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An Analysis of Map Matching Algorithm for Recent Intelligent Transport System

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ABSTRACT— ***Map matching is a technique combining electronic map with locating information to obtain the real position of vehicles in a road network. Map matching algorithms can be divided in real-time and offline algorithms. Real-time algorithms associate the position during the recording process to the road network. Offline algorithms are used after the data is recorded and are then matched to the road network. Real-time applications can only calculate based upon the points prior to a given time (as opposed to those of a whole journey), but are intended to be used in 'live' environments. This brings a compromise of performance over accuracy. Offline applications can consider all points and so can tolerate slower performance in favour of accuracy. The MM algorithms integrate positioning data with spatial road network data to identify the correct link on which a vehicle is travelling and to determine the location of a vehicle on a link. A map-matching algorithm could be used as a key component to improve the performance of systems that support the navigation function of intelligent transport systems. A number of map-matching algorithms have been developed by around the world using different techniques such as topological analysis of spatial road network data, probabilistic theory, fuzzy logic, and belief theory. The performances of these algorithms have improved over the years due to the application of advanced techniques in the map matching processes and improvements in the quality of both positioning and spatial road network data. However, these algorithms are not always capable of supporting intelligent transport system applications with high required navigation performance, especially in difficult and complex environments such as dense urban areas. The main objectives of this paper are thus to uncover the constraints and limitations by an in-depth literature review and to recommend ideas to address them. This paper also presents some ideas for monitoring the integrity of map matching algorithms. The map-matching algorithms considered in this paper are generic and do not assume knowledge of 'future' information (i.e. based on either cost or time). Clearly, such data would result in relatively simple map-matching algorithms.***

Keywords— Map-matching, Intelligent Transportation System, Vehicle Navigation System, Global Positioning System. Transport applications; Research Directions.

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1. INTRODUCTION

The automatic intelligent transport system applications and services such as route guidance, fleet management, road user charging, accident and emergency response, and other location based services require location information. The Global Positioning System has established itself as a major positioning technology for providing location data for intelligent transport system applications. Zito et al. (2009) provide a good overview of the use of GPS as a tool for intelligent vehicle-highway systems. This information is then used with spatial road network data to determine the spatial reference of vehicle location via a process known as map matching.

Map-matching algorithms use inputs generated from positioning technologies such as Global Positioning system and supplement this with data from a high resolution spatial road network map to provide an enhanced positioning output. The general purpose of a map-matching algorithm is to identify the correct road segment on which the vehicle is travelling and to determine the vehicle location on that segment (Greenfeld, 2010; Quddus et al., 2006). Map-matching not only enables the physical location of the vehicle to be identified but also improves the positioning accuracy if good spatial road network data are available (Ochieng et al.,2004). This means that the determination of a vehicle location on a particular road identified by a map-matching algorithm depends to a large extent on the quality of the spatial road map used with the algorithm. A poor quality road map could lead to a large error in map-matched solutions.

A map-matching algorithm can also be developed for real-time applications or for those where post-processing is sufficient. For instance, (Marchal et al. 2005) developed an efficient post-processing map-matching method for large GPS data. The map-matching algorithms are considered as most intelligent transport system services require a map-matching algorithm that can be implemented in real-time. It is essential that the map-matching algorithm used in any navigation module meet the specified requirements set for that particular service. Although the performance of a map-matching algorithm depends on the characteristics of input data (Chen et al., 2005), the technique used in the algorithm can enhance overall performance.

2. MAP MATCHING PRINCIPLE

The Map matching algorithm (Yang D.K., 2003; Joshi R. R et al., 2005) is based on the theory of pattern recognition. The location of the vehicle or truck travelling paths getting from other orientation methods such as Global poisoning system compares with electronic map road data of vehicle, and seeks matching metric degree. Regarding combination lines of the greatest matching metric degree as current vehicles travelling routes, and then finds the road where vehicle runs, and show the real-time location of vehicle. Map matching process based on the principle can be divided into two relatively independent processes:

- First, find the road of currently vehicles travelling.
- Second, project current positioning point to the road of vehicles travelling.

The first process is the key to the process, as shown in Fig. 1, the road passed by vehicle is road A → B →C, but the measurement track as shown in the curve does not coincidence with the actual path. The process of finding current vehicles travelling road is equal to eliminating the deviation between the measurement position and the actual position, then correcting the measurement position to match position by matching behaviour, it means that correcting the cars trajectory line represented by the dotted line with a positioning error of observation points to the three actual location of road A → B →C.

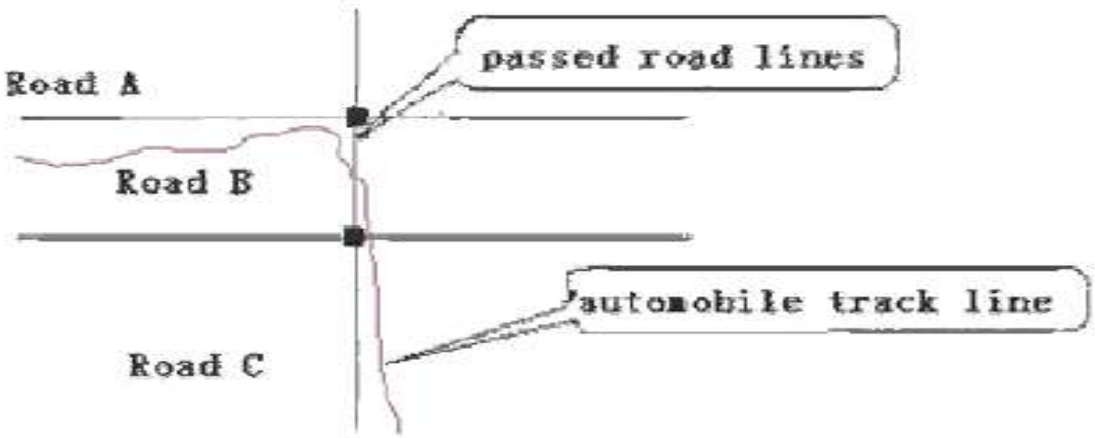

Fig. 1: Automobile track lines and passed road lines.

The second process is that use simple foot projection principle of point to straight line, and takes projection pedal line in the selected road line of measurement position point as the matching points. But the true position with the match position might still exist a gap. In fact map matching technology will only solve the vertical positioning error, not directly address the radial positioning error. Figure 2 illustrates this process.

Generally, map-matching algorithm should include the following process in the matching:

- Through pre-processing, feature extraction and so on the step carry on the analysis and description to all candidate road sections and extract the corresponding position or shape features.
- Based on the matching rules of the algorithm, calculate the matching similarity in turn between the vehicles path and all candidate road sections.
- Select the biggest position or path about cost function as the matching or classification results of vehicle location points or trace curve.

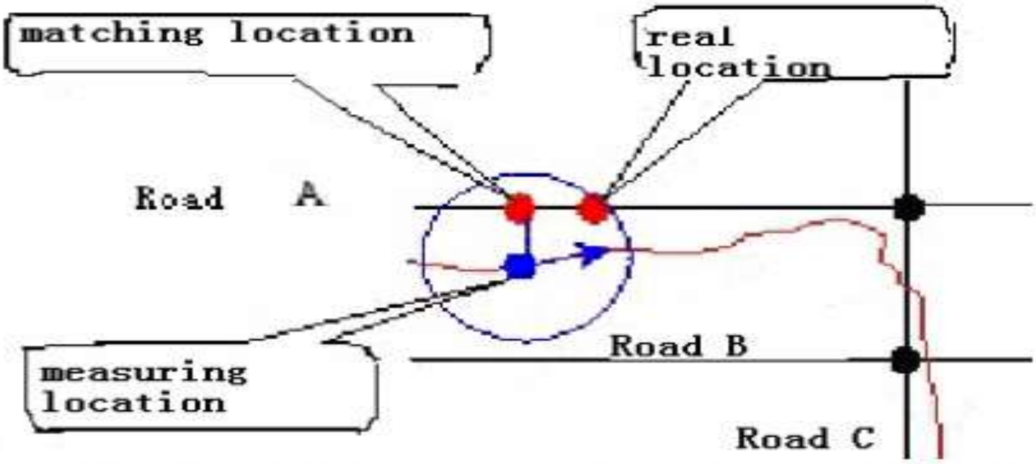

Fig.2: The matching process of the measurement location to the road line.

3. MAP MATCHING ALGORITHM

From the category perspective of matched samples, map matching algorithm can be divided into: matching position (Zhao K, et al., 2003) and track curves match. The commonly used position matching methods include direct projection, probability statistics and the fuzzy logic method and so on; the commonly used track curve matching methods include geometric matching, correlation coefficient method and so on. Position match algorithm is logic simple, timeliness good, but in such circumstances: intensive road, complex shape road and intersections road, the match accurate rate is lower. Accurate matching rate of track curve matching algorithm is high, but it is complex and large amount of computation. It is very difficult to meet the real-time requirements.

3.1. *Position Matching*

The road line where vehicles travel actually is defined as matching section. All road sections located in the rectangular region (motion window) which take the measuring point as a centre are called candidate road sections. Match road section is from the candidate road sections. The matching design of algorithm is calculating the match degree of all the candidate road sections to decide which candidate road section is the best. The matching degree is a concept to measure the possibility of a candidate section to be a matching road.

There are mainly three types of data to design matching degree:

- The projection distance of measuring point to candidate road section.
- The angle between measuring point travel direction and candidate road section direction.
- The topological connectivity between candidate road section and preceding matching road section.

There into the first and second lists respectively explains the matching degree between matching road section and candidate section. The smaller the distance between the two curves is, the more similar the two curves is. Angle between the two curves smaller also shows the two more similar.

3.2. *Curves Matching*

The position matching is lack of enough information's which result in matching accuracy not high when the road is complex shape and intersections. In order to obtain more abundant amount of information's and more effective map-matching to improve accuracy, researching curves matching algorithm is necessary. The track curve matching is to compare the vehicle history travel path with the path data which saves in the digital map, seeking reasonable matching algorithm, determining the road where vehicles drive, and showing the real-time location of vehicle. In general, travelling curve can be obtained as follow:

- Firstly gain the vehicle current locating point, and take out recent localization records, connect the locating point to form curve by the time order.

- The value is determined according to the sensor sampling intervals.

Then determine a region with a special definite distance value to curve, search all the roads in the region, determine candidate roads based on certain criteria and algorithm, match the candidate sections and curve, seek the best match section as the current road route. The point that current positioning points project to the driving route is the matching points.

4. APPLICATION AND PROSPECTS

The most basic application of map matching technology is achieved in the electronic tracking of vehicles on the map marked in the Intelligent Transportation System. Match the vehicles on its travelling road through map-matching technology. It can help drivers along scheduled routes and guide vehicles to arrive at the destination in car navigation system (Guan S.Q et al., 2005); In automatic scheduling of the public transportation system, using map-matching technology and dead reckoning technology can access to public transportation vehicles fast and accurately. It also can be used on Assisted Dispatching bus or bus to achieve automatic reporting station based on the road and the location of the historical record of passengers (Pu X et al., 2001); Map matching technology has been widely applied to the Global Positioning navigation system. Judging from the current development, further study of the vehicle control system is to achieve vehicle auxiliary safe driving and automatic drive by combining the matching maps and Geographic Information System information with the network, such as obstacles reminded or crossroads reminders along with the road network as the bend and adjusting speed (Gao B et al., 2007). With map-matching technology and Geographic Information System / Global Positioning System combination, the use of electronic maps and databases of road traffic information with automatic traffic will be driving a new development direction.

5. CONCLUSIONS

The intelligent transport system can be supported by a map-matching algorithm that integrates positioning data with spatial road network data. This paper has presented an in-depth application review of map-matching algorithms. A number of different techniques are used in the map-matching processes such as simple search techniques such as point-to-point matching, point-to-curve matching and complex ones including the applications of probability theory, fuzzy logic theory, and belief theory. These algorithms are not always capable of supporting the navigation module of some intelligent transport system applications such as vehicle priority at junctions, especially in dense urban areas. Therefore, to achieve the required navigation performance for some intelligent transport system services, further research and improvements to map-matching algorithms are essential. Also this paper has identified a number of constraints and limitations of existing map-matching algorithms and has suggested key areas for further research. The key constraints and limitations are the problems associated with initial identification of vehicle positions, the problem of matching positioning fixes in complex road layouts, performance evaluation, especially in dense urban areas, and development of confidence indicators. These algorithm enhancements will be aided by enhanced and new systems offer a significantly improved performance capable of supporting a wide variety of intelligent transport system services in different operational scenarios. In terms of implementation, most of the map-matching algorithms reviewed here have been developed in recent years with details on their actual implementation (for example in commercial applications of advanced traveller information systems) not being available in the public domain. However, the recent increase in collaboration between industry and research establishments in this area is indicative of a strong interest from industry in advanced map matching algorithms.

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