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Map Matching Algorithms in GPS Navigating System and Their Functions

R.Kamalambal

(M.Phil. Student)

Department of computer science & Technology

Kajamalai Campus, Bharathidasan University, Trichy, TamilNadu, India

E-mail: kamali.k26@gmail.com

Mobile no: 8903145875

Abstract

Fifth generation Global positioning system must be able to reconcile the user's location with the underlying map that process is known as map matching. Most existing research has focused on map matching when both the user's location and the map are known with a high degree of accuracy. However, there are many situations in which this is unlikely to be the case. Hence, this paper considers map matching algorithms that can be used efficiently in the gps navigating system. Map-matching 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 (ITS). The required horizontal positioning accuracy of such ITS applications is in the range of 1 m to 40 m (95%) with relatively stringent requirements placed on integrity (quality), continuity and system availability. A number of map-matching algorithms have been developed by researchers around the world using different techniques such as topological analysis of spatial road network data, probabilistic theory, Kalman filter, 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.

KEYWORDS: Map-matching algorithm, nodes, points, Gps data, algorithm function

I. INTRODUCTION

Since the first experimental satellite was launched in 1978, GPS has become an indispensable aid to navigate around the world, and an important tool for map-making and land surveying. GPS also provides a precise time reference used in many applications including scientific study of earthquakes, and synchronization of telecommunications networks. After the process of map-making then here it starts with the work of map-matching. Map-matching is the process of aligning a sequence of observed user positions with the road network on a digital map.

First-generation simply provide the user with a map and the ability to search the map in a variety of ways (e.g., search for an address, search for a landmark, scroll, and pan). Second-generation provide both a map and the user's current location/position. Third-generation provides map, the user's location, and directions of some kind. Fourth-generation provides a map, the user location, final destination, path direction. Clearly, a system that provides the user's current location is much more complicated than one that does not, and generally requires both additional hardware and software.

II. LITERATURE REVIEW

In the last few years, the Global Positioning System (GPS) has established itself as a major positioning technology for providing location data for intelligent transport system (ITS) applications. Zito et al. (1995) provide a good overview of the use of GPS as a tool for intelligent vehicle-highway systems. Deduced Reckoning (commonly referred to as 'Dead' Reckoning or DR) sensors consisting of an odometer and a gyroscope are routinely used to bridge any gaps in GPS positioning (Kubrak et al., 2006). 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 GPS or GPS integrated with DR) 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, 2002; Quddus et al., 2003). 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 be developed generically for all applications or for a specific application. For example, Taylor et al. (2006) developed a map-matching algorithm referred to as Odometer Map Matched GPS (OMMGPS) applicable to services where the most likely path or route is known in advance. In this paper, only generic map-matching algorithms are reviewed. 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. In the review presented in this paper, only real-time map-matching algorithms are considered as most ITS 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. For instance, the performance of a map-matching algorithm based on fuzzy logic theory may be better than that of an algorithm based on the topological analysis of spatial road network data if all else are equal.

There are at least 45 map-matching algorithms produced and published in the literature during the period 1989–2014, most of which are recent reflecting the growth in the need for ITS services. The positioning accuracy and quality offered by these algorithms has also improved over the years. This is mainly due to the use of advanced techniques in the algorithms such as Kalman filtering, fuzzy logic, and belief theory, and the improvement in the performance of positioning sensors and the quality and quantity of spatial road network data.

III. MAP MATCHING PRINCIPLE

Map matching algorithm is based on the theory of pattern recognition. The location of the vehicle or truck traveling paths getting from other orientation methods (such as GPS) 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 traveling routes, and then find the road where vehicle runs, and show the real-time location of vehicle.

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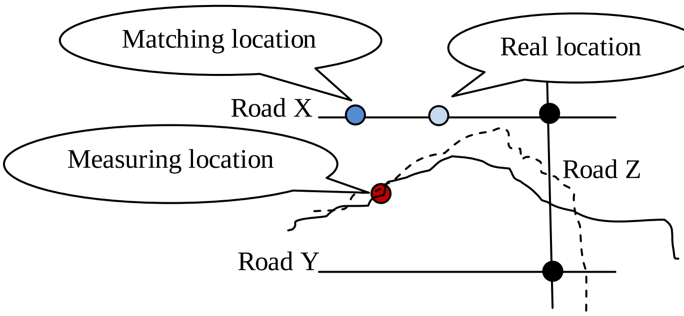
Map matching process based on the principle that can be divided into two relatively independent processes:



First:-Find the road of currently vehicles traveling
Second:-Project current positioning point to the road of vehicles traveling.

The first process is the key to the process, as shown in Figure, the road passed by vehicle is road X → Y → Z, but the measurement track as shown in the curve does not coincidence with the actual path. The process of finding current vehicles traveling 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 behavior, 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 X → Y → Z.

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.

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

- Through preprocessing ,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. The matching process of the measurement location to the road line.
- 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.

IV. MAP MATCHING ALGORITHM

From the category perspective of matched samples[1], map matching algorithm can be divided into: matching position 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. Algorithms of the map matching have been developed continuously and they can be classified into two categories roughly. First, map matching algorithms which consider only geometric relationships between GPS data and a digital map. Secondly, map matching algorithms which consider not only geometric relationships but also the topology of the road network and the history of GPS data. It has been reported that the latter worked better mostly.

The first map matching algorithms can be classified again into the map matching algorithm using the **distance of point-to-curve**, one using the **distance of curve-to-curve** and one using the **angle of curve-to-curve**. Some past studies used the distance of point-to-point. But the vertex-based map matching algorithms are appropriate when one pursues simplicity rather than accuracy. The second map matching algorithms use the result of map matching at **time t-1** for the map matching of GPS data at time t. And for the selection of candidate segments which GPS data will be matched, the topology of the road network is inputted as a constraint.

But these algorithms should be used under particular prudence. For example, if the result of map matching at time t-1 is wrong then the result of map matching after that time will be wrong also. Thus, it should be guaranteed that the result of map matching at time t-1 is exact to use these algorithms. Besides, if the vehicles with a GPS receiver follow abnormal routes (e.g. the left turn on the left turn restricted intersection) we cannot expect the right result of map matching because the normal topology respects traffic regulations. Most of previous studies of map matching was under circumstances of very short polling time interval (about 1 second).

The shorter the polling time interval is, the better the performance of the map matching algorithm is, because the availability of the GPS data history will be increased. But in practice, various problems restrict the shortening of the polling time interval. For example, there should be some telecommunication method to collect the GPS data of many persons on real time. And if the telecommunication is accomplished by the third telecommunication company, very short polling time will inevitably accompany with a vast cost as if you use your cellular phone for a long time, you will have to pay high cost. Therefore, we will review the previous map matching algorithms and discuss the map matching algorithms which can be used under circumstances of relatively long polling time intervals(about 2~5 minutes). And the focus will be laid on the map matching algorithm considering not only geometric relationships but also the topology of the road network and the history of GPS data.

V. CONCLUSION

The navigation function of an 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 literature review of map-matching algorithms. A number of different techniques are used in the map-matching processes such as simple search techniques (e.g., 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 ITS applications such as bus priority at junctions, especially in dense urban areas. Therefore, to achieve the required navigation performance for some ITS services, further research and improvements to map-matching algorithms are essential.

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