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Finding Fuzzy Shortest Path by Integrating historical and Real-time Traffic Data

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ABSTRACT

Because of the happenings such as accidents and road repairs, the traffic level of some links of the network can strongly be changed. Therefore, routing on the basis of merely historical traffic data is not always useful. On the other hand, routing based on real-time data is not adequate either. The reason is that the real-time data regarding near links can be trusted. However, this is not the case for the distant links; since their present traffic will certainly be changed before the vehicle gets there. The main goal of this research is to propose a new method of routing based on fuzzy integration of historical and real-time traffic data. In this method, the basis of routing for normal situations is the historical data. In case of an accident in the network, before getting to the vicinity of the accident, the shortest path will be recalculated. The weights allocated to the links are calculated based on the integration of historical and real-time traffic data, using a fuzzy inference system. These weights are variable and are a function of the distance between the present location of the vehicle and the accident location. The results of the research show that, using this method, in the case of accidents, the calculated path is clearly deviated from the location of the accident.

KEYWORDS

Shortest Path, Fuzzy, Traffic, Historical Data, Real-time Data, Dynamic Routing.

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1- INTRODUCTION

Traffic congestion has become a critical problem all over the world due to the fast development of cities and the persistent increase of motor vehicles.[1] One way of reducing the volume of traffic is using the car navigation systems that will lead drivers to reach their destination by the fastest path and avoid the traffic congestion in a zone. Therefore, it is the shortest path of interest in transportation.

Due to the time of the traffic and dependencies on the human behaviors for example, Pressure on gas pedal, move the parties, pedestrian crossing, and etc. therefore, The travel time can’t be calculated at each edge for the vehicle. In this case, we have uncertainty for the travel time. The Shortest Path Problem, when unknown certainly edge value, is one problem that can be studied with fuzzy theory.

Also, a large number of networks in the real world have a scale-free structure, and the parameters of the networks change stochastically with time. For finding the shortest path in the network, the cost function is used instead of the constant cost.

In this article, we calculate weight in each edge to consider uncertainty for the travel time in each edge and forecasting the traffic of historical traffic data and incorporate with the real time traffic data.

2- CONCEPTS

2-1- Traffic prediction

The most significant feature of the travel time prediction based method is its ability to provide a benchmark that can represent current traffic conditions and balance the requirement of spatial and temporal efficiencies. However, unexpected incidents, irrational operations of vehicles, and the collaborations of conjoint routes weaken the significance of the historical records and degrade the accuracy of the predicted travel time. This data may mislead the system to provide an improper guidance to the drivers and loss their trusts.

For example, we know that an arc usually has a good traffic condition between 10:00 AM to 12:00 AM. However, one day there was an incident that happened and blocked part of the route. If, at this time, we try to predict the transit time of this arc based only on the historical traffic behavior without noticing the incident, the predicted time will be much shorter than the actual travel time to go through it. And the congestion avoidance system may select this route for the drivers in order to increase their trip efficiency. However, this false decision cannot achieve this objective[2].

Historical data are divided into monthly, weekly and daily data, which can be considered days of the week and holiday in 8 groups. This article originates from the observation that the conventional travel time forecasting approaches only focus on investigating the relationship between the future travel time and the historical traffic patterns (daily, weekly, and monthly).

2-2- Fuzzy shortest path

Fuzzy numbers represent a number of whose value we are somewhat uncertain. The function is relating the member number to its grade of membership which is called a membership function, and is the best visualized by a graph such as Figure (1).

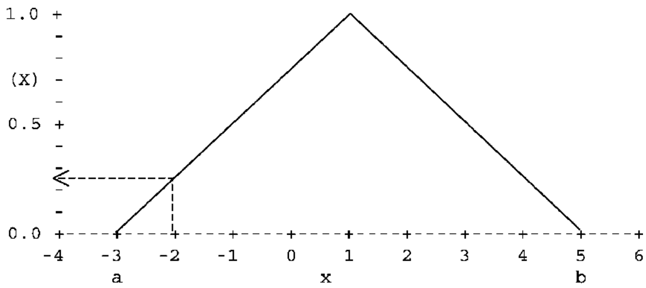

Figure (1): Membership function for a triangular fuzzy 1. Membership of 22 is 0.25 [3].

Definition 1. A triangular fuzzy number is represented by $\tilde{a} = (m, \alpha, \beta)$, with the membership function $\mu_{\tilde{a}}(x)$, defined by the expression

$$\mu_{\tilde{a}} = \begin{cases} 0 & if \quad x \le m - \alpha \\ \dfrac{x-(m-\alpha)}{\alpha} & if \quad m-\alpha < x < m \\ 1 & if \quad x = m \\ \dfrac{(m+\beta)-x}{\beta} & if \quad m < x < m+\beta \\ 0 & if \quad x \ge m+\beta \end{cases}$$

Where m is the center, α is the left spread and β is the right spread [3].

Definition 2. Let $\tilde{a}$ and $\tilde{b}$ be two fuzzy numbers, $\tilde{a} = (m_1, \alpha_1, \beta_1)$ and $\tilde{b} = (m_2, \alpha_2, \beta_2)$ then the fuzzy sum of these two numbers is given by [4][5]:

$$\tilde{a} \oplus \tilde{b} = (m_1, \alpha_1, \beta_1) \oplus (m_2, \alpha_2, \beta_2) = (m_1 + m_2, \alpha_1 + \alpha_2, \beta_1 + \beta_2).$$

$\tilde{a} \oplus \tilde{b}$ is like $\tilde{a}$ and $\tilde{b}$ a triangular fuzzy number, that is spread from right and left with sum $\tilde{a}$ and $\tilde{b}$. Therefore, more unreliability in sum of triangular fuzzy.

The classical fuzzy shortest path problem seems to have been first introduced by Dubois and Prade. They discuss the solution of this problem through the use of extended sum, $\oplus$, and extended min and max, mĩ n, mã x. To solve the problem, they use Floyd's Algorithm and Ford's Algorithm, and state that one problem that exists is that a fuzzy shortest path length can be found, but the shortest path with that length may not exist since the extended min of several fuzzy numbers may not be one of those numbers.

Floyd’s Algorithm is useful when the cost edges are fixed because in this problem, we are dealing with real-time data so this algorithm cannot be used. We used the Dijkstra’s algorithm and DSN model.

THE SCALE FREE DSN MODEL

Let $G = (V, E, \gamma, \langle k \rangle, W(t))$ be a connected scale-free DSN where V = {1, 2,...,n} is a finite set of n nodes; E = {(i,j)|i,j ∈ V} is a finite set of m undirected links; γ is the power-law exponent of the network degree distribution; $\langle k \rangle$ is the average degree of the network; and $W(t) = \{w_{ij}(t) \in [w_{ij,\min}, w_{ij,\max}] \mid (i,j) \in E\}$ is a set of time-dependent weight functions following the probability distribution $\varphi_{ij}(w_{ij}, t)$ for $w_{ij}(t)$, where t denotes the network evolution time. Furthermore, $w_{ij}(t)$ is regarded as the time cost through link *(i,j)* in this article [6].

It should be pointed out that, on the basis of the aforementioned scale-free DSN model, the travel time through link *(i,j)* is a stochastic variable depending upon the link weight $w_{ij}(t)$ where t_i is the departure time at node i. The expectation of weight $w_{ij}(t)$ can be calculated as follows:

$$\overline{w}_{ij}(t) = \int_{w_{ij,\min}}^{w_{ij,\max}} w_{ij} \varphi_{ij}(w_{ij}, t) dw_{ij}$$

In this paper, we further assume that waiting will not be allowed at the nodes, that is, the time of arrival at a node, which is also the time of departure from that node.
According to the above definitions, the shortest path $P_{opt}(t_0)$ in a DSN can be defined as the path through which the travel cost is minimal:

$$P_{opt}(t_0) = \arg\min_{P(t_0) \in P(t_0)} \left(\sum_{(i,j) \in P(t_0)} \overline{w}_{ij}(t_i) \right)$$

Where $P(t_0)$ expresses the set of paths departing from an origin node o at time t_0 and finally arriving at the destination node d, and $P(t_0)$ is one of the paths in $P(t_0)$.
In this article, we have used this method but here, we have table time instead [6].

3- IMPLEMENTATION

For finding the fuzzy shortest path, first, historical data and real time data are combined with fuzzy method, then with the proposed algorithm, the path is obtained. Before finding the path; because historical data are noisy, we should prepare them. A review of existing data and charting time can be seen that during the year, there is a lot of duplicate data. Therefore, we removed the duplicate data.

In this paper, we obtain the shortest path with combined historical and real-time traffic data. They have significant difference together when an event occurs. In this case, real-time data is very highly important but the historical data is very low important. For this combined, we use the fuzzy membership function.

- Fuzzy membership function for near

$$f(x) = \begin{cases} 1, & x \le a \\ 1 - 2\left(\dfrac{x-a}{b-a}\right)^2, & a < x \le \dfrac{a+b}{2} \\ 2\left(\dfrac{x-b}{b-a}\right)^2, & \dfrac{a+b}{2} < x \le b \\ 0, & x > b \end{cases}$$

- Fuzzy membership function for far

$$f(x) = \begin{cases} 0, & x \le a \\ 2\left(\dfrac{x-a}{b-a}\right)^2, & a < x \le \dfrac{a+b}{2} \\ 1 - 2\left(\dfrac{x-b}{b-a}\right)^2, & \dfrac{a+b}{2} < x \le b \\ 1, & x > b \end{cases}$$

The result of implementation has been shown in the figure (2).

Figure (2): Routing is done by combining historical and real-time data

4- CONCLUSIONS

As previously mentioned, routing could not be only based on historical data or real-time data. Combining the historical and real-time data is to maintain the initial path and in the event of an accident, calculate the new route to the destination. Therefore, combining data were used in this study.

Use the historical temporal data can make a good prediction of travel time have the edge. It makes little difference in travel time between the historical data and the real-time data. For this reason, the algorithm is repeated, if necessary. So there is no need to use dynamic algorithms.

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