DYNAMIC REAL-TIME ROUTE RE-PROGRAMMING AFTER DISTRACTED FROM SELECTED ROUTE FOR EMBEDDED NAVIGATION SUPPORTED BY ROUTE AVAILABILITY AND CENTRE

Zhang Dong

Xian Research Institute of Surveying and Mapping,
mid 1 of Yanta road, Xian, P.R.China, 710054
Navgrid@163.com

Abstract. In real time vehicle dynamic navigation, route programming is the basis work. But in most cases, there are always many situations of distracting from selected routs after the original programming and a group of routes is indeed given through re-programming from starting point PA to end point PB. The time cost in real time re-programming is key metric. The computation trap will arise after longer re-programming time, because new distracting state from selected route has appeared. Here, the spring term of distracting from selected route and the mid-point choice (CA) algorithm are put forward. At the same time, based on route availability and measurement models advanced by us in another article, this paper has constructed a dynamic mechanism upon on network communication chain to support real time vehicle navigation, which includes road traffic information collection, data updating, processing, management, dynamic information broadcasting, availability route re-programming, etc.. A route availability measurement model using probability method and a comprehensive metric F for analyzing and comparing route availability are presented to address the dynamic change in road network. A new route re-programming algorithm called REF-algorithm is designed. Unlike other current algorithms, it re-programs a new route after distracting from the selected route within several seconds based on real-time road traffic information changed along with time segment in stead of the static prefab road data. Comparison of the REF-algorithm and traditional route programming algorithms such as Dijkstra shows that the REF-algorithm has lower time cost and can meet the real-time navigation requirement.

1 Introduction

The primary navigation flow includes destination setting, route programming, real-time navigation, re-programming computation when distracted from the given route and continuation of navigation. The route is the major factor throughout the whole flow. There are more than 15 representative types of different route programming algorithms used currently (Gillieron Pierre-Yves, 2003). For calculating the shortest path between two points, Floyd’s algorithm is used commonly with a time complexity of $O(n^3)$. The double Sweep Algorithm can resolve the top-k routes between one node and others. The Bellman-Ford-Moore Algorithm, though with a better time complexity, is not good in practice (Guenther Retcher, 2006). A* algorithm is the most widely used heuristic algorithm. In the searching period, the most possible next point is selected firstly in calculation for reducing calculation times and improving efficiency. In navigation systems, the Dijkstra algorithm, brought forward in 1959, has been considered as one of the most efficient algorithms for finding the shortest path so far (Jagadeesh G. R, 2002). The shortest distance between a node and all of others in a graph can be calculated with a time complexity of $O(n^2)$, in which n is the number of nodes.

Often, in real route programming, above algorithms are mathematically meaningful and we should consider many specific factors, such as traffic restriction rules, turn-left forbidden presentation, across delay, traffic jam and other accidents, roads classification method, etc.. The issue rests with that only the original programmed route is insufficient to fulfill whole navigation. In real navigation, the route just is an option, we can drive according to actual situations and own desires. No one is restricted by given route and re-programming after distracting from selected route is frequent.

For numerous drivers, more applicable routes are achieved through many times of re-programming. Due to a series of errors, such as late lane changes, inappropriate traffic management, real time passing situation, etc, always driver can not get available route (Andrew J. May, 2003).The experiment shows: (1) In navigation process, it is not enough only to give out a original route to driver without re-programming. (2) How to construct the relationship between route re-programming algorithm and the availability model is essential to be studied. (3) It is necessary to construct background centre for obtaining dynamic traffic conditions of a route segment at different time and broadcasting to mobile navigators. Some navigation works with centre support were reported, but no dynamic information was used (Hunaiti Z., 2006). Most of the studies have focused on data structure and algorithms design, such as dynamic indexing mechanism, parallel algorithm based on double buffers, basic route programming algorithms, etc. This paper study re-programming issue with centre support and availability model, although it is very difficult to be established because of embedded environment, time cost, different demands, frequent road changing and traffic conditions.

2 Original Route Programming

For a larger geographical area crossing thousands km, it becomes difficult strongly and necessary to access through classification and partitioning blocks. In Figure 1, the scope of China is about east longitude 70-140 degree, north latitude 20-55 degree. The navigation data of background, road net, topological data is mass. We usually partition the area into three parts, starting area (S area), end area (E area) and the middle area. P displaying as a bold black line denotes the selected route with the direction from the upper to the lower. S and E area maybe cover 50-100km and the middle area covers 100-5000km normally.

The whole flow is shown in Figure 2. The navigation algorithm includes: (1) Original

Figure 1. Three areas in navigation programming

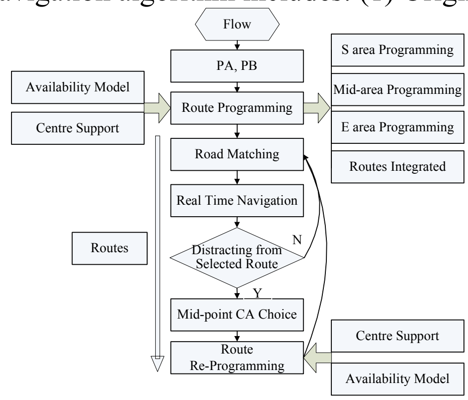

Figure 2. Whole navigation flow

route programming consists of three parts with different achievement details, and the original route is integrated by three sub-routes. In S and E areas, the topological data of all road classes is employed to route programming. In the middle area, only the roads with higher classes are considered in order to reduce the amount of data required. (2) In road matching and navigation course, the distracting route synchronous check is run circularly. When distracting from the selected route is detected, the system run into step 3; (3) Route re-programming is the main real-time mobile computation which should choice suitable mid-point CA on the existed route firstly, then the issue is changed to compute and achieve the new sub-route from current point to CA. Because of relative small computation area, the re-programming speed can be ensured effectively through importing CA. (4) In original programming or re-programming, the availability model and background centre are employed to support real-time characteristics and dynamic navigation.

3 Dynamic Real-time Re-programming after Distracted from Selected Route

The dynamic characteristic of route programming includes two parts: dynamic real-time re-programming after distracted from the original route and dynamic traffic information support by background centre to satisfy availability demands.

3.1 Check of Distracted from Selected Route

The condition of distracting from selected route (short as Con_DSR) is restricted with four factors: Current Position Precision (CPP), road Accuracy of digital Map(AoM), Selected Route(SR), and comparison value of Matching Buffer(MB). We can give the definition of Con_DSR as follow:

$$Con\_DSR = f(CPP, AoM, SR, MB) \tag{1}$$

Here: f( ) is a logical operator, maybe includes comparison, plus, and, etc., and takes consideration of the four factors. There are many channels to obtain current position (Duffet-Smith, P.J, 2004, Kong, H. 2004), for example, GPS, differential positioning, GSM location, dead reckoning, etc. Table 1 shows the different accuracy of CPP which will influence the Con_DSR directly.

Table 1. Main positioning ways and relative accuracy

Positioning method		Observations	Accuracy
GNSS	GPS DGPS	y, x, z	± 6-10m ± 1-4m
Cellular Phone Positioning(GSM)	Cell ID Solo matrix	y, x	± 150m-35km ± 50-100m
WLAN Positioning	IMST ipos	y, x, z	± 1-3m
RFID positioning (active landmarks)		y, x, z	± 6m
Bluetooth(active tooth)		y, x, z	± 10m
Dead Reckoning	Point Research DRM-III Dead Reckoning Module	y, x z	± 20-50m/km ± 3m
Barometer	Vaisala Pressure sensor PTB220A	z	± 1-3m

The road Accuracy of mobile Map (AoM) lies on the digital navigation map. In general, the AoM is fixed in data production process by special company, and it is always within 15-20m. The accuracy of Selected Route (SR) depends on AOM, because the SR is achieved through roads computation. The fourth metric, comparison value of Matching Buffer (MB), is the most pivotal factor which determines the real navigation effects. The value of MB should be different in varied road environment, bigger in rural road and smaller in city zone. After a large number of experiments, we define alterable initialization value of MB as 30m which can satisfy road matching demands always.

3.2 Choice of Mid-point on Existed Route and Possible Computation Traps

Distracting from the selected route arises at any time in real navigation process, so real-time route re-programming is very essential. Whole route algorithms include route programming and real-time re-programming. Figure 3 shows the re-programming process after distracting from the selected route.

Here, P denotes the selected original route displayed as the bold black line from the upper left to the lower. The speed of re-programming is very important. Suppose a vehicle distract the route P at crossing A towards B. Since crossings B, C and D are very close, perhaps B would be missed when a new programmed route is been calculated, thus a new distracting arises again. This can happen again and again, and cause an endless re-programming, and computation traps arise. Furthermore, the algorithm can be modified with some skills. We can select a temporary point F on P between A and E, and then the route programming between A and E can be reduced to that between A and F, resulting in a shorter distance and less computation which will improve the computation speed. However, the choice way of the mid-point F needs a lot of experiments to satisfy the real-time and availability demands. Under city roads environment, we generally choose the point F within 10 km to current position.

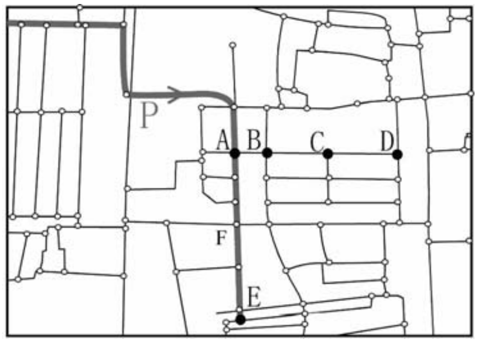

Figure 3. Re-programming after distracted from selected route

3.3 Route Availability Model and Employment Mode in Route Re-programming

In foregoing works, we have designed the route availability and relative measurement models which are appeared in another article (Zhang Dong 2007) and indexed by EI. $RR_{k(i)}^{g(j)}$ (PA, PB) is used to denote that there are k programmed sub-routes from PA to PB in actual navigation, and the current i^{th} sub-route consists of g segments, and the current segment is the j^{th}. The i^{th} sub-route will not be available if any RR_i^j of the segments can not be passed through.

The conjunction relation among route segments, expressed as C, is actually represented by the connecting point between two route segments, usually an intersection. Therefore, a route can be presented as a series of segments, separated by intersections. Let C_i^j be the conjunction between road segments j to j+1 in the sub-route i. When j=g, it denotes that the last segment of sub-route i is connected with the first segment of sub-route i+1.

Here, route segment RR_i^j and connection relation C_i^j are independent. Suppose the abnormal-passing probability of route segment RR_i^j is $f_s(RR_i^j)$, and that of conjunction C_i^j is $f_r(C_i^j)$. Then, the Route Availability based on probability model (RA) can be presented as:

$$RA(PA, PB) = \prod_{i=1,j=1}^{k,g} (1 - f_r(C_i^j)) \cdot \prod_{i=1,j=1}^{k,g} (1 - f_s(RR_i^j)) \qquad (2)$$

The acquiring mechanism of $f_r(C_i^j)$ and f_s (RR_i^j) is complicated. The probability data comes from: (1) Integrated experience data of $f_r^{'}$ (C_i^j) and $f_s^{'}$ (RR_i^j) based on the historical statistical data in certain period of time. (2) Traffic condition information broadcasting systems.

The distance L is the major criterion when selecting the next node in route programming. In real computation, the L should be adjusted according to L-Scale which is determined by the route programming modes and the dynamic information of availability demands. Actually, L-Scale is a changing factor of distance L in real computation. In most programming situation, L-Scale is the route segment availability metric RA (CA, PB). RA (CA, PB) is a special data set updated dynamically with the time and can be accessed through the link to the route segment ID mentioned above. In actual computation, we replace L with integrated comparison metric F, and F is represented as:

$$F=L* RA (CA, PB) \qquad (3)$$

Here: when $f_s(RR_i^j)$ 15%, F =L*100%; when $f_s(RR_i^j)$ 85%, F =∞. Take as an example, the transformation from road segment length to metric F according to route availability data in Table 2. For the road of ID 8910, the length used in the programming algorithms is changed from 789.2 to 1373.2 at 6:00-7:00pm. The dynamic availability data comes from availability experience data base in the centre through communication chain, according to special broadcasting rules.

Table 2. Road segment length transform in route programming

Road ID	Segment class	L(length)/m	f_s (RR_i^j)	Time/day	F
4729	freeway	2367.5	0.05	6:00-7:00 pm	2367.5
1097	third class	530.9	0.23	6:00-7:00 pm	653.0
8910	third class	789.2	0.74	6:00-7:00 pm	1373.2
3971	fifth class	210.1	0.10	6:00-7:00 pm	210.1

3.4 Dynamic Information Support by Background Centre

Figure 4 shows dynamic route programming and navigation framework with background centre support, unlike independent navigator without any real time information support. Here, there are three parts: Unit I, Unit II, and Unit III which communicate each other via the channel following GSM or CDMA protocol.

Unit I achieves dynamic traffic collection and uploading. The main information resources with obvious dynamic characteristics are collected through vehicle uploading. Primary comments are Current discrete Status of present road segment of vehicle defined as CS ranking as discrete three levels, fluent passing, weak-jam and strong-jam. Only the state of strong-jam is possible to be reported to the centre and the relative road weight is modified and employed in route re-programming. The route availability comes of the real-time dynamic information.

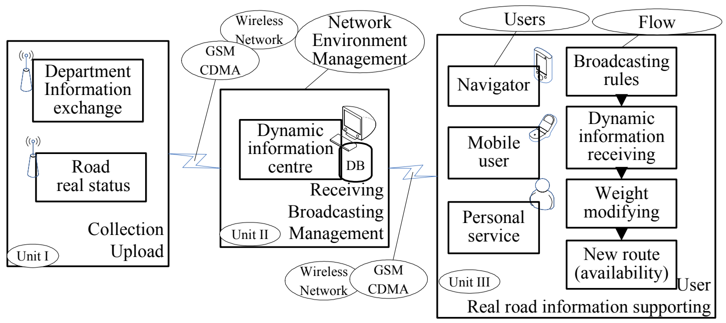

Figure 4. Dynamic data mechanism based on background centre

Unit II is dynamic information management centre for data receiving, data management, and broadcasting. A special updating DB is constructed to manage dynamic traffic information mentioned above. Here, the information must be integrated conformably and statistic experiment data is produced for use. At the same time, the information is downloaded to object vehicle according to time and spatial scope rules.

Unit III is user client to meet real navigation based on dynamic road traffic data. The user types include vehicle navigator, mobile user and personal location service. For any application, dynamic information receiving in term of broadcasting rules, weight modifying and route re-programming with availability form integrated dynamic flow.

Dynamic Information Acquisition Chain mainly includes the collection of CS which is complicated correspondingly. The variable CS is evaluated as 1, 2, or 3, which mean fluent passing, weak-jam, or strong-jam. In fact, only the situation of CS=3 possibly can be reported to the centre through a simple button on the screen. Historical statistical information for some route segments in certain period of time, provided by offices and many vehicles, need be processed as regular experience data through statistics and abstract method and put into special dynamic information data bases. The data must be analyzed, and generalized corresponding data model before use. The experience data combined with mobile map data to ensure availability computation. The final experience data will be transformed to the abnormal passing probability $f_s(RR_i^j)$ of route segment RR_i^j, and the $f_r(C_i^j)$ of conjunction C_i^j, in a certain period of time. Frame format meeting GSM or CDMA communication protocol is defined as:

$$\$CS, FType, <DATA> * hh <CR> <LF> \quad (4)$$

Here, " \$CS" denotes frame head flag; " FType" denotes frame type of 5 bytes

ASCII code <DATA> is binary data segment composed with CSpackage, every character is from 0x30 to 0x3F "*" means interval symbol "hh" is check sum; <CR><LF> present enter and new line.

Traffic information broadcast system provides real time traffic jam information or other road conditions. The data broadcasting adopts similar communication protocol format with data uploading.

Generally, a vehicle drives along to the selected route, and will receive broadcasting package one time for a road segment, when the segment on the route holds relative CS data at a certain time segment in the centre DB and synchronously the segment is within the scope of 10 km from current vehicle position. The scope of 10 km comes from a lot of test results. Experiment shows no system barrage arise when parallel 1000 vehicles are online synchronously.

3.5 REF-algorithm

REF-algorithm, based on the above dynamic mechanism and integrated metric F, is shown as:

Input: {PA, PB, $f_s(RR_i^j)$,$f_r(C_i^j)$}; Output: Real-time programming Route: RR;

```
Begin  {  CA=PB;
   L1:
   ReadToMem(CString &name2p5, CBitmap* Pointer1);  //Read map to memory;
   ConstructNodeSet(Struct &S1,&S2); //Set up a temporary node set S1 and a
     permanent node set S2;
   S1=null; S2={all nodes};
   BroadcastJudgement(Bool &SegofRoad);//Segment holds relative dynamic
     information or not;
   ReceivefromCentre(Struct &EDpackage); //Dynamic information;
   L2:
        SearchNode(Cstring &P1 from S2);//A new extended node P1 from S2;
        ConstructMetric(long* F); //Availability metric F with received data;
        If(P1• S1)and(F<value of P1 in S1) then Replace P1; //Replace P1 if it has
          existed in S1 with smaller F;
        If(P1• S2) then Delete P1;//Delete P1 if it is in S2;
        If P2=null then RR=S1; //Get route RR;
        else  goto L2;
   ……
   When Con_DSR==true then Re-programming: //Distracted from selected route;
   SearchMiddleNode(Cstring &CA, &RR); // Select a temporary point CA on RR;
   SetDestination(CString &CA); //Set CA as temporary destination point;
   Goto L1;
   …… }
End
```

4 Experiment and Analysis

The experiments are conducted by means of an embedded navigator Nav-2 which was developed with above algorithms by our lab. Nav-2 consists of 64MB SDRAM, and a 512MB CF storage. The CPU is a 206MHz Inter Strong ARM SA1110 processor.

The Dijkstra algorithm is suitable for single programming mode. REF-algorithm can be used for mixed modes to meet user's multi-demands. The experiment was carried out at 3 p.m. Two cars equipped with navigators implementing the Dijkstra algorithm and our REF-algorithm, respectively were used in the experiment. Hence, the route had to be re-programmed many times because of un-availability and distracting in the real navigation. In the experiment, the route was re-programmed ten times when driving along diagonal direction in Beijing. The second car using our REF-algorithm was able to reach the destination along ring road with one route re-programming and 45 minutes ahead of the arrival of first car.

Figure 5 shows the comparison of route programming time. It is obvious that the optimized REF-algorithm, which can meet actual requirements, is preponderant over the traditional Dijkstra algorithm. For example, the time of programming from the center of Beijing to Guangzhou city, more than 2000 km, is only a little bit more than 5 seconds. It is necessary to point out that the cost of computation time is related to not only the distance, but also the location of destination. For example, a route destined to the suburb of Guangzhou and the one to the city of Guangzhou will have quite different computation time costs though the distances won't have much difference. The road condition and topological data in the city area are much more complex. The computation time cost will increase tremendously.

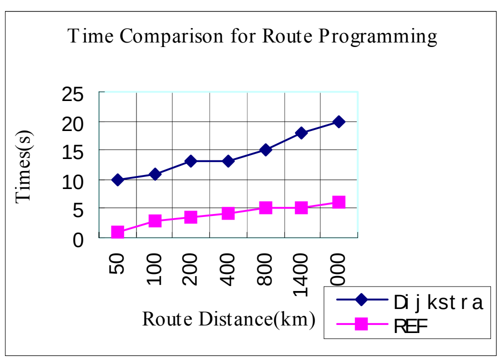

Figure 5. Speed comparison of two algorithms

5 Conclusion

This paper has researched a new dynamic navigation mechanism, including dynamic route programming and re-programming algorithm when distracted from selected route, satisfying availability demands supported by background centre with dynamic traffic information. The acquisition information, came from two different ways, can be effectively transferred to centre, and transformed to statistical experience data stored in updating DB. According to special rules and protocol, the dynamic passing information can be broadcasted to user clients and dynamic navigation is realized. The method presented in this paper for measuring road availability is practical. REF-algorithm, based on the road availability and centre, achieves a better navigation performance for smooth passing in real situation and shows better computation efficiency. But we have to know that road availability is only one metric of rationality which is more complicated and involves more factors to be taken into consideration. Our future research will focus on models and algorithms with more factors in real route navigation, such as segments availability data collection and management.

References

1. Andrew J. May, Tracy Ross and Steven H. bayer. Drivers' Information Requirements when Navigation in an Urban Environment. Journal of Navigation, 56, 89-100 (2003).
2. Duffet-Smith, P.J. and Craig, J., Matrix, and enhanced Satellite positioning, 5th IEE international conference on 3G mobile communication technologies, Savoy palace, London, UK, 18-20 OCTOBER 2004, 4pgs. (2004).
3. Gillieron Pierre-Yves,Konnen Jeff, Enhanced navigation system for road thematics, Proceedings of the 3rd Swiss Transport Conference, Switzerland (2003).
4. Guenther Retcher, Allison Kealy, Ubiquitous Positioning Technologies for Modern Intelligent Navigation Systems, Journal of Navigation, 59, 91-103 (2006).
5. Hunaiti Z.,Garaj V. and Balachandran w. A Remote Vision Guidance System for Visually Impaired Pedestrians, Journal of Navigation, 59, 497-504 (2006).
6. Jagadeesh G R, Srikanthan T. Heuristic, Techniques for Accelerating Hierarchical Routing on Road Networks, IEEE Transactions on intelligent Transportation Systems, 3(4), 301-309 (2002).
7. Kong, H., Kwon, Y. and Sung, T.. Comparison of TDOA triangulation solutions for indoor positioning, Papers presented at the 2004 international symposium on GNSS, Sydney, Australia, 6-8 December, 2004, 11pgs. (2004).
8. Zhang Dong, Qian Depei, Liu Ailong, et al. Study on Embedded Vehicle Dynamic Location Navigation Supported by Network and Route Availability Model [C/J]. Lecture Notes in Computer Science, Vol.4847, Speringer-Verlag Berlin Heideberg, Nov. 2007: 713-722. (2007).