

RESEARCH ON MATCH OF GPS SIGNAL AND ROAD INFORMATION FOR MOBILE NAVIGATION SYSTEM

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ABSTRACT

This paper presents two matching methods for mobile navigation system. One is on the basis of Index of Divided Zone and Dichotomy fuzzy Lookup; the other is on the basis of Road Network Topology and Electronic Compass. The positioning results of the two matching methods are compared and analyzed. In addition, the positioning error is also analyzed in detail in this paper. Through mobile navigation system experiments, it proves that the second method can acquire satisfactory precision, high reliability and real-time result.

1. INTRODUCTION

At present, the positioning precision of single GPS can merely reach 50~100 meters. Due to the limited cost, it is impossible to process the GPS signal by real-time difference to obtain high positioning precision. Therefore, in mobile navigation system, single GPS receiver is generally used to get the real-time position of car.

Because of the effect of American SA (Selective Availability) technology, the positioning precision of single GPS is only 100 meters. In this case, if suitable methods of processing the real-time positioning information can't be adopted, it is impossible to get better result in mobile navigation system. For example, when the car is running along the bridge, because of positioning error, the car may be positioned in the river.

As the car always runs on the road in normal situation and the database of road net has been acquired in advance before navigation. Those conditions can be used as restricted conditions during navigation. Before starting to navigate, topology of road net is built and the initial position of the car on the road can be acquired. At the same time, because the car is on the road under the control of road net, the error of vertical road direction is eliminated automatically. By the analysis of the positioning error, the error of along-road-direction is also decreased with the change of road direction during navigation automatically.

During navigation the GPS signal will match with the current road that the car is running by matching algorithm. When the car reaches a crossroad, it is critical to process the GPS signal. In this condition, several roads along which the car will run can be quickly found according to road topology. As the positioning error is 100 meters, it is very difficult to decide immediately along which road the car will run. So due to positioning error the car is likely to jump from one road to another road. Another restricted condition can be added by using the data of compass installed on the car. As compass can record the driving direction of the car, when the car comes closely to a crossroad, by analyzing the acquired data from compass in real-time. The road where the car will go can be decided. At the same time, each road direction in which the car will run can be decided. By road direction matching with the result direction of analyzed compass data, the road the car will go can be obtained.

2. THE MATCH OF GPS SIGNAL AND ROAD INFORMATION

In mobile navigation system, electronic map is generally used the navigation background with the real-time display positioning information of the car on the background. During navigation, as the car is always running on the road, the road net in GIS database can be used sufficiently to correct the positioning error of GPS.

But the car must be positioned at real time in the background of electronic map in the mobile navigation system. As far as mass road net data in GIS database of a city are concerned, if reasonable data structure can't be adapted to manage road net data, it would not meet the real-time demand of navigation. This paper will introduce two data structures and

the corresponding algorithms:

2.1 The Method Based on Index of Divided Zone and Dichotomy Fuzzy Lookup

As shown in Figure 1, the road net is divided into several zones along certain directions (such as X or Y. Figure 1 along Y direction). The zone width can be decided by practical need (for example 100 meter or 200 meter). Each zone can be stored according to ascending or descending order. An exclusive ID is assigned to each road in road net. Each road ID is stored in the zone, which the verge of rectangle of the road intersects with or is contained. The storage structure is shown as below (Table 1).



Figure 1. Index Diagram of Divided Zone

Zone No.	Zone Range	Road ID
I	500~600	1, 2, 3...
II	400~500	25, 26, 27...
III	300~400
IV	200~300
V	100~200
VI	0~100

Table 1. Index Table of Divided Zone

Based on this data structure, the algorithm of road matching is as follows:

1. Transform positioning information of GPS receiver to electronic map coordinate system.

As the positioning information from GPS receiver is longitude and latitude coordinate, but electronic map coordinate is Gauss coordinate, the transform of coordinate is necessary.

2. Look up the number of zone.

According to the transformed coordinate in step 1, to decide the zone in which the coordinate is. When looking up the number of zone, if the divided zone is based on Y direction, using Y coordinate merely can decide the zone number. Because zones are stored in order, dichotomy can be used. As the lookup results are not accurate, it is called Dichotomy Fuzzy Lookup.

Dichotomy has the degressive characteristic by 2 exponent, so the lookup speed is very quick, especially in the mass road net. It can satisfy the real time need.

3. Look up the Roads ID.

Using zone number in step 2, the roads ID which belong to this zone can be found based on table 1.

4. Look up the road ID that the car is running along.

In Roads ID of step 3, by calculating the uprightness shortest distance between the transformed coordinate (X, Y) in step 1 and each road, the road that the car is running along is decided.

The advantage of this matching method is that it can ensure the real time of car positioning, and can eliminate vertical direction error of the road. But when the road net is very dense or car runs at the crossroad, the car is likely to jump from one road to another on the electric map because the distance is the only restricted condition for deciding where the car is.

2.2 The Method Based on Road Network Topology and Electronic Compass

The matching method above can produce real time positioning result, but its reliability is very poor. If topology of road net and electronic compass is taken into account to decide the car position, the reliability can be improved. The data structure and algorithm is presented as follows.

2.2.1 Build the Topology of Road Net

In GIS, in order to describe real geographic objects, the recording data not only include the position, shape, size and attribute of the objects, but also should reflect the relations among the objects. These relations are called as topology, which include adjacency, conjunction and inclusion. They have the characteristics in common that topology will be unchangeable when graphics are distorted.

On the other hand, topology can make the global search into local search, and improve the searching speed greatly. So it provides better data structure for real-time data processing. In mobile navigation system, we only consider the road net information of electronic map; the relation between nodes and arcs in the road net is built.

Figure 2 is a schematic diagram of road net, 1,2... denotes the node number of each road, A, B denotes the Road ID.

The following are the steps to build topology:

1. Read out the first road from road net database. The node is numbered sequentially from 1. The number is added to table 2. There is a record for one side road and two records for double sides in Table 2. (In Figure 2, All roads are double sides)
2. Read out the other roads, to decide whether the node is numbered. If not, the node is to be numbered. Otherwise, the numbered node is as this road node number.
3. After ordering Table 2 on Field start node, the Sorted Table of Node Connection (Table 3.) is generated.
4. After combining the start nodes, the Topology of Node—Arc (Table 3.) is generated.

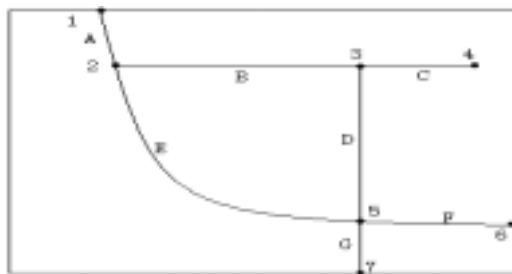


Figure 2. Schematic Diagram for Road Network

Node No.	Connected Road ID
1	A
2	A , B、 E
3	B、 C 、 D
4	C
5	D、 E、 F、 G
6	G
7	F

Table 4. Topology of Node—Arc

Start Node	End Node	Road
1	2	A
2	1	A
2	3	B
3	2	B
3	4	C
4	3	C
3	5	D
5	3	D
2	5	E
5	2	E
5	6	F
6	5	F
5	7	G
7	5	G

Table 2 Table of Node Connection

Start Node	End Node	Road ID
1	2	A
2	1	A
2	3	B
2	5	E
3	2	B
3	4	C
3	5	D
4	3	C
5	3	D
5	2	E
5	6	F
5	7	G
6	5	F
7	5	G

Table 3 Sorted Table of Node Connection

2.2.2 The Matching Algorithm

First, adding two directions into the attribute table of each road (As shown in Table 5) preprocesses the road net data. As we know each road in GIS database is stored in discrete points, in order to quicken the searching speed, each road is

resampled in 5-meter distance. (Based on the size of navigation vehicle and practical navigation precision, the worst case is that the position signal is on the vertical bisector of adjacent nodes, the error to be adjusted is 2.5 meter, when using 1:10000 electronic map, it can meet the precision needs.) Thus it can reduce calculating time and ensure real-time positioning.

The algorithm based on the network topology is as follows:

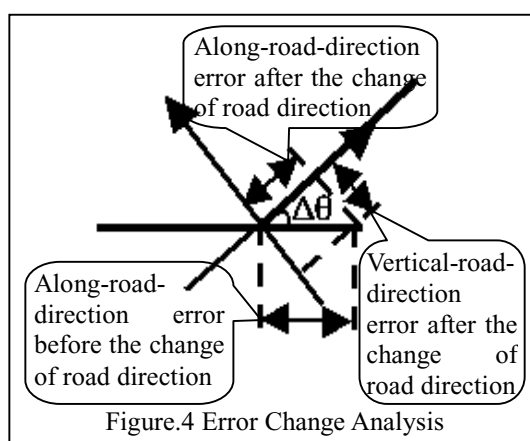
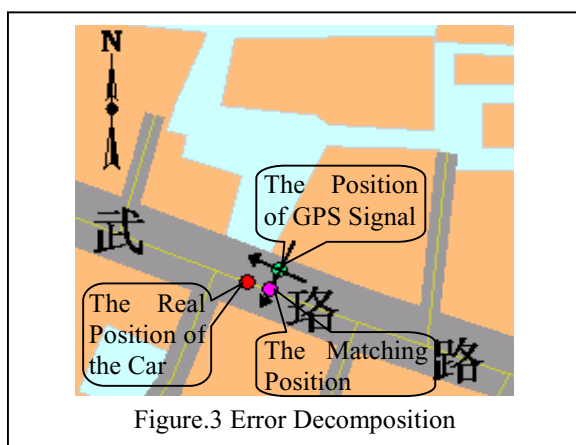
1. Transform positioning information of GPS receiver to electronic map coordinate system, the same as step1 of the first method.
2. Find the initial road ID along which the car is running.
3. According to road ID, find the number of the start point and the end point, coordinate data (after resampling) and attribute data.
4. Calculate the nearest point which GPS positioning information (X, Y) reaches to the points of road. The nearest point is the car position. The calculating rule of judgement is $\text{MIN}(|X-X_i|+|Y-Y_i|)$, in which MIN denotes the smallest value, (X,Y) denotes GPS position information and (X_i,Y_i) denotes the discrete points coordinate of the road.
5. At the crossroad, a special processing is needed: when the position point in step 4 is the start point or end point, it illustrates that the car is at the crossroad. In table 4, according to the node number, the linked roads can be found. Using the direction information of electronic compass to match these road directions, the road where the car will go can be decided. Then, according to step 4, search the positioning point repeatedly.

After a lot of experiments, it proves that this algorithm can achieve better reliability, especially at the crossroad and the dense section of road net. At the same time, this data structure can ensure the real-time and accurate position.

3. POSITIONING ERROR ANALYSIS IN MOBILE NAVIGATION SYSTEM

In order to discuss the positioning error, the decomposing method of vector is used. The positioning error can be divided into vertical road direction and along-road-direction, as shown in Figure 3.

As the road net is a restricted condition during navigation, the car can be drawn to the road by road net. Thus the error of vertical road direction is eliminated.



The error of along-road-direction changes with the track of the car, which may be expressed as:

$$r' = r \cos \Delta\theta \quad (1)$$

where: r' is the error of along-road-direction before the change of road direction

r is the error of along road direction after the change of road direction

$\Delta\theta$ is the change angle of road direction

From the above equation, when the road direction does not change, the error of along-road-direction does not change either. As time goes on, the error may accumulate. But when the road direction changes, the error is decreased. The decreased degree of error depends on $\Delta \theta$, when $\Delta \theta = 90^\circ$, the error is basically eliminated.

In practice, Most road directions are changing. So Each time of road direction change can make the error eliminated. Thus, the accumulated error is controlled and the navigation precision is ensured.

In addition, in many mobile navigation systems, including ours, wheel counter is combined for GPS positioning error correction, even for solving signal loss of GPS receiver.

4. CONCLUSIONS

In car navigation system, the GPS signal matching with road is the key technology, while the critical criteria to judge whether the matching result is good or bad is the real time, reliability and precision. After a lot of experiments, it proved that the method based on road network topology and electronic compass could obtain better results. The experiment results are as follows:

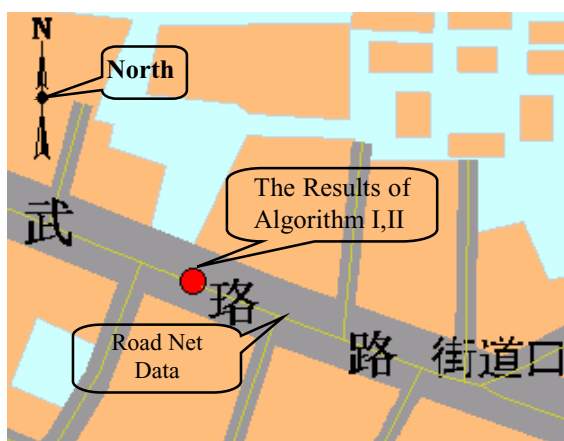


Figure.5 The Positioning Result of Algorithm I,II in the middle of a road

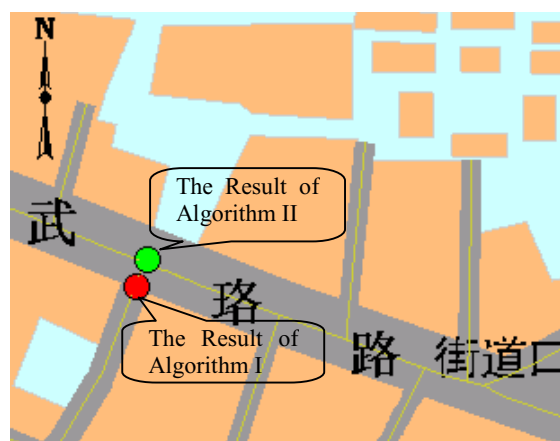


Figure.6 The Positioning Result of Algorithm I,II at the crossroad

In figure 5,6, the car is running on WuLuo Road. From the results of the experiments, there is no obvious difference to the positioning results of algorithm I and II. But when the car is at the crossroad, the reliability of algorithm II is obviously better than that of the algorithm I.

5 ACKNOWLEDGMENT

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