International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:2, No:10, 2008

Research of Dynamic Location Referencing Method Based on Intersection and Link Partition

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***Abstract*—**Dynamic location referencing method is an important technology to shield map differences. These method references objects of the road network by utilizing condensed selection of its real-world geographic properties stored in a digital map database, which overcomes the defections existing in pre-coded location referencing methods. The high attributes completeness requirements and complicated reference point selection algorithm are the main problems of recent researches. Therefore, a dynamic location referencing algorithm combining intersection points selected at the extremities compulsively and road link points selected according to link partition principle was proposed. An experimental system based on this theory was implemented. The tests using Beijing digital map database showed satisfied results and thus verified the feasibility and practicability of this method.

***Keywords*—**Dynamic location referencing, inter-section referencing, road link partition, road link point referencing.

I. Introduction

LOCATION reference is the string of data which is passed between different implementations of a location referencing system to identify the location. Location referencing method (LRM) is a methodology of assigning location references to locations. LRM is widely used, especially in the traffic information service system. Accurate positioning of traffic incident location is very important for information releasing, path planning and vehicle scheduling. Traditional LRM utilized pre-coded theory, which used pre-defined IDs to reference locations, such as TMC location table and VICS link ID [1]. This method had limited reference range, needed a lot of creation and maintenance costs and strictly demanded the encoder and decoder using exactly the same map.

Manuscript received Oct. 7, 2008. This work was supported in part by the Beijing Science and Technology Commission fund project –Demonstration of Key Technology and Application of Beijing Intelligent Transportation System, no. is: D0705060 0440000.

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The concept of dynamic location referencing method is to overcome these shortcomings. It references objects of the road network by its real-world geographic properties which are stored as information elements in a digital map database. This can compensate for differences that may exist between the map used on the sender and the map on the receiver. Such map differences can be caused by the receivers using an older map of the same supplier, or vice versa, or the receivers using a map from a different supplier.

Early studies in dynamic LRM included EVIDENCE and AGORA projects [2]. Now, it is mainly focused on AGORA-C [3]. These researches have high requests on information completeness of the geographic database, like standardized road name or road number definition. In addition, complex algorithm is not suitable for large-scale real-time data processing. On the basis of these researches, we brought forward a dynamic location referencing algorithm combining intersection attributes and link partition. The experimental results showed that the algorithm had good operating efficiency and high matching accuracy to meet the demands of practical applications.

II. Dynamic Location Referencing Method

Dynamic location referencing method relies on real-time access by the software to the original or translated values of the relevant attributes from its own digital map. This method will also be called “on-the-fly referencing”. On-the-fly means a location code will only be created when needed and discarded immediately after being decoded.

In recent years, AGORA-C project became the hottest issue in the field of dynamic LRM. AGORA-C improved the location point selection rules based on early researches, and solved too large encoding bytes problem by adopting compact encoding format.

AGORA-C uses three types of reference point to identify location, which are Location Point (LP), Intersection Point (IP) and Routing Point (RP). LPs mark the start and end positions of referenced location, IPs indicate intersections along the location, and RPs are added to guarantee the uniqueness of the referenced location in a certain range. The compact encoding format is divided into three parts. The first one is header, including version, language and some other basic information. The second one is overall information, explaining reference type, direction and some other general information. The last part is reference point sequence, listing the selected points and their attributes along the direction of the referenced location. Fig. 1 is an example of encoding one road section using AGORA-C [4].

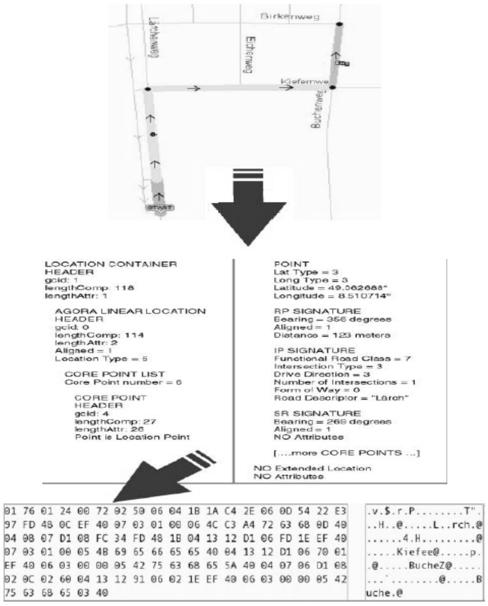

Fig. 1 AGORA-C encoding example

AGORA-C achieved good results in the experimental stage. The accuracy rate was more than 95% and the encoding bytes were lower than 50, which was the acceptable number recognized by experts in this area. However, AGORA-C had strict requirements on geographic database and needed standardized definition and complete road attributes indication. The GDF [5] map format widely used in European can meet these demands, but other map formats, like the ones used in some navigation products [6], have difficulties to reach such target. AGORA-C also defined complicated algorithm to guarantee unique reference point selection, which was very negative for real-time processing of massive data.

This paper uses two types of reference point. First, pick up intersection information which is relatively clearer and has smaller changes to set Intersection Point (IP). Then, set Road Link Point (RLP) according to link partition principle to describe the referenced location more detailed to ensure its uniqueness. The selection based on partition information which is defined by the original map database can decrease the complicated calculation and thereby effectively improve the efficiency.

The follow chapters will describe this dynamic LRM in detail by mainly explaining IP and RLP selection rules of road section reference type (also can be expanded to support a variety of types, such as POI reference).

III. Intersection Point Referencing

Due to road construction and other relative factors, there may be differences in road names, levels, lengths and even shapes among different maps (including maps from different suppliers or maps from the same supplier but of different versions). But the intersections, in particular the important ones are often of little change. Thus, at the very beginning of the research of dynamic LRM, some experts put forward the idea of ILOC (Intersection LOCation)[2], which encoded road sections by using the two bounding ILOC co-ordinate pairs, the road descriptor of the road section, and some other attributes like road class. Fig. 2 shows an example.

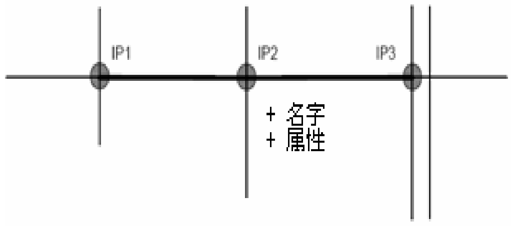

Fig. 2 ILOC encoding example

However experiments showed that this method did not have enough practicability. For complicated road conditions, numerous branches will cause a lot of crossings. If using above method, it will cost too many IPs. AGORA-C has already made some improvements, which provides that IPs are only be selected when the important attributes (like road name, road number, etc.) changing at the intersection [2]. As discussed above, this rule has excessive dependence on standardized definition and as a result is not conductive to wide applications.

With fully affirming the importance of intersections, we reference the road section by selecting mandatory IPs at the start and end extremities. This method on the one hand makes full use of the geographic information given by intersections and makes the road section describing manner more in line with the public habit, such as the north fourth ring road, Xueyuan bridge to Zhixin bridge. On the other hand, mandatory selection reduces the impact of other attributes.

Below is a more detailed explanation of IP selection rules.

A. *Selection Rules*

Rule 1: Select IP at the extremities of the road section to be referenced. There are three situations:

1) If this extremity is an intersection and there is no intersection of higher level within a certain area, this extremity will be selected as an IP;
2) If this extremity is an intersection but there is intersection of higher level within a certain area, the higher intersection will be selected as an IP and the offset from this intersection to the extremity will be recorded, as shown in Fig. 3;
3) If this extremity is not an intersection, using the alternative intersection within a certain area as IP, record the offset. If there is no replaceable intersection, this extremity will be selected as an IP and the offset will be set to the largest value.

Rule 2: For these connected roads at the IP, additional information will be recorded if there is any important attributes for these roads.

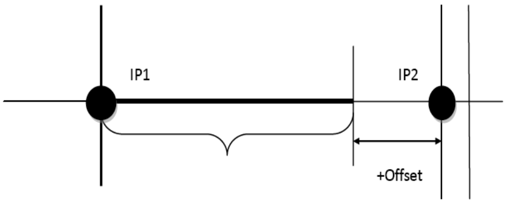

Fig. 3 Intersection encoding plus offset

B. Selection Algorithm

In accordance with these rules, the selection algorithm can be divided into the following four steps:

STEP 1: Generate the road network topology according to the original map data;

STEP 2: Determine if the extremity is a high level intersection, like complex crossing or important traffic hinge. If so, pick up the co-ordinate pairs and connected road attributes of this extremity to finish IP encoding, or to step 3;

STEP 3: Look for replaceable intersection in a certain area. If there is any, choose the nearest one and record its information and the offset to finish IP encoding, or to step 4;

STEP 4: Pick up the co-ordinate pairs of the extremity, and set the offset to the maximum value to complete IP encoding.

IV. Road Link Point Referencing

Road elements are always stored as a set of links in a digital map database. The partition principle is mainly according to intersections, which means one road is divided into several connected links by intersections along this road. If there is no intersection for a long distance, like on the freeways or national highways, the road may also need to be divided according to certain length limit or road geometry.

Based on the principle of road link partition, RLPs are set on each road link. As the partition of every road is some fixed information stored in the geographic database, the RLPs can be selected directly after reading information from the database. This helps effectively eliminating complicated calculation and improving the selection efficiency. For more complex road conditions, too many road links may be caused by large numbers of intersections or obvious shape changes. If only in accordance with the above idea, redundant RLPs may be created. Such problem can be effectively solved through adding appropriate length limitation into selection rules. When the length of a road link is less than a certain value, this road link will be put together with adjacent road link and RLP will be set on the joint road link.

Below is a more specific explanation of RLP selection rules and algorithm.

A. Selection Rules

In order to maximize the simplification of the encoding procedure and achieve more effective reference point selection, the selection of RLP is based on original map database as much as possible, and should neglect the impact of other additional attributes. Specific rules are as follows:

Based on the map database the encoder uses, RLPs are set at the middle of each road link of the referenced road section. If the length of one link is less than the decided value, it should be combined with adjacent links to select RLP as a whole.

As shown in Fig. 4, the dotted road section consists of three links. Two RLPs will be needed to indentify this section considering the length limitation.

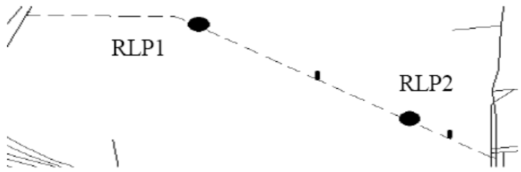

Fig. 4 RLP encoding

In the actual map database, a major road about 2,000 meters will generally be divided into three to four road links, and the less important road of the same length may consist of about ten links originally and about five links after length filter. Therefore, one referenced road section needs about three to five RLPs. This means that such rule can reduce selection calculation with no obvious increase in the number of reference points.

B. Selection Algorithm

The emphasis of RLP selection algorithm is the selection of midpoint of one road link. It can be divided into the following steps:

STEP 1: Partition the referenced road section into corresponding road links according to the division in the map database, and then deal with these links along the direction of the section, which always means the traffic flow direction along this road;

STEP 2: Calculate the length of the link. If the length is less than a certain value, read the next link and cumulate the length until it is greater than or equal to the defined value. Then pick up all the points describing the accumulation from the map database and form a point sequence to get ready for midpoint calculation;

STEP 3: Start with the first one in the point sequence, calculate the distance between adjacent points and accumulate the value until it is greater than or equal to half of the length of the referenced road section. If equal, encode the last cumulative point as the RLP; if greater, encode the midpoint of the last two cumulative points as the RLP. Then continue to step 2 until all road links have been disposed of.

V. Location Matching

Location matching, the decoding part of dynamic location referencing, is mainly reconstructing the referenced location on the receiver's map using a series of location points selected by encoding rules. Fig. 5 shows an example.

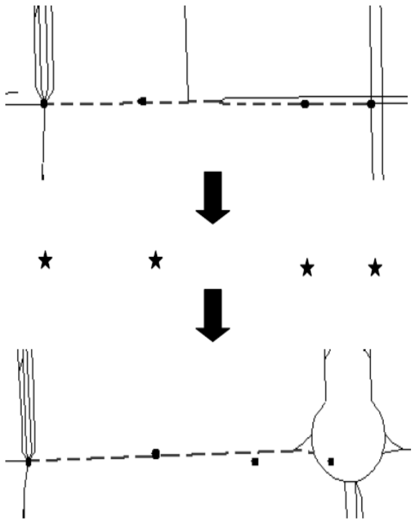

Fig. 5 Location matching example

The essential of location matching is the inverse encoding according to encoding rules. In specific implementations, user-defined decoding algorithms can be adopted according to different application demands. In this paper, the decoding algorithm is described as the following steps:

STEP 1: Use small-grid-based matching algorithm [7] to match the road link where selected reference points placed in the receiver's map database;

STEP 2: Check the connectivity of links got from step 1 based on the road network topology to get candidates;

STEP 3: If there are more than one candidate, using possible additional information, such as road name, road class, road length, etc. to do further filter;

STEP 4: Use IP to match the start and end position of referenced location to get final matching result.

VI. Experimental Results

The experimental map databases are from the same manufacturer and different versions, 07 version for encoder while 06 version for decoder. The main roads within the area from the secondary ring road to the fourth ring road at the northwest side of Beijing were chosen as experimental data. This area is about 120 km^2 and has 8998 road links. Approximately 200 road sections consisting of 1300 road links were picked for testing. The different rate between the two editions of maps is about 30%. The testing road sections highly reflected these differences, including differences in the number of links, the road shapes and some other aspects, and thus satisfied the comprehensive requirements. The overall test results are given in Table I.

TABLE I
Test Results

Item	Content
Test area	Main roads from 2^{rd} ring to 4^{th} ring in Beijing
Encoder map data	07 version
Decoder map data	06 version
Test road sections	200
Correct matching sections	192
Matching accuracy	96%

During the experiment, more than 95% of the IP encoding can be successfully completed by step 3 mentioned in III.B, only a few need step 4. This proved the feasibility of the algorithm described in III.B.

Table II is a further explanation of RLP matching accuracy. From the data in this table, we can tell that RLP selection has been able to reach a high matching accuracy by its own, and will even get a more satisfied result with the help of additional information. This proved the feasibility of the idea of RLP.

TABLE II
RLP Matching Accuracy

RLP matching	Accuracy
With no additional information	~90%
With additional information (road name, class, etc.)	~96%

Table III is the encoding efficiency comparison between the existing dynamic LRM and the new method we described here. The experimental environment is VC 2005 under Windows.

TABLE III
Efficiency Comparison

method	Operating efficiency (ms/100 road sections)
The method based on LP, IP and RP	219
The method based on IP and RLP	62

The new method does not have obvious advantage when dealing with a small amount of data. However, in traffic information service application, thousands or even ten thousands data will be needed to send out in as short as possible time because of real-time traffic condition updating in a wide range. Existing method will inevitably cause information delay so as to affect the real-time capability. The method we suggested can obviously provide better operating efficiency.

From the above results, we can see that the dynamic LRM based on intersection and link partition has high feasibility and practicability because of its high matching accuracy and operating efficiency.

VII. Conclusion

Dynamic location referencing method is the inevitable trend of the development of location referencing, due to its flexibility, high accuracy and better difference shield among map databases. One of the hot issues in this field is how to make it more efficient and more concise.

A dynamic location referencing method was put forward, which paid attention to both road link structure and intersection attributes through putting intersection points together with road link points. The accuracy and efficiency of this method has been proved by some experiments.

Of course, there are still some insufficient of this method. For example, the accurate ramp link matching on complex intersections, further reduction of encoding bytes, and so on.

Further researches will work on above lacks, and extend the experimental scale to better promote the development of dynamic location referencing method in both feasibility and practicability.

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