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Process of Positioning in Map-matching Algorithm - GPS vehicle Navigation System

Mr.R.Manikandan[1], Dr.R.Latha[2]

[1] *Ph.D Research Scholar, Computer Applications, St.Peter's University, Chennai.*

[2]*Prof & Head., Dept of Computer Applications, St.Peter's University, Chennai.*

ABSTRACT

A map-matching algorithm is an integral part of every navigation system.In general, map-matching algorithms can be categorized into four groups: geometric, topological, probabilistic and other advanced techniques. Geometric algorithm process 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.Distance between the GPS point and road segments, difference between the heading of the GPS point and direction of road segments, and difference between the direction of consecutive GPS points and direction of road segments are used to identify the best segment among candidates near intersections. In contrast to constant weights applied in existing algorithms, 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) traveled distance from previous GPS point. The algorithm considers a confidence level on the assigned segment to each GPS point, which is calculated based on the density and complexity of roads around the GPS point. The most important feature of our algorithm is that the high correct segment identification percentage achieved in urban areas is through a simple and efficient weight-based method that does not depend on any additional data or positioning sensors other than digital road network and GPS.

Keywords: GPS, Map-Matching, Road Network, Vehicle Navigation

I. INTRODUCTION

Process of Map Matching Algorithm can be classified into three categories to find out the position of particular object or vehicle. Macro scale: Navigation usually performs the task of finding a particular path between two nodes in the network consisting of link. Micro scale: (Manikandan et al., 2017) 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.

Map Matching algorithm which is used to Map the Physical Location using GPS. An Algorithm which is used to find the exact location of vehicle or particular position of an object is called Map Matching algorithm. 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, a number of map-matching algorithms have been developed, these algorithms include Kalman filter, fuzzy logic and belief theory (Antonio M.R. Almeida et al., 2016). In general, map-matching algorithms can be categorized into four groups: geometric, topological, probabilistic and other advanced techniques. The geometric map-matching algorithm was introduced by Bernstein and Kornhauser (Batarfi.O et al., 2015) first. This algorithm contains point-to-point matching, point-to-curve matching, and curve-to-curve matching and improved geometric map matching (Batarfi.O et al., 2015). 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 (Antonio M.R. Almeida et al., 2016).

II.LITERATURE REVIEW

Map Matching Algorithm is mainly used to control and monitor the vehicle in the Urban Areas which may leads avoid traffic, accidents and also reduce the time taken from one place to another place. (Manikandan et al., 2017) The eight based processes of Map Matching algorithm are a) weight based map matching 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 (Greenfeld J.S et al., 2002). 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: (1) positional accuracy, (2) speed, and (3) traveled distance from previous GPS point.b) Enhanced Based map matching algorithm In dense urban areas it is still difficult to obtain good positioning using a single technology. This problem has led to the introduction of combining multiple positioning techniques. Intelligent Urban Positioning (IUP) is based on combining positioning algorithms augmented with three dimensional mapping techniques for distinguishing between non-line-of-sight (NLOS) and line-of-sight (LOS) signals and multi-constellation GNSS, using signals from all visible satellites. c) Enhanced, Weight Based map matching algorithmhas the potential to be applied in a range ITS services with a low polling frequency positioning data. This enhanced MM algorithm is fast, simple and very efficient and therefore, has the good potential to be implemented by industry, especially in city with intricate road network. d) Fuzzy Based map matching algorithm compares the road membership value of candidates by fuzzy sorting, and adjusts the measure coefficient to improve the accuracy of map matching. e)

Hidden Markov Based map matching algorithmis 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. f) Activity of Edge Based map matching algorithm:The Existing map-matching algorithms are not suitable for the low-frequency FCD (floating car data). By analyzing local map-matching algorithms and global map-matching algorithms, and overall considering the FCD trace, a map-matching algorithm for low-frequency FCD based on improved AOE (activity on edge) network was proposed. g) Distributed Based map matching algorithm 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. h) Offline Based map matching algorithm 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 literature review made by (Shenjingwei et al.,2015) states that the majority of the existent algorithms are for real-time applications, since the demand here is higher than in post-processing ones. In fact, only one offline algorithm is presented (Xin R.S et al., 2009). We mainly classified process of Map Matching algorithm as feasibility study, which is mainly implemented in the Urban Cities.

III.GEOMETRIC MAP MATCHING

A geometric map matching algorithm makes use of the geometric information of the spatialroad network data by considering only the shape of the links (Greenfeld et al., 2002). It does notconsider the way links are connected to each other. There are three strategies for the matching:point-to-point, point-to-curve and curve-to-curve matching. Point-to-pointmatching simply matches each point to its closest point in the road network. Point-to-curvematching matches each point to its closest road link. Curve-to-curve matchingcompare several points at a time with the positions and shapes of the links in the roadnetwork. Geometric algorithms are generally simple and fast but yield poor results sincethey do not guarantee that the resulting path is executable.

3.1. Point to Point Matching

The first geometric map matching approach is point-to-point. The most commonly used geometric map matching algorithm is a simple search algorithm. Inthis approach, each of the positioning fixes are matched to the closest 'node' or 'shape point'of a road segment. This is known as point-to-point matching (Bernstein et al., 1996).

A number of data structures and algorithms exist in the literature to select the closestnode or shape point of a road segment from a given point (Bentley et al., 1980).This approach is both easy to implement and very fast. However, it is very sensitive to theway in which the spatial road network data was created and hence can have many problems inpractice. That is, other things being equal, arcs with more shape points are more likely to beproperly matched. In a straight arc with two end nodes, all positioning points above the arcmatch only to the end nodes of the arc.

3.2. Point to Curve Matching

The second geometric map matching approach is point-to-curve (Bernstein, 1996; White et al., 2000). In this approach, the position fix obtained from thenavigation system is matched onto the closest curve in the network. Each of the curvescomprises line segments which are piecewise linear. Distance is calculated from the positionfix to each of the line segments. The line segment that gives the smallest distance is selectedas the one on which the vehicle is apparently travelling. Although this approach gives betterresults than point-to-point matching, it has several shortcomings that make it inappropriate inpractice. For example, it gives very unstable results in urban networks due to the high roaddensity. Moreover, the closest link may not always be the correct link.

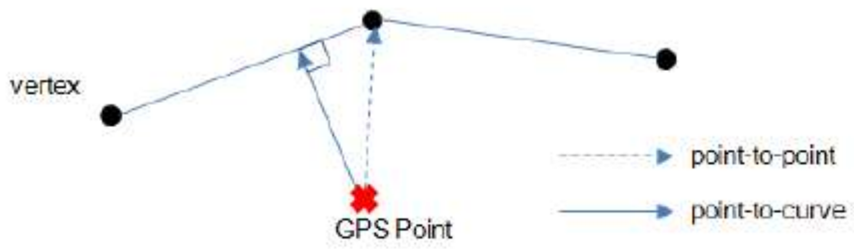

Fig.1: Geometric Matching example of Point-to-Point & Point-to-Curve

3.3. Curve to Curve Matching

The third geometric map matching approach is curve-to-curve. In this approach is to compare the vehicle's trajectory against known roads.This is also known as curve-to-curve matching (Bernstein, 1996; White et al.,2000). This approach firstly identifies the candidate nodes using point-to-pointmatching. Then, given a candidate node, it constructs piecewise linear curves from the set ofpaths that originates from that node. Secondly, it constructs piecewise linear curves using the vehicle's trajectory, and determines the distance between this curve and the curvecorresponding to the road network. The road arc which is closest to the curve formed frompositioning points is taken as the one on which the vehicle is apparently travelling. Thisapproach is quite sensitive to outliers and depends on point-to-point matching, with theconsequence of sometimes giving unexpected results (Quddus et al., 2006).

IV.TOPOLOGICAL MAP MATCHING

The geometric algorithms can be improved by taking advantage of information aboutthe road network connectivity and contiguity. Such algorithms are called topologicalalgorithms and tend to generate smoother paths and avoid frequent errors. However,they do generally ignore useful information from the GPS receiver, like speed or headingof the vehicle, in order to stay simple.the analysis of topological matching refers to the relationship between entities (points, lines, and polygons). Therelationship can be defined as adjacency (in the case of polygons), connectivity (in the case oflines), or containment (in the case of points in polygons). Therefore, a map matchingalgorithm which makes use of the geometry of the links as well as the connectivity andcontiguity of the links is known as a topological map matching algorithm (Greenfeld,2002; Chen et al., 2003; Quddus et al, 2003).

4.1. Weighted Topological Algorithm

This is based on a topological analysis of a roadnetwork and uses only coordinate information on observed positions of the user. It does notconsider any heading or speed information determined from GPS. This method is verysensitive to outliers as these can lead to the calculated vehicle heading being inaccurate.This algorithm is based on the correlation between the trajectory of thevehicle and the topological features of the road (road turn, road curvature, and roadconnection). A number of conditional tests are applied to eliminate road segments that do notfulfil some pre-defined thresholds. The thresholds are obtained from statistical analysis offield-test data. The algorithm is implemented using navigation data from GPS/DR and spatialroad network data including information on the turn restrictions at junctions which cansubstantially improve the performance of the map matching algorithms. The algorithm doesnot work well at junctions where the bearings of the connecting roads are not similar. In thesecircumstances, the algorithm switches to a post-processing mode to identify the correct link,making it unsuitable for real-time applications.

4.2. Enhanced Topological Algorithm

Enhanced topological map matching algorithm based onvarious similarity criteria between the road network geometry and derived navigation data.However, the objectives of the research are to use fewer inputs and to make the algorithm assimple and as fast as possible. The similarity criteria developed by (Greenfeld et al., 2002) areapplied also. To improve the performance of the algorithm, the weighting scheme is enhancedby introducing additional criteria and other parameters including vehicle speed, the positionof the vehicle relative to candidate links, and heading information directly from the GPS datastring or the integrated GPS/DR system. Different weighting factors are used to control forthe importance of each of these criteria in determining the best map matching procedure.

V.PROBABILISTIC MAP MATCHING

Probabilistic algorithms generally use a rectangular or an elliptic confidence region forthe search of a suitable match to each GPS point. The matched point in the roadnetwork is selected from the confidence region according to consistency in direction, speed, connectivity, and proximity.

The probabilistic algorithm requires the definition of an elliptical or rectangular confidenceregion around a position fix obtained from a navigation sensor. This technique was firstintroduced by (Honey et al., 1989) in order to match positions from a DR sensor to a map. The errorregion is then superimposed on the road network to identify a road segment on which thevehicle is travelling. If an error region contains a number of segments, then the evaluation ofcandidate segments is carried out using heading, connectivity, and closeness criteria. enhanced probabilistic map matching algorithm. In thisalgorithm, the elliptical error region is only constructed when the vehicle travels through ajunction (in contrast to constructing it for each position fix as suggested by (Zhao et al.,1997) andthere is no need to create the error region when the vehicle travels along a link. This makesthe algorithm faster as there are a number of processes involved in the creation of the errorregion and hence the identification of the correct link. This method is more reliable as theconstruction of an error region in each epoch may lead to incorrect link identification if otherlinks are close to the link on which the vehicle is on. In their study, they also develop anumber of criteria based on empirical studies to detect a turning of the vehicle at ajunction. Moreover, an optimal estimation for the determination ofvehicle location on a link is developed. This technique takes into account various errorsources associated with the navigation sensor and the spatial road network data quality.

VI.ADVANCED MAP MATCHING

Advanced map-matching algorithmsuse more refined concepts such as Kalman filter, fuzzy logic, multiple hypothesis technique,Dempster-Shafer’s mathematical theory of evidence, or Bayesian inferences. Themajor goal of these algorithms is to improve the accuracy of the resulting path. Theyoften use more extensive information besides the GPS position such as speed, heading,quality of the input data, and correction errors from third party systems.

They attempt to achieve this accuracy of positioning by the efficient use of digital road maps. First, a simple point-to-curvematching approach is used to identify the correct link. Then the orthogonal projected locationof the position fix onto the link is used to obtain an initial vehicle location. Due to theprojection, the cross-track error (i.e., the error across the width of the road) is reducedsignificantly. However, the along-track error remains a key issue. An extended Kalman Filter(EKF) is then used to re-estimate the vehicle position with the objective of minimizing thealong-track error. The inputs to the KF comes from GPS position fixes. The performance ofsuch a filter may depend on the quality of spatial road network data, specifically how a roadcurvature is represented. As stated earlier, the point-to-curve method is not sufficient to selectthe correct link especially in dense urban road networks. If the identification of the link isincorrect, then the inputs to the Kalman filter will also be inaccurate which may lead tofurther positioning errors. The method can be improved using a more efficient technique forthe selection of the correct link taking into account the heading and speed of the vehicle aswell as a topological analysis of the road network.

The algorithm uses a number of new input variables (at no extra cost). These are: (1) thespeed of the vehicle, (2) the connectivity among road links, (3) the quality of position solution, and (4) the position of a fix relative to a candidate link. These inputs are incorporated intothe fuzzy rules in order to improve the performance of the algorithm.

VII.TECHNIQUES USED IN THE MAP MATCHING PROCESSES

The methods used in the map matching algorithms vary greatly from using simple searchtechniques to a highly mathematical approaches. The performance and speed of thealgorithms in turn largely depend on the technique used in the algorithm. For instance, it hasbeen found that the fuzzy logic based map matching algorithms provide better performancecompared with other methods for the same inputs. Other potential techniques would be toemploy a pattern recognition approach, or a hieratical fuzzy inference system optimized by a genetic algorithm, or a hybrid method. Currently, map matching algorithms generateoutputs exactly on the road centerline of a road segment. This may be desirable for many Intelligent Transportation Systemsapplications. However, some Intelligent Transportation Systems applications require more accurate positioning information.Therefore, the current methods introduce large errors in the location estimation, specificallythe case of low resolution spatial road network data. A method can be developed so that thefinal positioning outputs from the map matching algorithm can optimally be determinedanywhere within the edges of the carriageway.

VIII.CONCLUSION

We conclude that, each process of Map Matching algorithm has its own identity. Simplification of each identity is as follows.Geometric algorithms- simple and fast but yield poor results sincethey do not guarantee that the resulting path is executable, Topological map matching-to generate smoother paths and avoid frequent errors, Probabilistic algorithms- consistency in direction,speed, connectivity, and proximity, Advanced map matching-GPS position such as speed, heading,quality of the input data, and correction errors from third party systems.Weight Based –Segmentation identification, Enhanced Based-Narrow Street and Tall building, Enhanced Weight Based-low pooling frequency data, Fuzzy-Region determination, Hidden Markov-Expansion and Contraction, Activity on Edge based-Low Frequency Car Data, Distributed Map-High Accuracy and Scalability for Trajectory points and offline based-Reliable and Robustness. Each process has its own pros and cons. These processes mainly focus on Time Efficiency and accuracy of map matching algorithms in the URBAN Areas.

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