Research on Map-matching method in Vehicle Guidance System

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[Abstract] As the part of Intelligence Transportation System, Vehicle guidance system plays an important role in improving urban traffic jam, increasing the efficiency of city traffic network and people’s lives. In this paper, the key research of map-matching method in vehicle guidance system is committed. Firstly the real time dynamic position accuracy of single point of GPS is analyzed. Based on this, HDOP received directly form GPS receiver can be a foundation of the size of buffer. And the size of buffer can be defined by different confidence level. Cyrus-Beck algorithm is used to choose the nearest route from the GPS point. The GPS point is projected to the selected route. From the result of the test, a good effect of the map-matching method is received and a quick response speed is achieved. These are in accordance with the limitation ability of the terminal and the demand of real time resonance of the vehicle guidance system.

[keyword] vehicle guidance system, intelligence transportation system, map-matching

1 Summary

In many parts of the world, mobility has vastly improved vastly over the past century. Increasing mobility combined with urbanization and (in some cases) rapid population growth is creating undesirable negative impacts on economies and individual quality of life. In 1995, commuters in the United States spend more then 2 billion hours in traffic jams, generating US$100 billion in lost productivity [8]. In Japan, about 5.6 billion person hours were spent in traffic congestion. Economic losses due to traffic congestion in urban areas amounted to 12 trillion yen per year [9].

To solve the traffic problems, researches on ITS are developed in the world. Japan’s research community stared to explore advanced technologies as far back as th 1960s[9]. Many countries in Europe began the research in 1970s and experienced the projects of ALI,PROMETHEUS, DRIVE PROGRAM,DRIVER II PROGRAM, TAP et al. The Fifth Framework Program (FP5) is set up in 1998 by European Union. It is a broadly conceived program intended to help solve problems and respond to the major socioeconomic challenges facing Europe. And FP5 consists the research of ITS. In1986 some institutes of America established the Partners for Advanced Transit and Highway (PATH). In 1991, the U.S. National ITS Program was authorized by the U.S. congress as part of the Intermodal Surface Transportation Efficiency Act (ISTEA). And until 1994 the concept of ITS is formed [11]. According to reference literature 9, ITS can be grouped into seven parts. The first parts is traffic control and guidance. It intends to keep highway traffic flowing smoothly and efficiently. There are two kinds of traffic flowing. They are variable messages signs and vehicle guidance. Variable message signs system provides timely information about traffic, e.g., the traffic congestion, the transit availability to travelers, traffic accidents and so on. It also provides real time parking indication on the variable message boards on the key parts of the road. After the travelers get the information, they can decide how to choose route on the basis of their knowledge of routs. Vehicle guidance system is a system that provide the real time guidance information for single vehicle using the advanced technology which collect and deal with the dynamic traffic information.

In the vehicle navigation system, single GPS is usually used as orientation equipment to get the real time positioning information of the vehicles dynamically. Although USA canceled the SA policy in May 1,2000, the real time single point positioning precision of GPS is 15-20m. Such precision is not ideal in real time navigation. How to improve the GPS positioning precision is the focus in the research of map matching method of the navigation system. Wang Mi (2000) et al. set up road network topological relationship with known road network data. And a quick path matching algorithm is presented based on network topological relationship and position information of electrical box and needle. Error buffer analyze method is adopted to match the GPS dynamic positioning data and GIS map data by Wu Xuyan and Luo Dean(2001). In 2001, Su Jie, Zhou Dongfang and Yue Chunsheng presented a real time map-matching algorithm of GPS positioning surveying and digital map of vehicle guidance. Map matching algorithm are used in all these researches. The GPS positioning signal is received to pull the vehicle to the right position by force.

Map matching method adjusted the GPS positioning error to improve the GPS positioning precision of vehicle guidance system with its high precision information and make the guidance result accord with the people’s habits. At the same time, the terminal of the system can’t have strong real time process ability because of its character as a guidance system. This requires the simpleness and efficiency. We presented global positioning technology, visualized geographical information process technology, mobile communication technology and other advanced technologies. Road topological information and positioning precision information are integrated with these technologies to develop the map matching method suitable for vehicle guidance system.

2. GPS dynamic positioning precision analysis

GPS positioning virtually is the spatial range resection in surveying. Three unattached observed ranges are needed to get the position of the observing station. In the process of measuring, the practical observing range is the pseudorange because of the influential of the clock difference between GPS receiver and the planet. So the current positioning method is to use survey code pseudorange. The error equation of the survey code pseudorange is:

$$v_i(t) = a_i(t)\delta Z + l_i(t) \qquad (1)$$

where, $\underset{(n^j\times 1)}{v_i(t)} = [v_i^1(t) \quad v_i^2(t) \quad \ldots\ldots \quad v_i^{n^j}(t)]^T \qquad 4 \le n^j \le 12$

$$\underset{(n^j\times 4)}{a_i(t)}=\begin{bmatrix} l_i^1(t) & m_i^1(t) & n_i^1(t) & -1 \\ l_i^2(t) & m_i^2(t) & n_i^2(t) & -1 \\ \cdots & \cdots & \cdots & \cdots \\ l_i^{n^j}(t) & m_i^{n^j}(t) & n_i^{n^j}(t) & -1 \end{bmatrix} \qquad (2)$$

where, $l_i(t)=[L_i^1(t) \quad L_i^2(t) \quad \cdots \quad L_i^{n^j}(t)]$

$$\delta Z=[\delta X_i \quad \delta Y_i \quad \delta Z_i \quad c\cdot\delta t_i(t)]^T$$

The coordinate in WGS-84 system of the observe station can be calculated by the least square method. The coefficient array is

$$Q_Z=[a_i^T(t)a_i(t)]^{-1} \qquad (3)$$

To estimate the precision of the observer, the express format in geodetic system is adopted.

$$Q_B=HQ_XH^T \qquad (4)$$

where Q_B and Q_Z is the children coefficient arrays,

$$H=\begin{bmatrix} -\sin B\cos L & -\sin B\sin L & \cos B \\ -\sin L & \cos L & 0 \\ \cos B\cos L & \cos B\sin L & \sin B \end{bmatrix} \qquad (5)$$

To get Q_B, we can compute kinds of dilution of precision such as horizontal dilution of precision (HDOP) and position dilution of precision (PDOP). The GPS positioning error and its dilution of precision are in direct proportion. In all GPS receivers and CMOS chip, data of NME0183 standard format are output. The ASCII code is adopted and the GGA is most often used. Standard positioning time, latitude, longitude, positioning symbol, planet number, horizontal dilution of precision, height and other information are included in the GGA.

3. Map matching method

People always have some intentions when they are out. The vehicle guidance system makes use of the traffic situations to regulate the users travel courses during the their trip between origin and destination. In this process to confirm the current route and position of the vehicle are the most important. The matching process of GPS and the route network according to GPS positioning error mentioned in chapter 2 is presented as below.

3.1 GPS positioning point buffer created based on HDOP

Observing error is subjected to normal distribution and linear combination function is also subjected to normal distribution. So the GPS positioning error distribution function is:

$$f(x,y)=\frac{1}{2\pi EF}\exp\{-\frac{1}{2}(\frac{x^2}{E^2}+\frac{y^2}{F^2})\}$$ [6] (6)

where E and F are long and short axis of the error ellipse can be calculated by coefficient array Q_B.

The plane paralleled with the plane XOY intersect on the distribution curve plane and a group of ellipses with the same center are achieved when the transversal projected to the XOY plane. The function expressing the ellipses is:

$$\frac{x^2}{E^2}+\frac{y^2}{F^2}=k^2$$ [6] (7)

The probability B_K that can show the positioning point in the ellipse mentioned above is:

$$P((x,y)\subset B_K)=\iint_{B_K} f(x,y)dxdy = 1-e^{-\frac{k^2}{2}}$$ [6] (8)

From the variance of k, the probability that the point fall in the error ellipse can be calculated. When k=1, the probability is 0.3935; when k=2, the probability is 0.8647; when k=3, the probability is 0.9889, when k>3, the variance of the probability is small. So we can consider the ellipse that k=3 as the biggest error ellipse.

From the GPS receiver, the HDOP can be got. The corresponding horizontal position of precision and HDOP are in direct ratio as follow:

$$m_H = HDOP\cdot\delta_0 = \sqrt{E^2+F^2}$$ (9)

Where δ_0 is unit power mean square error. The buffer size could be determined by HDOP. The buffer of the positioning point is defined as a circle that the point is the center in GIS analysis. The radius of the circle R is defined as the summation of the long axis and short axis of the error ellipse to get bigger probability.

When k=1, $R_1 = \delta_0 HDOP$

When k=2, $R_2 = 2R_1$

When k=3, $R_2 = 3R_1$

Where, δ_0 can be taken from 15 to 20 meter which is the nominal precision of real time kinematical positioning. In this paper, δ_0 =15.

Considering the convenience of operating the line, the buffer circle is replaced by an octagon.

The area of the octagon is 90% of that of the circle and good result is achieved.

3.2 The match principle of GPS observer and road

After the GPS observer buffer is created, which road to be projected can be decided by the fact that whether the road is in the buffer. In fact this process is the line operation in computer graphical science. Now an example using Cyrus-Beck algorithm to describe the process of matching is presented as below.

Road is composed of several parts. Every part can be divided into some lines. So this problem is to judge whether the line is in the buffer. From the above section 3.1, we can see using octagon to simulate the circle buffer of the GPS observer is practical. The following figure is a line operation sketch map in buffer.

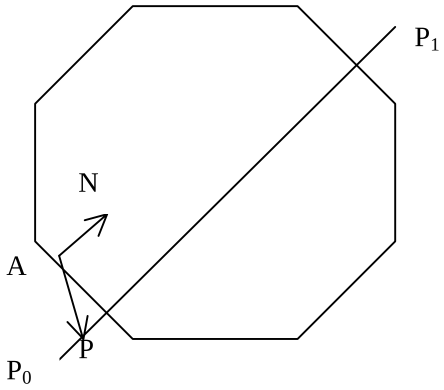

Fig1: a line operation sketch map in buffer

Line P_0P_1的 parameter equation is :

$P(t)=(P_1-P_0)t+P_1 \quad (0\leqslant t\leqslant 1)$ (10)

In the octagon we pick up a random point A_i 和该处 and its inner normal vector is N_i (i=1:8). So the parameter of the line that fall in the buffer can satisfy such equation:

$$\begin{cases} N_i \cdot (P(t)-A_i) \geq 0 & (i=1:8) \\ 0 \leq t \leq 1 \end{cases} \quad (11)$$

Put the equation 10 in, we can get:

$$\begin{cases} N_i \cdot (P_0-A_i)+N_i \cdot (P_1-P_0)t \geq 0 & (i=1:8) \\ 0 \leq t \leq 1 \end{cases} \quad (12)$$

let

$$t_i = \frac{N_i \cdot (P_0-A_i)}{N_i \cdot (P_1-P_0)} ,$$

the parameter is that of intersection point of the line and the no. I line.

So equation 12 can be converted into:

$$\begin{cases} t \ge -t_i & \text{当} N_i \cdot (P_1 - P_0) > 0 \\ t \le -t_i & \text{当} N_i \cdot (P_1 - P_0) < 0 \\ & 0 \le t \le 1 \end{cases} \quad (13)$$

In fact, we concern about the maximum value and the minimum value of t when line intersect with the octagon. We mark the minimum value as t_l and the maximum value as t_u. In literature 7 the value is given as:

$$\begin{cases} t_l = \max\{0, \max\{-t_i : N_i \cdot (P_1 - P_0) > 0\}\} \\ t_u = \min\{1, \min\{-t_i : N_i \cdot (P_1 - P_0) < 0\}\} \end{cases} \quad (14)$$

If $t_l \leqslant t_u$, the line intersect with the buffer, if $t_l > t_u$, the line is outside the buffer.

3.3 Matching algorithm of GPS observer and the road

From the above description the matching algorithm is :

Step1: receive positioning information and HDOP information from GPS receiver.

Step2: assume k=1, compute the buffer octagon of the GPS positioning point.

Step3: Cyrus-Beck algorithm is used and the projected road of GPS positioning point is chosen. If road is not chosen, k++, go to step2; else if several roads are chosen in the buffer, go to step4; and else only one road go to step5.

Step4: if there are no lines are intersected in the buffer, the above point is used to get the road attribute from GIS attribution base and a unique road is chosen. Then go to step5. If there is a public node in the buffer, the next positioning point is obtained to estimate the trend of the vehicle.

Step5: Project the GPS point to the line and the projected point replaces the GPS positioning information.

3.4 the experiment of the matching algorithm

The experiment is executed by the road-matching algorithm with Embed Visual C++ installed in the palmtop of Windows CE 2.0 or above. The following map is the result map. From the result the matching effect is ideal.

Fig 2 Matching result map

4. Result

Based on the precision analysis of GPS dynamic positioning a method is presented. HDOP received directly from GPS receiver can be a foundation of the size of buffer. And the size of buffer is analyzed at different confidence levels. Cyrus-Beck algorithm is used to choose the nearest route from the GPS point and the point is projected to the selected route. From the result of the test, a good effect of the map-matching method is received and a quick response speed is achieved. These are in accordance with the limitation ability of the terminal and the demand of real time resonance of the vehicle guidance system.

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