

Comparative Study of Map Matching Algorithms - GPS Vehicle Navigation Technology

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ABSTRACT:

Several map-matching algorithm techniques have been developed to improve vehicle positioning in navigation technology, using Global Positioning System (GPS) data and other wireless sensors. This paper deals with a comparative study of existing map-matching algorithm for GPS positioning and vehicle navigation. The main objectives of this paper are to gather knowledge about existing map matching algorithms. Especially Hidden Markov model, Weight based Model and other map matching algorithms. The Hidden Markov Model is a statistical model with two states a) Observed State, b) Unobserved State, well known for providing solutions to temporal recognition applications such as text and speech recognition. Weight based map matching algorithm is the high accuracy for segment assignment using minimum input variables of latitude and longitude of the vehicles. We mainly classified process of HMM, Weight based and other Map matching algorithm as comparative study, which is mainly implemented in the urban cities.

Keywords: GPS, Map Matching, Navigation.

I. INTRODUCTION

Map Matching algorithm which is used to Map the Physical Location using GPS. Map matching is a technique combining electronic map with locating information to obtain the real position of vehicles in a road network. Map-matching is a basic operation for improving positioning accuracy by integrating positioning data with spatial road network data to identify the correct road link on which a vehicle is travelling and to determine the location of a vehicle on a road link. An Algorithm which is used to find the exact location of vehicle or particular position of an object is called Map Matching algorithm. Manikandan et al., (2017)

Map Matching algorithm are divided into two categories: one is offline where the data are processed after the data are recorded and other is online, where the data are processed during recording time. Map-matching algorithm is actually a pattern identification process. Map-matching algorithms can be categorized into four groups: geometric map matching, topological map matching, probabilistic map matching and other advanced techniques. The geometric map-matching algorithm was introduced by Bernstein and Kornhauser, M.A. Qudus et al., (2016). This algorithm contains point-to-point matching, point-to-curve matching, and curve-to-curve matching and improved geometric map matching. Point-to-point and point-to-curve matching don't fully make

use of historical information, while curve-to-curve matching constructs piecewise linear curves from the paths that originate from the candidate nodes. Whereas it is quite sensitive to outliers and depends on point-to-point matching in result of sometimes yielding unexpected and undesirable results Qunyong Wu et al., (2014).

II. PROCESS OF MAP MATCHING ALGORITHM

Process of Map Matching Algorithm can be classified into three categories to find out the position of particular object or vehicle. (Manikandan et al., 2017)

Macro scale: Navigation usually performs the task of finding a particular path between two nodes in the network consisting of link.

Micro scale: Typically consider navigation at the vehicle and is concerned with task such as lane keeping as well as detecting and avoiding obstacles.

Mesoscale: which is a level in between micro scale and macro scale, consider vehicle operation at link level. Form a Navigation point of view, mesoscale route planning is generally concerned with vehicle such as passing, pulling off the side of the roadway, moving out of the way of emergency vehicle, merging in and out special.

III. FEASIBILITY STUDY OF MAP MATCHING ALGORITHMS

Mahdi Hashemi et al., (2016) this paper deals with process of weight based Map matching algorithm. This algorithm has three steps: initialization, same-segment, and next-segment. Distance between the GPS point and road segments, difference between the heading of the GPS point and direction of road segments Manikandan et al., (2017). The difference between the direction of consecutive GPS points and direction of road segments are used to identify the best segment among candidates near intersections. The weight of each criterion in this algorithm is dynamic. The weights of criteria are calculated for each GPS point based on its: (a) positional accuracy, (b) speed, and (c) travelled distance from previous GPS point.

Jimenez et al., (2011) this paper mainly focused on process of Enhanced Map Matching algorithm. In dense urban areas it is still difficult to obtain good positioning using a single technology. In this process, it has to be taken into account that both information sources (GNSS positioning and digital map data) have associated errors, and therefore the algorithm attempts to found the location of the vehicle on the link that most approaches its real position.

Haiqiang Yanga et al., (2013) this paper deals with process of Enhanced weight map matching algorithm. This process includes the classification of urban area by urban road density, the derivation of four weights (including heading, proximity, link connectivity and turn restriction) in different areas through an optimization process, the different performances of the algorithm before and after enhancement using a real positioning data set. The

whole Process is divided into three keys: a) Initial MM, b) MM on a Link, c) MM at a Junction Manikandan et al., (2017).

Marchal et al., (2005) this paper deals with process of Fuzzy based map matching algorithm. The algorithm compares the road membership value of candidates by fuzzy sorting, and adjusts the measure coefficient to improve the accuracy of map matching.

Newson.P ert al., (2009) this paper deals with process of Hidden Markov Method based Map Matching algorithm. Hidden Markov Model (HMM) is a Markov process comprising a number of hidden (unobserved) states. Transitions between states can occur with a certain probabilities. Each state is assigned with a set of observations. One of them is to be output, as the state is reached. For a given state conditional probabilities of observations occurrence (emission probabilities) sum up to 1, Manikandan et al.,(2017).

Shen Jingwei et al., (2015) this paper deals with process of improved AOE based map matching algorithm. Firstly, intersection analysis between a buffer around a GPS point and road segments was carried out to acquire the candidate road segments and candidate map-matching points. Secondly, quad tree spatial index and Dijkstra algorithm were introduced to obtain the shortest path between the adjacent candidate map matching points. Thirdly, the improved AOE network was built to search the FCD shortest path and the map-matching points were acquired. Lastly, the proposed algorithm was evaluated in terms of time efficiency and accuracy Manikandan et al.,(2017).

Batarfi.O et al.,(2015) this paper deals with process of Distributed map matching algorithm. The main idea is to reduce the algorithm running time by distributing the processing across multiple working nodes. Each trajectory point is a position that must be mapped to a corresponding point in the road network. Considering GPS precision errors, the nearest point is not necessarily the correct one.

Quddus et al., (2007) this paper deals with process of offline based map matching algorithm. Offline algorithms can take the advantage of not only matching each point according to past data but also based on the following “future” point, which helps the algorithm to select the correct road near to junctions. The purpose of a Map-Matching algorithm can be divided in two parts. Firstly, the algorithm determines which road segment, from a given network, corresponds to each given position. Afterwards, it will determine the exact location of the same position inside the segment previously selected. Manikandan et al.,(2017).

IV. FUNCTIONS OF NAVIGATION SYSTEM

The navigation system is mainly focused on map database and user interface. Functions of navigation system can be classified into five categories.

Map Database: Map database management systems are software programs designed to efficiently store and recall spatial information. They are widely used in localization and navigation. It contains the geometry, topology, and attributes of a map network (Road Network).

Geo-positioning: Geo Positioning is a method that facilitates the location of a single point relative to the surface of the earth and the process of measuring location updates of an object in real time.

Map Matching: Map Matching algorithm which is used to Map the Physical Location using GPS. Map matching is a technique combining electronic map with locating information to obtain the real position of vehicles in a road network.

Routing and guidance: Routing computes user-preferred routes and guidance gives step-by-step instructions on how to travel on routes.

User interface: A user interface accepts the user's requests for directions. It responds with map-matched positions on the map and audible or displayed directions at the right time.

V. COMPARATIVE ANALYSIS OF MAP MATCHING ALGORITHMS

The eight based processes of Map Matching algorithm are a) weight based b) Enhanced Based c) Enhanced, Weight Based d) Fuzzy Based e) Hidden Markov Based f) Activity of Edge Based g) Distributed Based and h) Offline Based (Manikandan et al., (2017)). We mainly classified process of map matching algorithm as comparative study, which is mainly implemented in the urban/Suburban cities.

As per our feasibility study, the both geometric and topological map matching algorithms are used for developing other advanced map matching algorithms. These advanced algorithms contain additional techniques to improve performance.

Comparison among performance of various map matching algorithms for vehicle navigation system.

Comparative Analysis:

Author and year of Publication	Navigation Sensors	Test Environment	Link Identification (Percentage)
Yankai Liu et al., (2017) (HMM)	GPS	Urban	88.32
Yue Jiao Gong et al., (2017) (HMM)	GPS / DR	Urban / Suburban	-
*Malcolm Mielle et al., (2016) (HMM)	GPS / DR (robot navigation)	Urban	98
Wu et al., (2007)	GPS	Urban	95.14

Quddus et al., (2006) (Fuzzy-Logic)	GPS / DR	Urban / Suburban	99.2
Liu et al., (2008)	GPS	Urban	99.4
Haiqiang Yanga et al., (2013)	GPS	Suburban	-
Marchal et al., (2005)	GPS / DR	Urban	72.52
Batarfi.O et al.,(2015)	GPS	Suburban	-
Shen Jingwei et al., (2015)	GPS	Urban (FCD) (Shortest Path)	-
Liu et al., (2008)	GPS	Urban	99.4 in one case
Yang et al., (2003)	GPS	Suburban	96
White et al., (2000)	GPS	Suburban	-
Newson.P et al., (2009) (HMM)	GPS	Urban	-
Jimenez et al., (2011)	GPS (GNSS)	Urban/Suburban	76.3

- **(DR Dead Reckoning Technology / High accuracy Sensor)**

The navigation sensors and percentage of correct link identification ranges from 72% to 99%. It shows that many of these algorithms are based on utilizing multiple geo-positioning technologies in combination to obtain results with good accuracy. We conclude that the HMM (Hidden Markov Model) map matching algorithm produces best results when GPS and DR (Dead Reckoning) are considered. It should be noted that since those map matching algorithms in comparative analysis were tested on different areas with different road maps, the performance in accuracy is not only a function of the geo-positioning technologies and the map matching algorithms they use, but also a function of the road networks used in the tests.

VI. CONCLUSION

We conclude that the HMM (Hidden Markov Model) map matching algorithm produces best results when GPS and DR (Dead Reckoning) are considered. And also each process of Map Matching algorithm has its own identity. Simplification of each identity is as follows. Weight Based –Segmentation identification, Enhanced Based-Narrow Street and Tall building, Enhanced Weight Based-low pooling frequency data, Fuzzy-Region determination, Activity on Edge based-Low Frequency Car Data, Distributed Map-High Accuracy and Scalability for Trajectory points and offline based-Reliable and Robustness. These processes mainly focus on Time Efficiency and accuracy of map matching algorithms in the URBAN Areas.

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