DEVELOPMENT OF A HIGHLY ACCURATE NAVIGATION SYSTEM FOR FORESTRY VEHICLES AND WORKERS

Tetsuhiko Yoshimura and Naoto Hasegawa
Kyoto University, Japan
yoshimu@bre.soc.i.kyoto-u.ac.jp; hasegawa@bre.soc.i.kyoto-u.ac.jp

Abstract: *Map matching has been widely used for car navigation in Japan. However, it requires complicated geographical data, and requires a map equipped with such data for forest roads or mountain trails. Therefore, we suggested a simplified map matching method that can be easily or temporally used for forest roads or mountain trails. We tested the algorithm of the method through field experiments. The results showed that the method worked well on condition that appropriate radius of the movement limit circle was used. It was suggested that the appropriate radius of the movement limit circle should be changed dynamically according to moving speed.*

1. Introduction

Global Positioning System (GPS) technology is now widely used for navigation and surveying. GPS is also essential for supporting logistics in forestry. Despite removal of Selective Availability (SA) in May 2000, there is the error in GPS positioning without a differential GPS is 10-20 m (Tsuchiya and Tsuji 2001). which could be temporally larger due to signal degradation and multipath. To reduce positional errors, it is known that differential GPS (DGPS) is useful, but broadcast differential corrections can not always be available in mountainous areas in Japan. The objective of this study is to develop a highly accurate navigation system for forestry vehicles and workers. This system navigates forestry vehicles and workers very accurately without broadcast differential corrections based on the assumption that they walks only on forest roads or mountain trails. In this study, map matching and some filtering methods were used to realize highly accurate navigation by using autonomous GPS.

Map matching (Kakumoto and Kiwi-W consortium 2003) has been widely used for car navigation in Japan. This method is based on the idea that cars run only on roads, and positions of cars are forced to move to the most probable point on the roads considering many factors. However, it requires complicated geographical data, and it is not easy to make a map that is equipped with such data for forest roads or mountain trails. In addition, it often requires some additional information obtained by using sensors such as gyro sensors or acceleration measurement units. Generally, roads or trails in mountains are much simpler than road networks in cities. Therefore, we believe that a simplified method of map matching can work well for such roads or trails. On the other hand, there are many hairpin curves in mountainous areas, and it is important for the simplified method to fully match such a condition. This method can be used not only for vehicles or workers navigation but for carriage control because it does not require complicated geographical data. Therefore, we developed a simplified method of map matching and evaluated it through field experiments.

2. Materials and methods

2.1 Study site

Field experiments were conducted in Kamigamo Experimental Station, Kyoto University, which is located in the city of Kyoto. This forest station has an area of 47 ha, in which there are forest roads with width of approximate 2 m.

2.2 Map structure of road networks

The data set of road networks on the map is very simple and can be easily made. An example of a road network is shown in Figure 1. There are 5 nodes and 6 links in this example of the road network. The data set representing this road network is shown in Figure 2, and coordinates of all nodes and their links are designated in two text files.

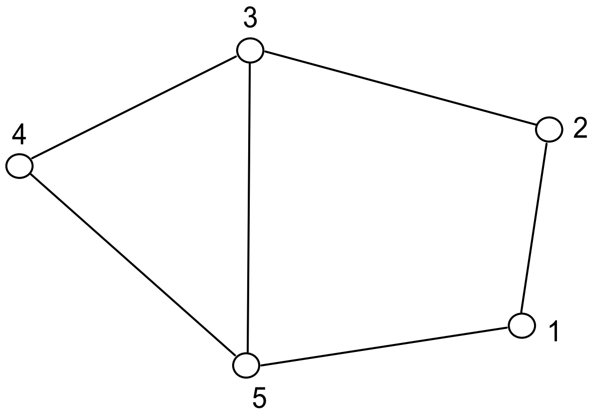

Figure 1: Example of a road network

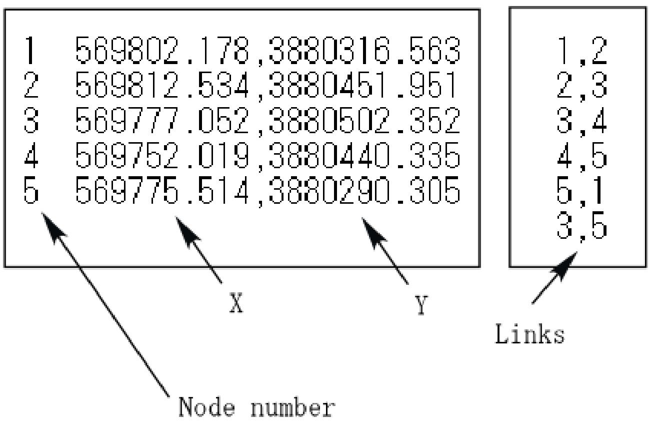

Figure 2: Coordinates of all nodes in UTM (left) and their links (right)

2.3 Algorithm of map matching

The simplified method of map matching is shown in Figure 1. In this figure, the point ‘O’ is the present position of a moving object. The circle in this figure shows the movement limit circle, inside which the moving object is expected to be after specific time. The radius of the movement limit circle can be set arbitrarily. For example, if the next point measured by GPS falls at the points of b or c in this figure, it will be forced to move to the points of b’ or c’, respectively. That is, the next point measured by GPS is always forced to move on the line representing a road alignment by using the shortest way. However, if the next point measured by GPS falls out of the movement limit circle, it will be forced to move to the nearest point where the road line and the movement limit circle are crossing. For example, if the next point measured by GPS falls at the points of a or d in this figure, it will be forced to move to the points of a’ or d’, respectively.

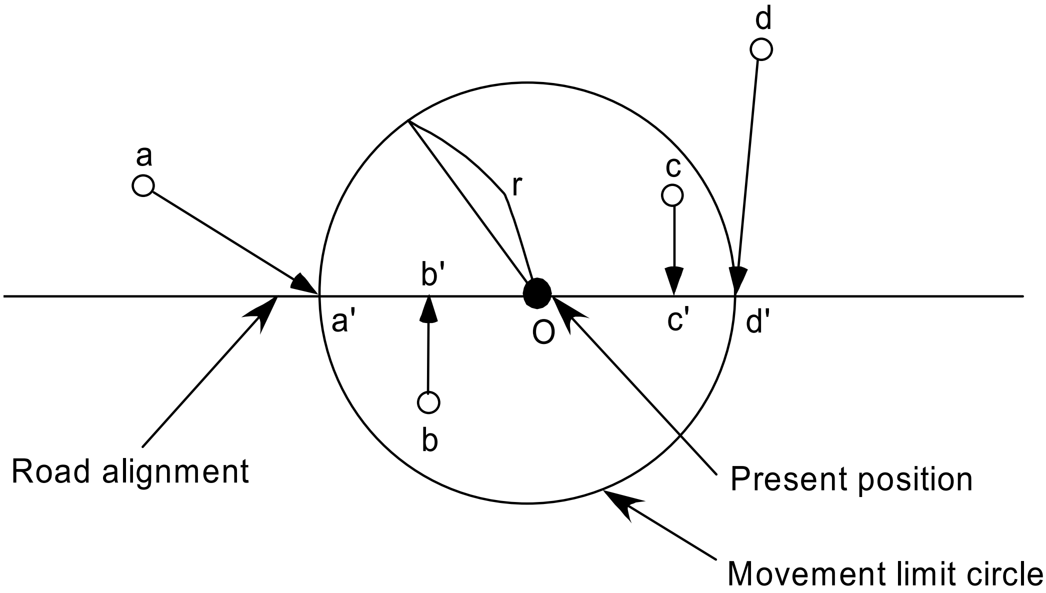

Figure 3: Simplified method of map matching

2.4 Field experiments

In the field experiments, which were conducted on 7 August 2003, two types of GPS receivers, that is, GPSMAP 76S (Garmin) and Pathfinder Pocket (Trimble), were used. Two testers with these GPS receivers walked along the circular road in the forest. A car with these GPS receivers also ran along the same road at a speed of 10 – 20 km/h. The logging intervals of GPS positioning were 2 and 1 seconds for GPSMAP 76S and Pathfinder Pocket, respectively. In the field experiments, the radius of the movement limit circle can be set at 1, 2, 3, ... and 25 m.

3. Results and discussion

Table 1 shows the results of field experiments. According to this table, GPSMAP 76S gave better results than Pathfinder Pocket. Actually, GPSMAP 76S has its own filtering method and this worked well with the combination of the method of simplified matching.

Table 1: Summary of the field experiments

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	×	×	×	×	×	×	×	×	Δ	Δ	○	○	○	○	○	○	○	×	×	×
B	×	×	×	×	×	×	×	×	○	○	○	○	○	○	○	○	○	○	○	○
C	×	×	×	×	○	○	○	×	×	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ
D	×	×	×	×	×	×	○	○	○	Δ	Δ	Δ	Δ	Δ	×	×	×	×	×	×

Note: Numbers from 1 to 20 show a radius of the movement limit circle in (m).
Legends: A, car with GPSMAP 76S; B, walk with GPSMAP 76S; C, car with Pathfinder Pocket; D, walk with Pathfinder Pocket.
Legends: ○, success; Δ, small failure; ×, failure.

Figure 4 shows the results of map matching when GPSMAP 76S was used for walking. This is a successful example of the simplified method of map matching with the radius of the movement limit circle was 10 m.

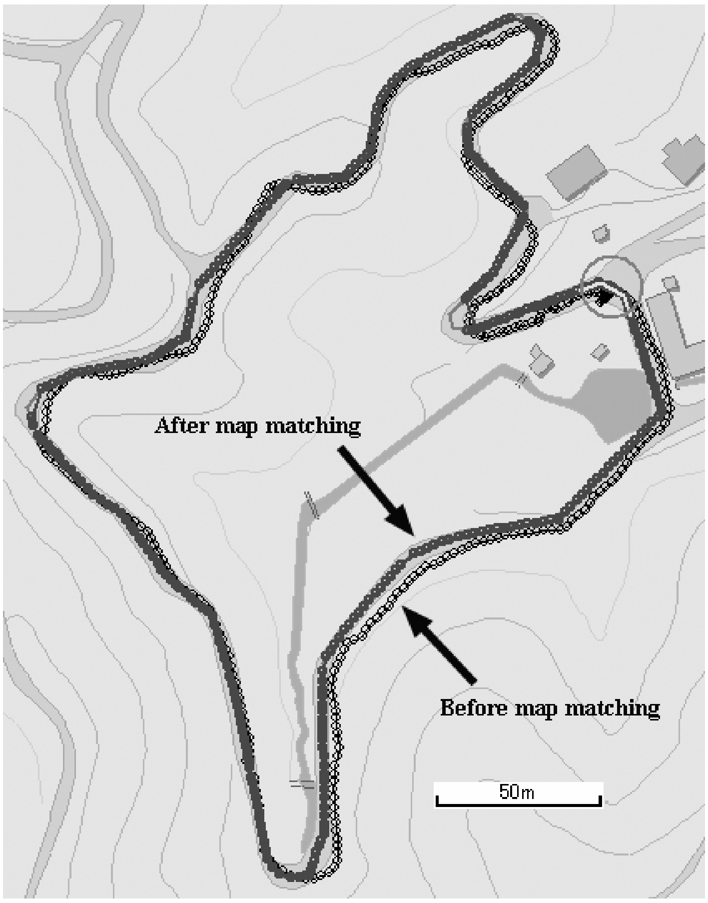

Figure 4: A successful example of the simplified method of map matching with the radius of the movement limit circle of 10 m applied for walking with GPSMAP 76S

Figure 5 shows a typical problem of the simplified method of map matching. When the radius of the movement limit circle is too long, this method did not work as shown in the lower part of this figure. In this case, GPSMAP 76S was used on the car with the radius of the movement limit circle of 25 m.

Another problem is that the points after map matching are greatly behind the points measured by GPS when the radius of the movement limit circle is too short as shown in Figure 6. In this case, GPSMAP 76S was used by the tester walking on the forest road with the radius of the movement limit circle of 7 m.

As a result of field experiments, the simplified method of map matching worked better with the combination of GPSMAP 76S, which has its own filtering method and produces very few unusual measured points. The simplified method of map matching worked well on condition that appropriate radius of the movement limit circle was used. It was also suggested that the appropriate radius of the movement limit circle should be determined dynamically according to moving speed. Actually, the appropriate radius range of the movement limit circles was different between a walker and car.

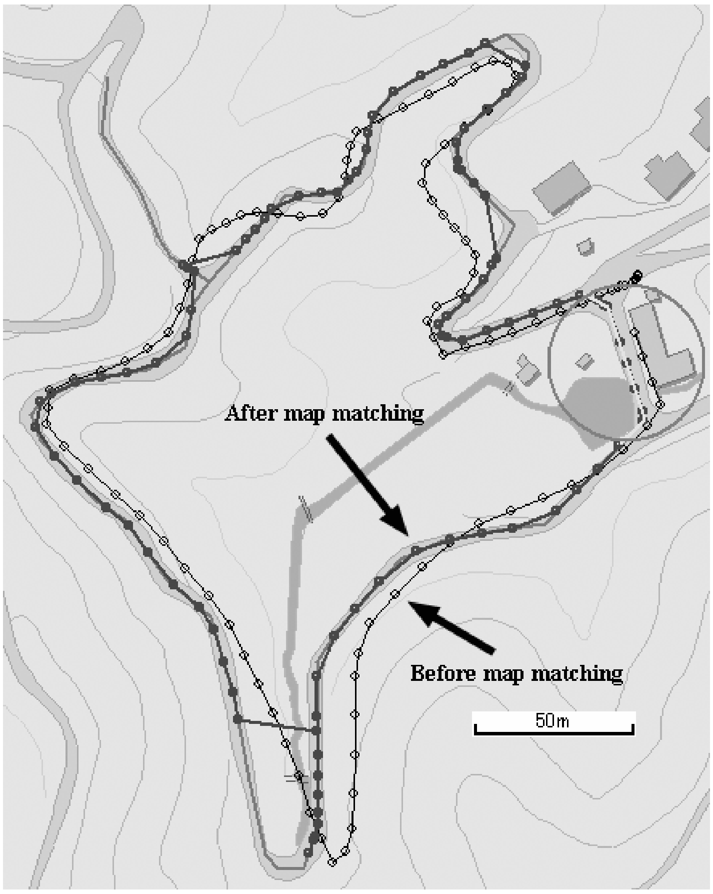

Figure 5: Result of the simplified method of map matching with the radius of the movement limit circle of 25 m applied for driving with GPSMAP 76S

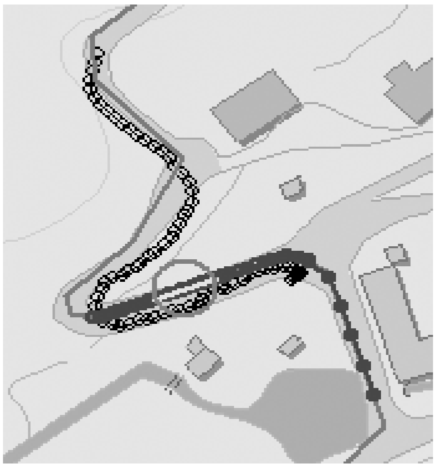

Figure 6: Result of the simplified method of map matching with the radius of the movement limit circle of 25 m applied for walking with GPSMAP 76S

4. Conclusions

The objectives of this study were to develop a simplified method of map matching and to evaluate it through field experiments. The result showed that it worked well for both a walker and car on condition that appropriate radius of the movement limit circle was used, so the developed method is useful to forestry vehicles and workers, which move on forest roads. It was also found that the radius range of the movement limit circles of GPSMAP 76S was larger than that of Pathfinder Pocket. To make the simplified method work better, the results of field experiments suggested as follows:

- Simplified method of map matching should be developed for a specific GPS receiver because GPS receivers have performance that is different among its model. GPSMAP 76S is a good choice when considering cost and performance.

- Differential GPS (DGPS) can be combined with the developed system, but it is important that the system work without DGPS because differential corrections often cannot be received.

- The appropriate radius range of the movement limit circle differs according to types of GPS receivers and moving speed.

- The radius of the movement limit circle should change dynamically according to moving speed.

- If the present point after map matching is far from the point measured by GPS before map matching, the present point should be forced to be reset.

Further development will be continued to improve the developed method based on the results of this study.

5. References

Tsuchiya, J. and Tsuji, H. (2001) New plain GPS surveying (in Japanese), 449 pp, Japanese Association of Surveyors, Tokyo (in Japanese).

Kakumoto, S. and Kiwi-W consortium (2003) Car navigation system - open data structure and its utilization. 191 pp, Kyoritsu-shuppan, , Tokyo (in Japanese).