market penetration rate and compliance rate for best transportation system performance. However, those studies would not be generalized due to unique characteristics in transportation network topology, travelers' compliance in which would vary by time-of-day and trip purpose, and dynamically varying market penetration rates.

With the advances in communications, location and computing technologies, one could take advantage of the information and communication technology (ICT) applications in developing and disseminating route guidance to travelers, and receiving feedback from travelers on their route selections. We envision that capturing market penetration rate (i.e., portion of those who have access to route guidance information) and compliance on a given route are key to the success in the route guidance system in which would result in reductions in travel times.

Proposed Approach

Base Case

A regional transportation system, consisted of freeways, highways, urban arterials serving people and freight movements between pairs of origins and destinations, is considered. To improve urban transportation system performance by providing route guidance to participating travelers, state of the art route guidance system utilizes existing network conditions and possibly provides shortest path based on existing travel times or distances. This often results in much less benefits than expected depending on the compliances.

Proposed Case

A traveler, John, already agreed to opt-in for sharing his information such as origin-destination, location data, behavior data (compliance to advisory guidance), etc. His information kept encrypted in his smart phone is used in predicting his compliance on the advisory route guidance. In developing route guidance, a cloud computing environment implements real time optimization based on the origin-destination information from opted-in travelers and other information such as estimated origin-destination tables of those who did not opt-in.
Based on the OD information, an optimization program develops shortest path for each opted-in traveler and compares the shortest path and the current path chosen by traveler. If the two routes differ, a compliance behavior model, specific to each traveler, predicts whether a traveler selects a new path or not. Depending on the model predictions, the optimization program develops a new set of shortest paths. This continues until it converges or reaches a pre-specified time. Once converged or reached the limit, the advisory guidance is given to each opted-in traveler – the results should have much higher compliances than route advisories given without the proposed optimization.

In order to continuously update the traveler's compliance behavior model, at the end of trip, the traveler is asked if he or she would have chosen the advisory guidance or not based on the actual travel times and their variances. This continuously updates the traveler's compliance behavior model over time and the encrypted information is only kept in his/her cell phone.

The proposed approach ensures route guidance (i.e., development of advisory route and its selection) is implemented in cyber space, and travelers in physical system benefit from the converged route guidance system – this results in decreased travel times and increased speeds.

The Traveler Compliance Behavior Model

We will explore both non-parametric models (e.g., neural network, fuzzy logic or hybrid neuro-fuzzy) and parametric models (e.g., non-linear regression model) and find a way to efficiently keep the model parameters inside the cell phone and transfer the model parameters (for parametric model) or matrix (for non-parametric model) to cloud sourcing.

Significance of the proposed approach

The proposed approach closes the gap between advisory route guidance and compliance of travelers. This could have not been done without utilizing the cyber physical system approach. Again, individual traveler's compliance behavior model is to be kept in his/her cell phone and continuously updated based on the actual travel times and their variances of the alternative routes.

References

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