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Local Path Searching Based Map Matching Algorithm for Floating Car Data

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Abstract

The information acquisition of road traffic flow is requisite for urban traffic control and management. Floating car data (FCD) is emerging technique for traffic flow collection of urban large-scale road network, and it can provide effective means to model and analyze road traffic conditions. Map-matching is one of the key techniques for FCD. The typical navigation map-matching algorithms are not suitable for handling FCD with large sample interval. Through analyzing FCD characteristics, we first propose FCD map-matching algorithm based on local path searching. The information of the previous matched GPS point is utilized to reduce the search space significantly. Square confidence area is constructed to decrease the number of candidate paths. This algorithm can not only achieve FCD location with high accuracy, but also determine vehicle moving trajectory. The experimental results show our method is robust for the different sample intervals of FCD.

keywords: Floating car data; Local path searching; Map-matching, Sample interval; Square confidence area

1. Introduction

The information acquisition of road traffic flow is requisite for urban traffic control, management, and transportation planning. The existing collection methods of road traffic flow mainly adopt the fixed-point

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modes including induction loop, microwave, radar and video techniques, which have some drawbacks such as limited coverage region, high costs, and difficulty to maintenance.

In comparison to the fixed-point collection modes, FCD has advantages of large coverage region, ease of maintenance, and low costs. It can offer large-scale dynamic traffic information, and is thus effective

means for traffic real-time guidance, management and control. FCD has received significant attention in the past decades [1, 2]. Map-matching algorithms have become a topic of FCD research. So far, FCD map-matching mainly relies on navigator map-matching algorithms. In general, navigator map-matching algorithms in the literatures can be classified into four groups: geometric analysis, topological, probabilistic, and other advanced methods [3].

The commonly utilized geometric analysis methods include “point-to-point” [4], “point-to-curve” [5], and “curve-to-curve” [6] map matching algorithms. Considering the shape of road, these methods exploit the geometric information of spatial road network data for map matching, and have simple and fast performances. As the relations of connectivity and contiguity are not taken into account, these methods have worse identification results in the conditions of intersection, parallel lines, and roundabout [7]. A map matching algorithm, which makes use of geometric feature, connectivity and adjacent relations among road segments, is called a topological map matching algorithm [8]. As vehicle heading and speed are not taken into account, topological methods are sensitive to outliers. Probabilistic map matching methods construct elliptical or rectangular error region around position fix. The error region can be determined by the related error variance of GPS positioning. The road segments within the error region are candidate solutions. These algorithms use heading, connectivity and close metric for map matching [9]. Advanced map matching algorithms utilize Kalman filter, evidence theory, fuzzy logic and neural network for map matching. These methods are superior to the other three kinds of methods in the same conditions, but they need more input data, and have some drawbacks such as slower matching speed and difficulty to implement [10].

Navigation map matching algorithms can obtain good results for the GPS data with high sample frequency (e.g. 1 Hz). However, the sample interval of FCD is from 10 seconds to 2 minutes, and it may be time-varying due to noise inference and error. Therefore, it is difficult for navigation map matching algorithms to deal with FCD. So far, little work has done for FCD map matching. Liao et al. proposed a bidirectional heuristic map matching algorithm for intersections based on a data structure for intersections [11]. This algorithm apply the data structure of intersections to separates the intersection part from common map matching, and decreases the FCD map matching mistakes. However, its computational complexity is significantly increased due to adding too many the shape nodes and links for intersection. Based on grid division of GIS digital map, Wang et al. proposed a quick map matching algorithm for FCD [12]. This approach designs a structure of road network which divides the road network into two levels, and partitions the road network into mesh. However, it is high difficult to determine the size of grid.

The objective of this work is to study map matching algorithm for floating car data with large and dynamic sample interval. According to the characteristic analysis for FCD, we first proposed FCD map matching algorithm based on local path searching. Maximal possible distance is adopted as heuristic information to reduce search space. Square confidence region centered position fix from GPS is constructed to determine candidate matching paths effectively, and then vehicle heading and the distances between position fix to links are integrated to match FCD to correct road segment.

The rest of this paper is organized as follows: section 2 introduces FCD map matching, the principle of heuristic local path searching and the construction method of square confidence region are presented. Section 3 givens the description of FCD map matching algorithm. In section 4, the results of experimental testing are given and discussed. A final section concludes the entire work.

2. The Principle of FCD Map Matching

Map-matching is one of key techniques for FCD. Each FCD record consists of vehicle ID, longitude & latitude, time, vehicle heading, and instantaneous velocity. FCD technique is mainly applied to provide traffic managers and users with the traffic conditions of road networks. The common sample frequency of FCD is from 10 to 120 seconds by considering communication costs. The environmental interferences can cause the time interval between two FCD more than 30 seconds in remote monitoring center. In allusion to dynamic sample interval of FCD, we propose a map-matching algorithm based on local path searching. This proposed method can identify travel path between two adjacent GPS positions for a vehicle, which is requisite for traffic guidance, control, and traffic condition estimation based on FCD technique.

This proposed algorithm mainly including three steps: local path searching, square confidence region generation, and map matching. For the issues of position fix for the first GPS point in FCD packets, considering the related information unavailable, we locate this GPS point using "point-curve" method with high accuracy.

2.1. local path searching

GIS (GIS: geographic information system) digital map is a directed connected graph. This proposed map matching algorithm firstly searches all candidate paths in which current position fix is destination node and its previous matched position is original node. Due to huge urban road network, the maximal possible distance is introduced as heuristic information to decrease the computational complexity of this traversal search algorithm. It is defined in the following.

$$d_{\max} = v_{\max} \Delta t \qquad (1)$$

Where v_{max} is permissible maximum speed of vehicle in urban road, Δt is time interval between two adjacent GPS points of a vehicle. The terminal condition of path searching is:

$$d \le d_{\max} + \delta \qquad (2)$$

Where d is path length, and δ is GPS error caused by environmental interferences. Search space can be significantly reduced by introducing maximal possible distance. After traversing the road network, all acyclic paths which satisfy Equation 2 are candidate solutions.

2.2. square confidence region construction

After the local path searching process, there may be too many candidate matching paths. Therefore, square confidence region is defined to further reduce the number of candidate paths. Square confidence region is constructed according to the center point P_i and the distance d_{max} (shown as Fig.1). The detailed description is as follows.

Assuming P_i is current position fix from GPS and P_{i-1} is its previous matched location. The coordinate of position fix P_i is (x, y), and the coordinate of P_i is (x_1,y_1), where x and x_1 are latitude, y and y_1 is longitude.

The vertexes coordination of square confidence region can be calculated according to the distance from P_i to each edge d_{max} and the center point P_i. The difference of latitude can be obtained in term of Equation 3.

$$\Delta_{lat} = d_{\max} / \deg ree \qquad (3)$$

where $\deg ree = \dfrac{24901 \times 1609}{360}$.

The difference of longitude is calculated by Equation 4 and 5.

$$k = \deg ree \times \cos(x \times \pi / 180) \quad (4)$$

$$\Delta_{lon} = d_{max}/k \quad (5)$$

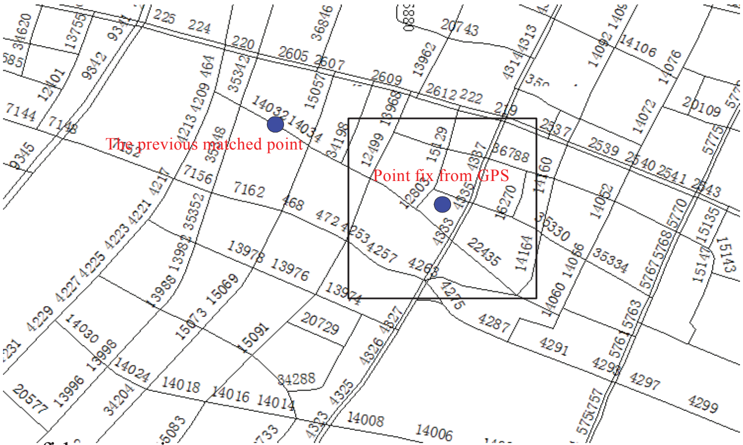

Figure1. Square confidence region

As a result, the vertex coordinates of square confidence region can be obtained as follows:

$(x - \Delta_{lat}, y)$, $(x + \Delta_{lat}, y)$, $(x, y - \Delta_{lon})$, and $(x, y + \Delta_{lon})$.

Square confidence region can be used to further select candidate matching paths. A candidate path is valid if its end road segment is within square confidence region. The next step is to determine the matching path. The candidate paths are selected by the information of vehicle heading provided by the corresponding FCD record. If the difference of vehicle heading and the end road segment heading of a candidate path satisfies certain error range (e.g. 15o), this path is reserved, otherwise, it is removed from candidate path set. Finally, the distance between the fix point from GPS and the end road segment in candidate path is calculated for all the residual candidate matching paths. The candidate path with shortest distance is matched. The fix point from GPS is located by projecting it on the end road segment of matched path.

3. The Description of FCD Map Matching

Suppose δ is threshold of GPS error, σ is threshold for difference between two direction angles, and v_{max} is maximal possible speed for a vehicle. FCD map matching algorithm is described as follows.

Initialize the parameters δ, σ and v_{max};

If current position fix from GPS is the first FCD then "point-to-curve" method is used for matching process

else

{ Repeat

$s \leftarrow$ the previous matched GPS point,

GPS data from FCD of the same vehicle is taken and assigned to s',

Calculating $d_{\max} = v_{\max} \Delta t$, Traversing road network by starting from s, a acyclic path, which satisfies the condition of $d_{path} \leq d_{\max} + \delta$, is candidate matching path and stored in $A_{candidate}$ // d_{path} is path length,

Square confidence region is constructed by the vertexes coordinates:

$(x - \Delta_{lat}, y)$ $(x + \Delta_{lat}, y)$, $(x, y - \Delta_{lon})$, and $(x, y + \Delta_{lon})$,

A path is removed from set $A_{candidate}$ if its end road segment is outside square confidence region,

Calculating difference c of vehicle heading from FCD record and the end road segment of candidate path,

If $c \leq \sigma$ then the corresponding candidate path is reserved, else it is removed from set $A_{candidate}$,

For all the candidate paths in set $A_{candidate}$, calculating the distance between GPS point and the end road segment,

The path with shortest distance is selected,

Projecting point *s'* on the end road segment of this path}

Until all the FCD records are handled.

4. The Experiment and Discussion

To evaluate this proposed algorithm, we employed probe vehicle to collect field data of road network in Hefei city, China. 20,000 FCD records were obtained to build a standard sample base, which is used to validate our algorithm. At first, the experiments were conducted respectively using our algorithm and "point-curve" method with high accuracy. In the experiment, the sample interval of FCD is 10 seconds, five groups of FCD packets were used and each group has 400 FCD records. The experimental results are listed in table 1. From table 1, we can see that the matching accuracy of our algorithm is 85.2%, accordingly, the matching accuracy of "point-curve" method is 82.4%.

Table 1. Comparison of the proposed algorithm and "point-curve" map-matching algorithm

FCD data group	Matching accuracy	
	Point-to-curve method	Our algorithm
1	86%	88%
2	81%	85%
3	82%	84%
4	81%	83%
5	82%	86%

Table 2. The experimental results of the proposed algorithm for FCD with different sample intervals

FCD data group	Matching accuracy	
	Sample interval:50s	Sample interval:100s
1	87%	88%
2	88%	87%
3	85%	86%

Further, we adopted the FCD records respectively with 50 and 100 seconds to test the influence of the sample interval on this proposed algorithm. In this experiment, three groups of FCD packets were selected. Each group had 200 FCD records. The experimental results are shown in table 2. It is easy to see that the matching accuracy of our algorithm is insensitive for sample interval of FCD.

5. Conclusion

FCD map matching is one of key techniques for urban traffic dynamic route guidance. Navigator map matching methods are not suitable for handling FCD record with large sample interval. By analyzing the characteristics of FCD records, we propose FCD map matching algorithm based on local path searching. The time series information of FCD is utilized to reduce the search space significantly. Further, square confidence region is introduced to decrease candidate matching paths. This proposed algorithm has high matching accuracy and is robust for sample interval of FCD. It can accomplish FCD map matching and the identification of vehicle trajectory simultaneously. This work offers an effective way for FCD map matching.

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