Chapter 40
Map Matching Algorithms for Intelligent Transport Systems

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ABSTRACT

Map matching algorithms integrate positioning data with spatial road network data to support the navigation modules of intelligent transport systems requiring location and navigation data. Research on the development of map matching algorithms has significantly advanced over the last few years. This article looks at different methods that have been adopted in map matching algorithms and highlights future trends in map matching and navigation research.

INTRODUCTION

A map matching algorithm integrates positioning data with *spatial road network data* for the identification of the correct link on which a vehicle is travelling and to determine the physical location of the vehicle on the link. This algorithm could be used as a key component in the navigation modules of intelligent transport systems (ITS) that require locational data of a relatively high quality. Such ITS applications include navigation and route guidance, bus priority at junctions, fleet management, road user charging, accident and emergency management, and Location-Based Services. Two essential components required for the navigation module of an ITS are: (1) a device to determine the geometric position of the vehicle and (2) a spatial road network database for spatial (physical) reference of the vehicle location.

The most common geometric positioning devices used to obtain inputs to a map matching algorithm are Dead Reckoning (DR) motion sensors, global navigation satellite systems (GNSS) such as the Global Positioning System (GPS), and integrated navigation systems such as the integration of GPS and DR. The review of the literature suggests that the integrated GPS and DR system increases the performance of a map matching algorithm if all other factors are equal, especially in the case for dense and built-up urban

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areas. However, even with good *sensor calibration* and sensor fusion technologies, inaccuracies in the GPS/DR system are inevitable. This is mainly due to the errors in both GPS and DR sensors.

The spatial road network data are the other important component of a map matching algorithm. Since land vehicles primarily travel on known road networks, the spatial road network data are used as a spatial reference to locate them. This, for example, assists drivers to relate their observed positions obtained from the navigation system with a physical location in the real-world and hence can guide them along a pre-calculated route. However, the spatial road network data also contain errors arising mainly from the processes of creation and digitization of maps. The errors can be estimated using either the scale of the map or field experiments.

The performance of a map matching algorithm can be improved in two ways: (1) by controlling the errors in both positioning sensors and spatial road network data and (2) by improving the technique used in the map matching process. 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 performance of these algorithms has improved over the years due to the application of advanced techniques in the map matching processes and to the improvements of the quality of both positioning data and spatial road network data over time. The purpose of this article is to present an in-depth literature review on map matching algorithms and to suggest the future trends in map matching research.

The rest of the article is structured as follows. The next section describes methodologies used in map matching algorithms. This is followed by a description of future trends in the development of map matching algorithms. Finally, the conclusion is given.

METHODOLOGIES USED IN MAP MATCHING ALGORITHMS

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. The parameters used to select a precise road segment are mainly based on the proximity between the position fix and the road, the degree of correlation between the vehicle trajectory derived from the position fixes and the road centreline, and the topology of the road network. Orthogonal projection of the position fix onto the selected road segment is normally used to calculate the vehicle location on the segment. Figure 1 shows a general map matching process (see Quddus, 2006 for details) which takes inputs from an integrated GPS/DR such as easting (E), northing (N), speed (v), and heading (θ) and the error variances associated with them. The map matching process also takes inputs from a spatial digital road network database. The outputs of the algorithm are the correct link on which the vehicle is travelling and the location of the vehicle () and the error variances associated with them.

Approaches for map matching processes found in the literature can be categorised into three groups: geometric, topological and advanced. These are briefly discussed below.

Geometric Map Matching Algorithms

A geometric map matching algorithm makes use of the geometric information of the digital road network by considering only the shape of the links (Greenfeld, 2002). It does not consider the way links are connected to each other. The most commonly used geometric map matching algorithm is a simple search algorithm. In this approach, each of the positioning fixes matches to the closest ‘node’ or ‘shape point’ of a road segment. This is known as *point-to-point matching* (White et al., 2000). This approach is both easy to implement and very fast. However, it is very sensitive to

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