Improvement of Autonomous GPS Accuracy with the Crisscross Arrangement of Low-cost GPS Receivers

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Abstract:
In Japan, many borders of forest ownership still have not been determined, and such undetermined borders make it difficult to construct forest roads or spur roads and to harvest trees efficiently. As a result, the Japanese forest industry is suffering from high production costs. Therefore, it is necessary and urgent to make more forest/spur roads and to reduce the production cost by determining the borders of forest ownership. The GPS is a promising tool to determine such borders more efficiently than conventional surveying methods. However, GPS receivers for surveying are still expensive for the low-profitable Japanese forest industry. That is why low-cost GPS receivers for navigation are often used instead of high-cost ones, but the autonomous GPS accuracy is not always acceptable when low-cost GPS receivers are used for this purpose. The only solution to improve the autonomous GPS accuracy is to average the result of a long-time GPS measurement, but a longer GPS measurement clearly leads to the low efficiency of border determination with the GPS. Therefore, we propose a new technique to improve the autonomous GPS accuracy with the crisscross arrangement of five low-cost GPS receivers. The advantage of this method is to obtain five times more positioning results to be averaged for higher accuracy than the conventional method. In this study, we conducted a field test in the Sanbe University Forest, Shimane University to determine the autonomous GPS accuracy with the crisscross arrangement of low-cost GPS receivers. The results of the field test showed that the autonomous GPS accuracy was improved by averaging the measurements of five low-cost GPS receivers in crisscross arrangement.

Keywords: GPS, crisscross arrangement, low cost

1 Introduction

Many borders of forest ownership still have not been determined in Japan, and such undetermined borders make it difficult to harvest trees efficiently as well as to construct forest roads or spur roads. As a result, the Japanese forest industry is suffering from high production costs. Therefore, it is necessary and urgent to make more forest/spur roads and to reduce the production cost by accelerating the determination of the borders of forest ownership. However, it is well known that forest canopy adversely affects positional accuracy of GPS measurements due to signal attenuation, and this has been a major obstacle of GPS measurements under forest canopy. Therefore, many studies have been conducted to determine the performance of GPS positional accuracy under forest canopy. Martin et al. (2001) evaluated DGPS positional accuracy and precision on Irish forest roads with typical peripheral canopies and discussed the relationship between position dilution of precision (PDOP) and the percentage of open sky. Næsset (1999) showed that the accuracy of GPS positioning was significantly higher with the 12-channel GPS receiver than with the 6-channel GPS receiver and was significantly higher with the combined use of the C/A code and carrier phase than with the use of the C/A code only. Kobayashi et al. (2001) evaluated five GPS receivers' performance by comparing the positional accuracy of the autonomous GPS, real-time DGPS, and carrier phase GPS. Results indicated that the autonomous GPS and real-time DGPS produced positional errors of 15.4–48.6m and 2.7–21.7 m, respectively, which were based on the condition that SA was on. Sawaguchi et al. (2001) discussed the effect of stand conditions on positioning precision with real-time DGPS and found factors that affected positional precision by using multiple regression analysis. Mori and Takeda (2000) showed the effects of SA removal on positional accuracy of the DGPS. In most of these studies, high-end GPS receivers that work well even under forest canopy were used, but they often cost too much for forest owners and managers in Japan, who are struggling with the difficult market environment. In fact, high-end GPS receivers normally cost more than USD 3,000-10,000 while consumer GPS receivers cost only USD 50-500 USD, and the former GPS receivers are still expensive for the low-profitable Japanese forest industry. That is why low-cost GPS receivers are often used instead of high-cost ones although the autonomous GPS accuracy is often not acceptable. For this reason, it is recommended to develop a method of making more use of consumer GPS receivers by overcoming difficulties in getting better positional accuracy under forest canopy. The objective of this study is to find and validate a method of acquiring acceptable results of GPS measurements for forest management and utilization with the use of consumer GPS receivers.

2 Material and methods

We assume that the only solution to improve the autonomous GPS accuracy is to average the result of a long-time GPS measurement, but a longer GPS measurement clearly leads to the low efficiency of border determination with the GPS. In this study, therefore, we propose a new technique to improve the autonomous GPS accuracy with the crisscross arrangement of five low-cost GPS receivers. The advantage of this method is to obtain five times more positioning results to be averaged for higher accuracy than the conventional method.

To validate the new method, we conducted field tests in the Tane block, Sanbe University Forest, Shimane University on July 18, 2012. In the field test, the five consumer GPS receivers were set up crisscross in the sugi (*Cryptomeria japonica*) plantation forest planted in 1955 as shown in Figure 1. Figure 2 shows the arrangement of the five GPS receivers in the field tests. The GPS receivers used in this study were Garmin eTrex 20, which receives signals from GPS, GLONASS and MSAS. The forest is almost flat, and the effects of terrain to the GPS accuracy are negligible. Table 1 shows the schedule of the field tests. As shown, GPS/GLONASS/MSAS signals were used in the morning session, and only GPS signals were used in the afternoon session.

Prior to the field tests, the coordinates of the surveying points were determined by using a L2 GPS receiver and a total station (electronic theodolite integrated with an electronic distance meter), and positional errors of this surveying are supposed to fall within several centimeters, which are accurate enough to validate the accuracy of consumer GPS receivers.

Figure 1: GPS measurements with the crisscross arrangement of the five GPS receivers

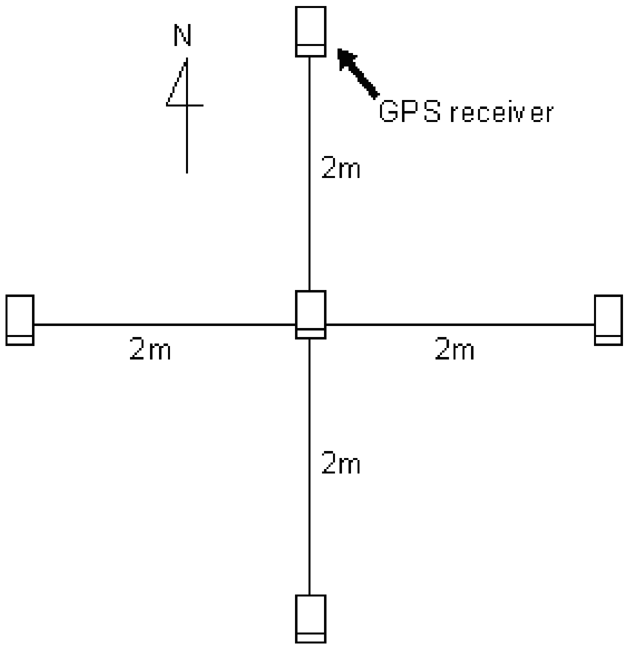

Figure 2: Crisscross arrangement of the five GPS receivers in the field tests

Table 1: Schedule of field tests

Session	Satellites	Antenna height [m]	Starting time (JST)	Ending time (JST)	Measurement interval [sec]
Morning	GPS/GLONASS/MSAS	1.25	9:42:12	13:11:13	1
Afternoon	GPS	1.25	13:13:06	15:00:06	1

JST, Japan Standard Time (UTC+9 hours).

3 Results

Figure 3 shows the results of GPS measurements in the morning session. In this figure, GPS data in the center indicates the points logged by the GPS receiver placed in the crisscross center every one second during the morning session (GPS/GLONASS/MSAS). Average GPS data indicates the averaged points logged by the five crisscross-arranged GPS receivers every one second during the morning session. As shown in this figure, the GPS data in the center is scattered more widely than the averaged GPS data. Averaging the GPS data every one second obviously make the size of their distribution smaller by eliminating the positional errors specific to each GPS receiver. Figure 4 shows the results of GPS measurements in the afternoon session. In this session, the reception of GLONASS/MSAS signals was turned off, and only GPS signals were received to obtain the more common results with widely distributed GPS receivers. The results of the afternoon session also showed that averaging the GPS data every one second make the size of their distribution smaller.

We evaluated the positional errors in terms of precision and accuracy. Precision refers to the closeness of repeated observations (or quantities derived from repeated sets of observations) to the sample mean, and Accuracy refers to the closeness of the observations (or quantities derived from the observations) to the true value. For example, as shown in Figure 5, both precision is good but accuracy is good while in B, precision is bad but accuracy is good. In C, both precision and accuracy are good. The calculated precision and accuracy for each session is shown in Table 2. As shown, precision was greatly improved by averaging GPS data of the five low-cost GPS receivers in crisscross arrangement for both morning and afternoon sessions. On the other hand, accuracy was slightly improved in the same way for both sessions. In conclusion, the crisscross arrangement of consumer GPS receivers improves precision but accuracy. Accuracy errors are often caused by satellite distribution, and in this case, the coordinate determined by each GPS receiver often shifts in the same direction. That is why the crisscross arrangement did not improve accuracy. However, precision improvement is still useful to exclude outlier points and to enhance the reliability of coordinate determination. Further research will be conducted to clarify the possibility of the crisscross arrangement of consumer GPS receivers.

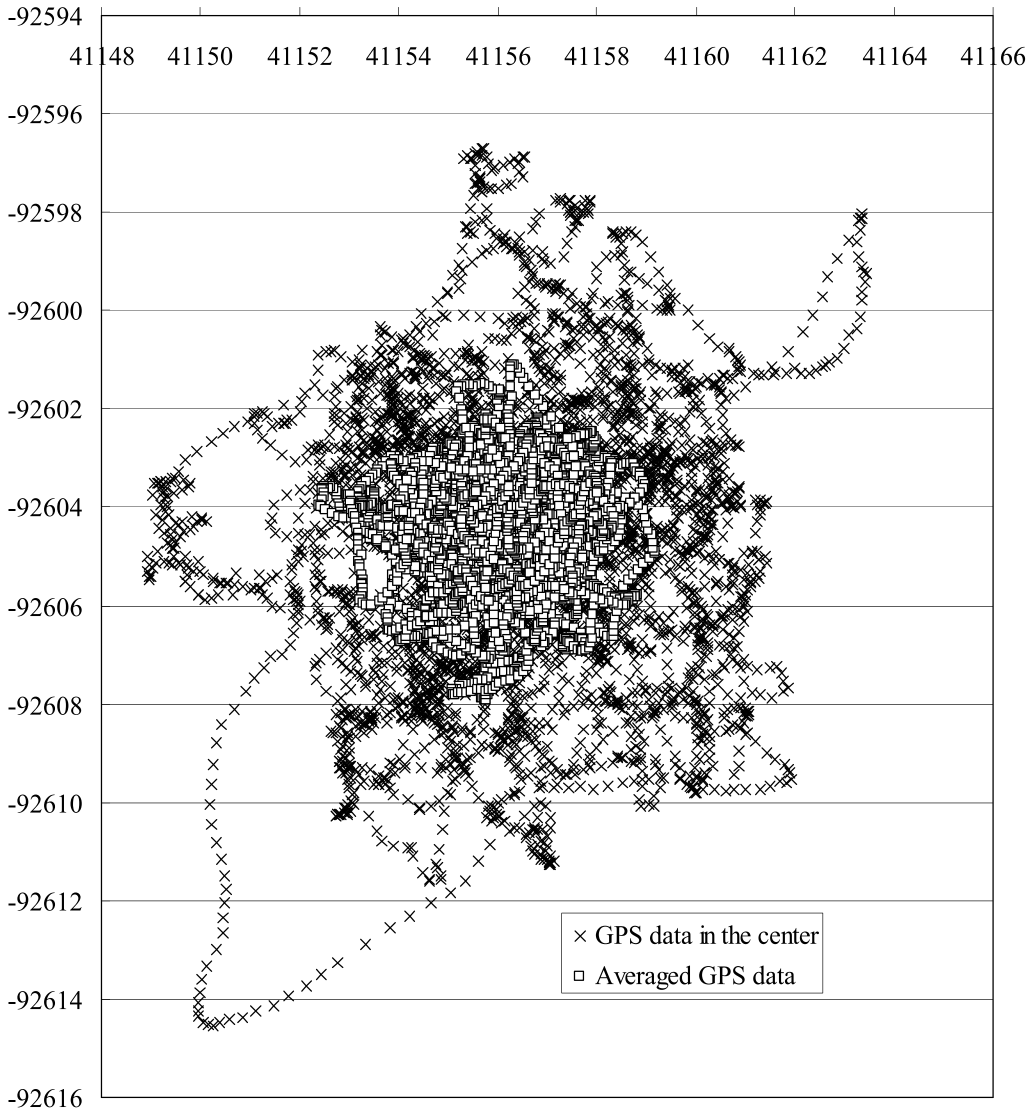

Figure 3: Results of GPS measurements in the morning session. Coordinates are in meter

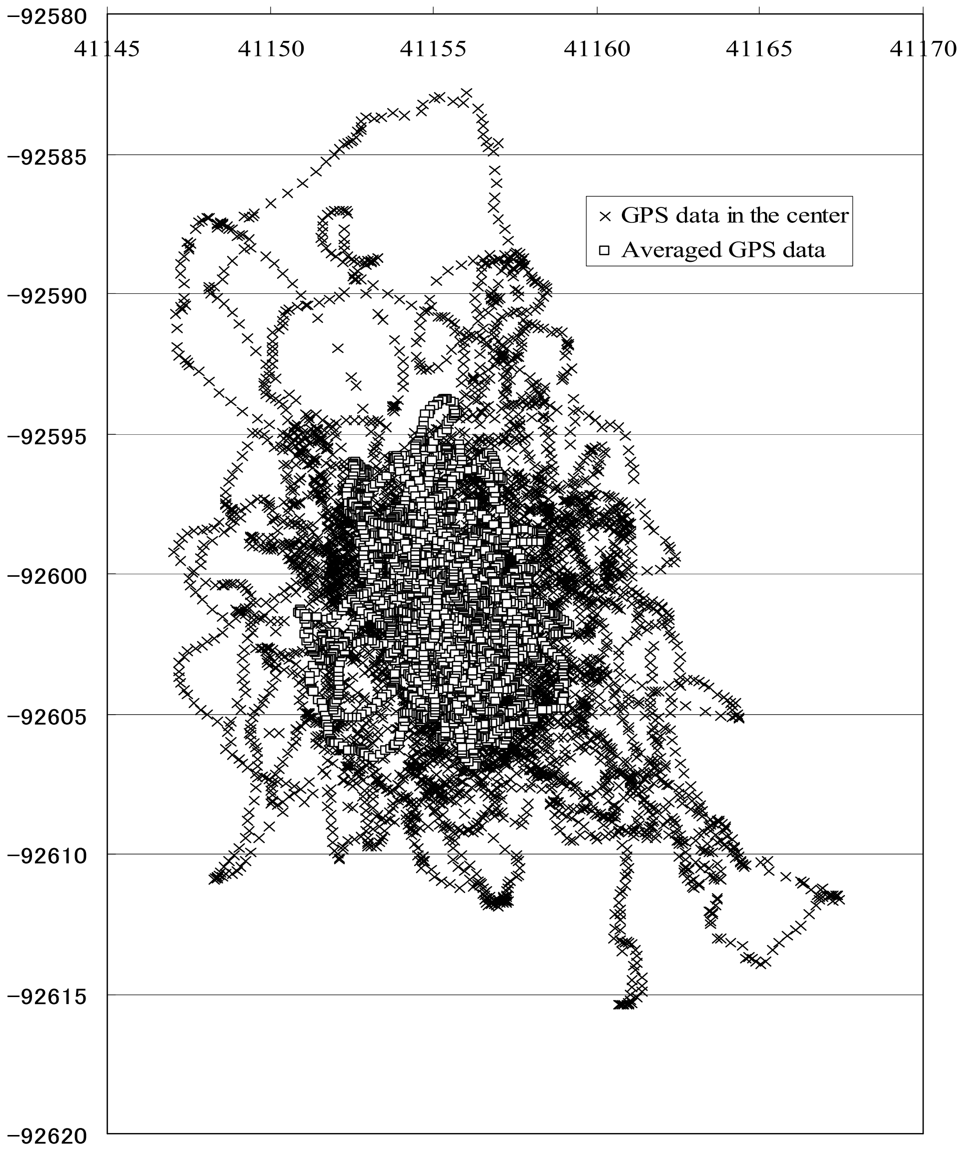

Figure 4: Results of GPS measurements in the afternoon session. Coordinates are in meter

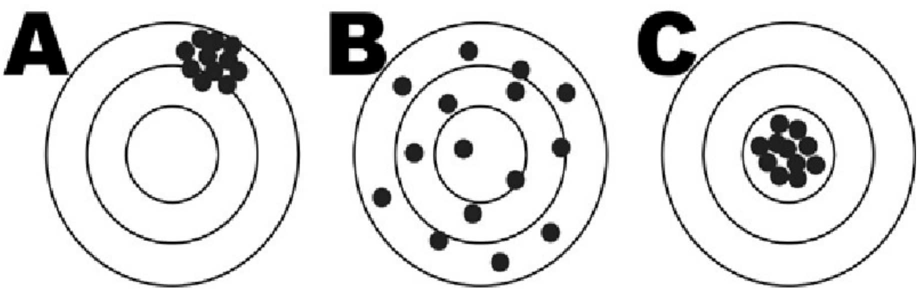

Figure 5: The center of circles indicates the true value, and the dots means the point distribution of GPS measurements.

Table 2: Precision and accuracy of GPS measurements in the field tests

Session	Accuracy [m]		Precision [m]	
	Center	Averaged	Center	Averaged
Morning	4.73	4.56	3.71	1.64
Afternoon	5.39	5.13	6.00	2.72

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