MATCHING GPS MEASUREMENTS ON LOCATIONS IN DIGITAL MAPS USING NEURAL NETWORK

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ABSTRACT: In general, Global Positioning System (GPS) has been widely used in Vehicle Navigation Systems (VNSs). It helps the users to determine the vehicle position or provides users with proper maneuver instruction. Because of the unknown GPS noise, the estimated position has an undesirable error. To solve this problem, a Map Matching (MM) method is introduced, which uses a digital road map to correct the position error. In VNS, MM approach plays an important role. It is a method of using digital map data and GPS satellite signal to locate the vehicle on proper position relative to digital map. In this paper, a MM method based on Neural Network (NN) is proposed. This network is made of three layers: input layer with 2 neurons, hidden layer with 15 neurons and output layer with 2 neurons. The effectiveness of this algorithm is verified by real road experiments. For the experiments, a car navigation system is implemented with a low cost GPS receiver and a microcontroller chip. The proposed algorithm is easy to calculate. It requires little computation time without need to extra sensors and can find the mobile exact position which moves on the road.

1. INTRODUCTION

Currently, Global Positioning System (GPS) is the only fully operational Global Navigation Satellite System (GNSS) available. It consists of 28 operational satellites in earth orbits, where at least four satellites have to be in view for simultaneous observation to obtain a three-dimensional receiver position utilizing measured distances between satellites and receiver. GPS positioning errors occur from the cumulative effects of receiver, satellite and atmosphere, and also due to the US military intentionally (Winter and Taylor, 2004).

Map Matching (MM) is a main technique of the navigation system because the user needs to know his/her current position on a road map instead of only coordinates. MM algorithms are usually used to reconcile the inaccurate location data with inaccurate digital road network data. If both digital maps and vehicle location are perfectly accurate, the algorithm is simple and the output from the positioning sensor will indeed lie accurately on the correct road segment. However, in real life it is not possible to use such simple algorithms as many noise sources affecting the signals along with the map inaccuracies, result in the estimated position not correctly snapping to the road network. Therefore, more complex MM algorithm is an essential component for vehicle location and navigation systems (White et al., 2000; Zhang and Gao, 2008).

Artificial Neural Networks (ANNs) have been proposed as a multi-sensor integrator. It is well known that NNs are capable of adapting themselves to learn input-output relationships. This means that no initial dynamic or noise models need to be set as these are learned over time. NNs can also adapt to the changes of the system model or vehicle dynamic (Mosavi, 2007a).

In this paper, a new NN MM algorithm is proposed for reducing of GPS position error. It is easy to implement and requires little computation. Also, this method can find the mobile exact position on the road. A car navigation system is developed for the real road experiments. The aim of this study is to research how ANN may be developed and adapted for MM purposes in general. The effectiveness of this algorithm is verified by the real road experiments. For the experiments, a car navigation system is implemented with a low cost GPS receiver and a microcontroller chip. This paper is organized as follow. Section 2 explains MM principle. Multi-layer feed forward network is described in section 3. Section 4 shows proposed MM algorithm. The experimental results of navigation system are described in section 5. Conclusions are explained in section 6.

2. MAP MATCHING PRINCIPLE

MM algorithm is based on the theory of pattern recognition (Yang et al., 2003; Joshi, 2002). 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, find the road where vehicle runs and show the real-time location of vehicle. MM process based on the principle 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. As shown in Figure 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 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 A → B → C.

3. MULTI-LAYER FEED FORWARD NEURAL NETWORK

A Feed-Forward Network (FFN) has a layered structure. Each layer consists of units which receive their input from units from a layer directly below and send their output to units in a layer directly above the unit. There are no connections within a layer. The $V_i$ inputs are fed into the first layer of $q$ hidden units. The input units are merely 'fan-out' units; no processing takes place in these units. In most applications a FFN with a single layer of hidden units is used with a sigmoid activation function for the units, as shown in Figure 2.

The layers in an ANN are connected by weights and bias units. An output of a neuron in the hidden layer, $\varphi(I_j)$ can be calculated from the following logistic function:

$$\varphi(I_j) = \frac{1}{1 + \exp(- \sum_{i=1}^{p} V_i W_{ji})} \quad (1)$$

where $W_{ji}$ is the connection weight between the input and the hidden layer. The output of a neuron in the output
layer, $\varphi(I)$, can be defined as:

$$
\varphi(I) = \frac{1}{1+\exp(-\sum_{j=1}^{q} \varphi(I)W_{ij})}
$$

(2)

where $W_{ij}$ is the connection weights between the hidden and the output layers. The Learning (training) effect can be achieved by adjusting the connecting weights in the training phase. Training aims to determine a set of weights, which minimizes the error between the desired and the computed unit values. Back Propagation (BP) algorithm has been used widely in NN learning. The standard BP algorithm is based on the steepest descent gradient approach applied to the minimization of an energy function representing the instantaneous error. BP algorithm is adopted to train NNs and minimize the function which is defined as equation (3) (Mosavi, 2007b):

$$
E = \frac{1}{2} e^2 = \frac{1}{2} (y - d)^2
$$

(3)

where $d$ represents the desired network output for the input pattern and $y$ is the actual output of the NN shown in Figure 2. Using the steepest descent gradient approach and the chain rules for the partial derivatives, the learning rules for the biases and weights of the model are given in equations (4) and (5), respectively:

$$
\Delta b_j = -\eta \frac{\partial E}{\partial b_j}
$$

(4)

$$
\Delta w_{ji} = -\eta \frac{\partial E}{\partial w_{ji}}
$$

(5)

where $\eta$ is a learning rate parameter, which is used for controlling the convergent speed of the algorithm. One problem is that the NN easily drops into the local minimum, causing the learning failed.

4. PROPOSED MAP MATCHING ALGORITHM DESIGN

Different types of NNs have been employed in the past for MM, road extraction purposes and navigational satellite selection. In this study the NN is multi-layer perceptron with three layers. Input layer with no activation function is a layer with two nodes that receive x and y coordinates of GPS point. The proposed NN has 15 neurons in hidden layer and uses BP learning. The following is a summary of the steps that occur in this algorithm:

**Step1:** Transferring all x and y data to dots matrix.

**Step2:** Normalizing x and y values into the domain [-1,1].

**Step3:** Recognition of relevant NN belongs to certified data is doing by the following procedure:

**Step3.1:** The distances of subjected point are calculated from all segments ends which formed whole the map.

**Step3.2:** Each two distance which are related to one segment are added together and divided to segment length.

**Step3.3:** Minimum value obtained in above determines selected segment and NN for that point. For example in Figure 3, there are nine segments which form the map. The distances of test point “T” from all segment ends are $TA~TI$. Since $\frac{TF}{TE+TF}$ is minimum between all other options, the test point “T” belongs to segment 5 and consequently NN number 5 will be candidate.

**Step4:** Mapping of GPS data by NN. Mapping point is obtained by drawing of perpendicular line passing trough GPS point to map’s line.

**Step5:** Converting NN data from domain [-1 1] to x and y data.
5. EXPERIMENTAL RESULTS

A field test was conducted in Iran University of Science and Technology, to validate the performance of the algorithm. The test lasted for about 15 minutes. The test was conducted at variety of speeds ranging from 10 to 60 km/h. A car navigation system consists of several subsystems, such as a positioning system, a route guidance system, and a user interface system. The main role of a car navigation system is to find the car position as precisely as possible. In this research, a low cost GPS engine manufactured by Rockwell Company was used. The Rockwell “Microtraker Low Power (MLP)” is a single board, five parallel-channels, L1-only Coarse Acquisition (C/A) code capability. To read the GPS receiver data as well as to calculate the car position simultaneously at every sampling time, the developed navigation system consists of two serial ports, a sensor handling serial port for the GPS receiver and a serial port for communication to computer. A 16-bit microcontroller 80C196KB is used for the MM algorithm. All the programs for microcontroller and computer are coded in C-language and visual basic 6, respectively. As mentioned above, the developed car navigation system is a subsystem that has the positioning ability only. The mapped position from the developed car navigation system is sent to the notebook computer through RS232 serial communication. The map matched position is displayed on the notebook monitor.

In his algorithm Mean Square Error (MSE) is calculated for algorithm’s error. This error for each line of map and for each NN has been showed in the Table 1.

Table 1. Algorithm’s error for each line of map

<table>
<thead>
<tr>
<th>Number of line</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error (m)</td>
<td>0.2724</td>
<td>0.2584</td>
<td>0.6324</td>
<td>0.7515</td>
<td>0.5393</td>
<td>0.8897</td>
<td>1.2026</td>
<td>0.5283</td>
<td>0.8362</td>
</tr>
</tbody>
</table>

Table 1 shows the map matched output using the proposed algorithm. The algorithm gives a good map matched solution.
6. CONCLUSIONS

MM is a technique combining electronic map with locating information to obtain the real position of vehicles in a road network. In this paper, a new MM algorithm based on NN was successfully used to project the vehicle location on the digital map 2-dimensional road network. For experiments, a car navigation system was developed with a small number of sensors, such as a low cost GPS receiver and a microcontroller chip. The effectiveness of the proposed MM algorithm was verified with several experiments. Moreover, the proposed algorithm needs little computation time. This feature makes it suitable for using in a car navigation system with a low power microcontroller.

References