A Constrained Time-Dependent K Shortest Paths Algorithm Addressing Overlap and Travel Time Deviation

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ABSTRACT
Theoretical research often assumes all users are homogeneous in their route choice decision and will always pick the route with the shortest travel cost, which is not necessarily the case in reality. This paper documents the research effort in developing a Constrained Time-Dependent K Shortest Paths Algorithm in order to find K Shortest Paths between two given locations. The goal of this research is to provide sound route options to travelers in order to assist their route choice decision process, during which the overlap and travel time deviation issues between the K paths will be considered. The proposed algorithm balancing overlap and travel time deviation is developed in this research. A numerical analysis is conducted on the Tucson I-10 network, the outcome of the case study shows that our proposed algorithm is able to find different shortest paths with a reasonable degree of similarity and close travel time, which indicates that the result of the proposed algorithm is satisfactory.

Key words: K shortest Paths Algorithm (KSP), Time Dependent Shortest Path (TDSP), Constrained Shortest Path, Route Overlap, Travel time Deviation, Active Traffic and Demand Management (ATDM), Route Choice

1. BACKGROUND
In the field of transportation engineering, an interesting problem derived from Shortest Path (SP) Problem that has been widely researched theoretically and employed in real world application, is how to find K Shortest Paths (KSP) between a given origin

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(denoted as O) and destination (denoted as D) that satisfy certain pre-defined constraints. In other words, how to find multiple Shortest Paths within a certain geographic network and rank them according to the cost. This problem is of particular interest in the area of Advanced Traveler Information System (ATIS), where one of the most important features is to take in user's origin address, destination address and expected departure time, and based on dynamic traffic condition, find and present multiple quickest paths to guide their travel.

Theoretical research on transportation often assumes all users are homogeneous in their route choice decision and will always pick the route with lowest travel cost, and as a result, the SP is usually sought for and assigned to the user in the traffic assignment model, although this assumption does not hold in the real world. For example, researchers in Minnesota found only 34% people strictly traveled on the shortest path based on the analysis of 3-weeks GPS trajectory [1]. This research finding indicates that for an effective ATIS, a good KSP algorithm is critically important to assist driver's travel decision making process. One of the many merits of KSP research lies in its capability of providing multiple feasible path options, which includes not only the shortest path between origin and destination addresses, but also additional K-1 paths in order of increasing travel cost. Such multiple options generated by KSP algorithm provide additional information to the drivers, so that they can correlate with their personal travel preferences, individual schedule and other user specific constraints, and in the end have the flexibility of choosing among these offered route choices to travel from origin to destination.

In this paper, a Constrained Time-Dependent K Shortest Paths (CTDKSP) Algorithm that can be used in an ATIS to find Time-Dependent K Shortest Paths is proposed. The objective of finding KSP in this research is to provide multiple sound route options to travelers in order to assist their route choice decision process. With this in mind, we defined the KSP satisfying the following constraints as the ones to be sought for:

1. The K paths found should not be highly overlapped. If the paths are highly overlapped and look alike, they are likely to be perceived as the same path and thus don't bring additional utility to the drivers. However, certain degree of overlap shall be allowed as long as significant spatial deviation is observed between the routes. This feature distinguishes the proposed algorithm from the disjoint KSP research in previous literatures (which will be reviewed in Section 2) - either node disjoint or link disjoint method.
2. Travel times should be comparable between the candidate routes. If the travel time of route K is significantly higher than route K-1, although it might be a very different route, it can be overwhelmingly worse in terms of travel cost than others available. As a result, this new route will be unattractive to travelers and in the end, the chances of them selecting this route become very low.

This research proposes a CTDKSP algorithm that takes into consideration the aforementioned constraints. In addition to the algorithmic development, a numerical analysis is conducted on the Tucson I-10 network, and the degree of similarity is computed to quantify the degree of overlap between paths found. The outcome of the