Accuracy enhancement of GPS positioning by changing antenna height

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Abstract: It is known that forest canopy adversely affects the accuracy of GPS positioning, and forest canopy is still a serious obstacle for determining coordinates of control points when using remote sensing technology in forested areas. There have been many attempts to enhance the accuracy of GPS positioning under forest canopy, but they still have not fully met requirements of surveyors or researchers who need to obtain accurate coordinates inside forests. We believe that one of the most effective methods for enhancing accuracy of GPS positioning inside forests is to raise a GPS antenna over forest canopy to change a positional relationship between a GPS antenna and forest canopy. Therefore, we experimentally produced a height-adjustable GPS pole (max. 15m), which was made of carbon to reduce its weight and to enhance its portability in the forest environment. Subsequently, we investigated the effects of raising GPS antenna height over forest canopy on the accuracy enhancement of GPS positioning, which was evaluated in terms of both precision and accuracy and with two positioning modes, that is, autonomous and post-processed differential GPS. For this purpose, field experiments were conducted at three points located in the Kamigamo Experimental Station, Field Science Education and Research Center in Kyoto University. The GPS receiver used in this study was Pathfinder Pro XR (Trimble), and Pathfinder Office (Trimble) was used for data processing. The results showed that post-processed differential GPS improved precision and accuracy of GPS positioning. It was also found that there was a positive effect of raising GPS antenna height over forest canopy in terms of not accuracy but precision. Accuracy was not improved by raising GPS antenna height over forest canopy because the GPS antenna pole was not stable enough especially at the top of the pole where GPS antenna was attached.
Keywords: accuracy, forest canopy, GPS, GPS pole.

1. Introduction

When GPS is used inside forests, it is known that forest canopy adversely affects the accuracy of GPS positioning because GPS signals are attenuated. Many studies have shown the performance of the GPS and DGPS in forested areas. 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. This study also showed that both DGPS accuracy and precision improved with decreasing peripheral obstruction. 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. However, these studies have not shown any proactive methods of improving accuracy of GPS positioning. D'Eon (1996) concluded that GPS positions obtained within 5 min uder mixed forest canopies were better at an antenna height of 4 m than at an antenna height of 2 m. In addition, D'Eon (1996) pointed out that raising the antenna completely above the canopy would be ideal, but was not operationally practical in situations where the canopy is 10 m or higher. Gandaseca et al. (2001) also tried to improve the accuracy of GPS positioning by increasing GPS antenna height up to 4.2 m. The results showed that there was only slight improvement of the accuracy of GPS positioning probably because GPS antenna was still located under forest canopy.

The objective of this study is to clarify the effects of raising GPS antenna height over forest canopy on the accuracy enhancement of GPS positioning, which was evaluated in terms of both precision and accuracy and with two positioning modes, that is, autonomous and post-processed differential GPS. For this purpose, we experimentally produced a height-adjustable GPS pole (max. 15m), which was made of carbon to reduce its weight and to enhance its portability, and conducted field experiments by using it to the forest environment.

2. Materials and Methods

1) Field Experiments

Field experiments were conducted inside the forest of the Kamigamo Experimental Station, Field Science Education and Research Center in Kyoto University on 18-20 July 2005. The rover (Trimble Pathfinder Pro XR) was set up at three points, that is, A5, A13 and K2, inside the forest. A5 and A13 were located on a forest road, and surrounded by natural forest stands consisting of Japanese cypress (*Chamaecyparis obtusa*) and broad-leaved species with a thick shrub layer. On the other hand, K2 was located at the top of the hill inside the forest with few low trees around it. At each point, GPS measurements were conducted for one hour and repeated twice with an antenna height of 2 m and 11 m by using the height-adjustable GPS pole. The base station (Trimble 4700) was operated as a continuous operating reference station and located in the campus of Kyoto University, which was about 5km away from the three points in the Kamigamo Experimental Station. The settings of the GPS receivers used in this study are shown in Table 1. Table 2 shows the schedule of the field experiments. The weather was fair during the period of the field experiments. We started each GPS measurement four minutes earlier on the next day because the same distribution of GPS satellites appears four minutes earlier day bay day. The weather was fair during this period.

Table 1. Receiver settings.

Type of GPS receiver	PDOP mask	SNR mask	Elevation mask (degree)	Logging interval (sec)
Pathfinder Pro XR (rover)	25	0	10	1
4700 (base station)	25	0	10	1

Table 2. Schedule of field experiments.

Date	Starting time (HH:MM:SS)	GPS antenna height (m)	GPS positioning point
18 July 2005	9:49:30	2	A5
	11:06:34	11	A5
	12:19:58	2	A5
	15:27:52	11	A5
19 July 2005	9:45:30	11	A13
	11:02:34	2	A13
	12:15:58	11	A13
	15:23:52	2	A13
20 July 2005	9:41:30	11	K2
	10:58:34	2	K2
	12:11:58	11	K2
	15:19:52	2	K2

2) Data analysis

In this study, horizontal positional errors were calculated and compared in terms of precision and accuracy. Accuracy refers to the closeness of the sample mean to the true value, and precision refers to the closeness of repeated observations to the sample mean (Leick 1995). We used the methods of calculation as shown in Yoshimura and Hasegawa (2003).

3. Results and discussion

1) Precision

Fig. 1 shows the calculated precision errors of autonomous GPS measurements. For example, ‘A5-1’ in this figure indicates the precision error calculated based on the first autonomous GPS measurement data at A5. As shown, precision errors were greatly improved when GPS antenna height was set to 11m over forest canopy at A5 and A13. On the other hand, precision errors were only slightly improved at K2 where there was no canopy cover over the GPS antenna. Fig.2 shows precision errors of GPS measurements when differentially corrected by using Trimble Pathfinder Office 3.0. It was also found that precision errors were greatly improved when GPS antenna height was set to 11m at A5 and A13. It should be noted that post-processed differential correction improved precision errors especially when GPS antenna height was set to 2 m under forest canopy especially at A5 and A13.

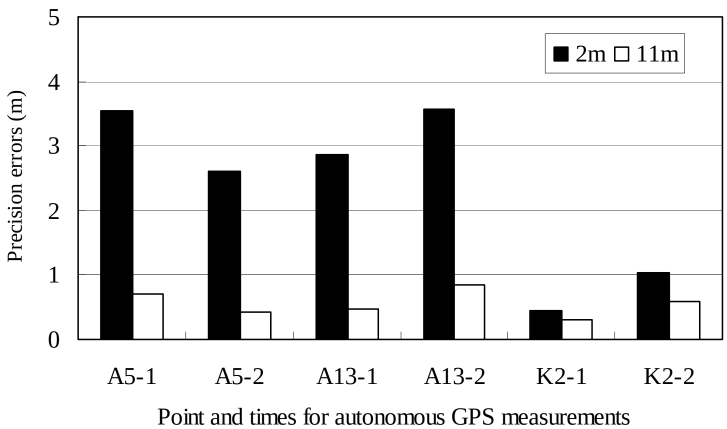

Fig. 1 Precision errors for autonomous GPS measurements.

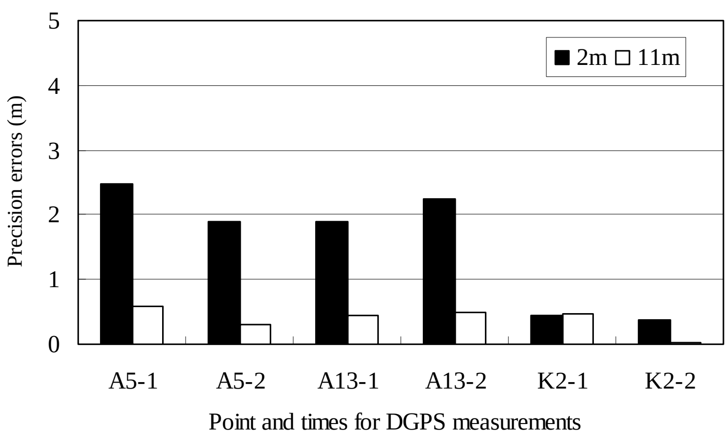

Fig. 2 Precision errors for DGPS measurements.

1) Accuracy

Fig. 3 shows the calculated accuracy errors of autonomous GPS measurements. According to this figure, there was no advantage in using an antenna height of 11 m in terms of accuracy. When differentially corrected by using Trimble Pathfinder Office 3.0, accuracy errors were greatly improved (Fig. 4). However, it was also found that there was no advantage in using an antenna height of 11 m in terms of accuracy. Yoshimura and Hasegawa (2003) reported that the DGPS improved horizontal accuracy through field experiments conducted after SA was turned off. This is probably because verticality of the GPS pole was not assured at an antenna height of 11 m. Actually, as shown in Fig. 5, the GPS pole leaned due to the weight of the GPS antenna with its weight of 400 g, and in addition, the GPS pole swung slightly when the wind blew, especially at K2. We also found that GPS antenna cable intensified this swing when the wind blew, especially at K2. When the GPS pole was used at A5 and A13, it was somehow supported by standing trees, but there was no such support at K2.

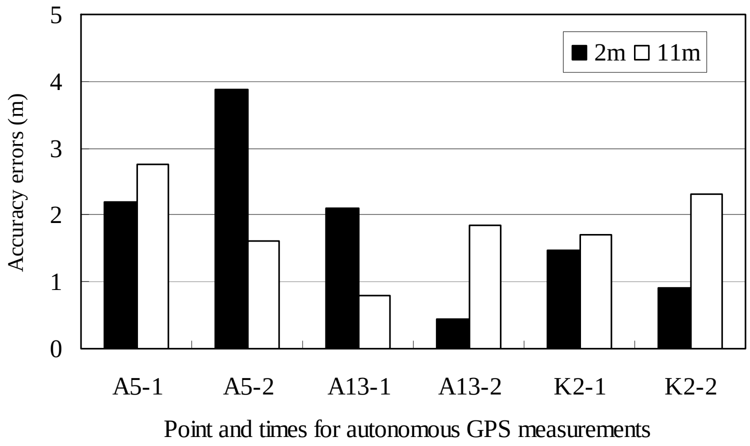

Fig. 3 Accuracy errors for autonomous GPS measurements.

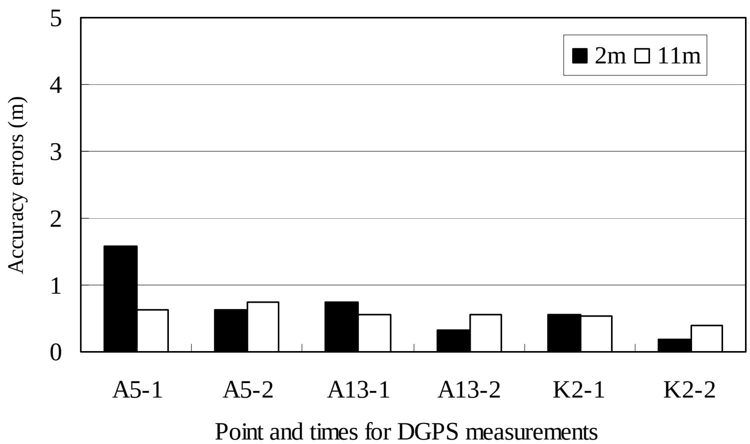

Fig. 4 Accuracy errors for DGPS measurements.

Fig. 5 The GPS pole slightly leaned when used for GPS measurement at K2.

3. Conclusion

We investigated the effects of raising GPS antenna height over forest canopy on the accuracy enhancement of GPS positioning, which was evaluated in terms of both precision and accuracy and with two positioning modes, that is, autonomous and post-processed differential GPS. The results showed that precision errors were greatly improved by raising a GPS antenna height to 11 m over forest canopy. However, accuracy errors were not improved by raising GPS antenna height to 11 m due to incomplete verticality of the GPS pole. Post-processed DGPS reduced both precision and accuracy errors of GPS positioning at antenna heights of 2 m and 11 m. Finally, some issues were identified to reduce accuracy errors as well as precision errors of GPS positioning:

1. The body of the GPS pole should be strengthened.
2. The GPS pole should be firmly fixed to keep complete verticality.
3. Verticality should be assured by taking a level when the GPS pole is set up.
4. Lighter GPS antenna is recommended, otherwise GPS with Bluetooth technology is recommended.

There have been new GPS technologies to obtain very accurate positional data, but it is known that they still cannot work well under forest canopy. To develop a GPS positioning system more suitable for the forest environment, future studies should focus on the integration of such new GPS technologies with the GPS pole used in this study.

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