ACCURACY OF 3D MEASUREMENT WITH AN AIRBORNE LASER SCANNER SYSTEM AND ITS APPLICATION FOR CHANGE DETECTION OF URBAN BUILDINGS

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ABSTRACT

Since the introduction of airborne laser scanner systems, few comprehensive studies have been reported on data accuracy assessed with well-defined ground features. This study employed well-defined and accurately surveyed urban features like manhole tops and buildings to assess the accuracies of 3D measurement with an airborne laser scanner system developed by Nakanihon Air Service Co., Ltd. in Japan. The accuracies of the system were approximately 20 cm and 100 cm (S.D.) in the vertical and the horizontal directions, respectively. The large horizontal error was caused by inadequate attitude control of the system.
This study also employed the data acquired by the system at two different occasions separated by 53 days to detect changes of ground features. An image generated by subtracting one of these two images from the other clearly showed newly constructed buildings, the detection of which, otherwise, would require intensive manual airphoto interpretation.

1. INTRODUCTION

At the Kobe earthquake that occurred in January 1995, collapsed buildings killed more than 4,000 people. One of the reasons for the large death toll was that little information on the extent and magnitude of the damage was available outside the damaged areas, which prevented prompt rescue operations. Good weather conditions after the earthquake allowed the Geographical Survey Institute (GSI), the mapping agency of Japan, to take airphotos of the damaged areas immediately after the earthquake. However, it took GSI 10 days to compile and print maps of these areas of over 150 square km at a scale of 1:10,000 using the conventional airphoto interpretation technique. Although it was considered a prompt response from the conventional mapping standpoint, the time spent for the compilation made these maps no use in terms of rescuing people who might have been alive for a while inside collapsed buildings. Difficulty of finding collapsed buildings through manual interpretation of vertical airphotos also prevented adequate detection of damaged areas (Sekiguchi, 1996). In this context, conventional photogrammetric methods are considered not adequate for detecting collapsed buildings. Consequently, a new technology that is independent of weather conditions and allows automated mapping of damaged areas is needed for far quicker response to this kind of disasters.

Recent development of an airborne laser scanner system (ALSS) has opened a new way of directly measuring elevation (Ackermann, 1996; Flood and Gutelius, 1997). In this study, ALSS is considered to have the following advantages over the conventional photogrammetric approaches in quickly detecting collapsed buildings: 1) direct elevation measurement of ground features; 2) quick, automated data processing with almost no human intervention or manual data handling; 3) almost independent of weather conditions when boarded on a helicopter due to lower flying height compared to airplanes; and 4) if the system is used regularly, the data could help detect the changes in urban features, especially buildings, which would help revise an urban GIS database.

The objective of this study is to assess the accuracy of ALSS measurement and the potential of this ALSS technology for change detection of urban features, which would help detect collapsed buildings and could make decision makers well prepared for disasters like earthquakes, as well as making the revision of urban GIS databases easier than manual photo interpretation (Murakami, et al., 1997a, b).

2. SYSTEM SPECIFICATIONS

The ALSS employed in this study was developed by Nakanihon Air Service Co., Ltd. The basic specifications of the system are summarized in Table 1. The system includes GPS and laser scanner subsystems as well as data recording and data processing subsystems. The GPS and laser scanner subsystems had positional accuracy of 13 cm (RMSE, in the vertical direction on board a car) and 9 cm (RMSE, for the measurement of 450 m on the ground), respectively, when tested independently on the ground.

Table 1. Specifications of ALSS employed in this study.

Laser emission cycle	20,000 Hz
Scan cycle	25 Hz
Scan angle	-30-+30 degrees
Ground resolution	approximately 50 cm
Platform	Helicopter
Flying height	200-400 m above ground

Figure 1. Study area and control points employed in this study (central part of the whole study area).

3. STUDY AREA AND AVAILABLE DATA

A study area that covers approximately two square km of the city of Minokamo, Japan was selected to assess the ALSS data in terms of both positional and temporal accuracies. Minokamo city has a variety of typical Japanese urban features including tall buildings, a railroad station, and commercial areas mixed with residential houses and apartments. A GIS database developed by the city government has the information of roads, buildings, residential houses, and railroads with the horizontal accuracy of 30 cm. The number of stories of the building had been surveyed by the government for urban planning. A number of control points were also prepared for the central part (approximately 0.12 square km) of the study area to conduct the accuracy assessment as shown in Figure 1. For the vertical control, elevation values at nine manhole tops surveyed for the sewerage system were available. The building heights above the ground were manually measured from airphotos of 1:8,000 scale. Thus, the Minikamo city presents a suitable area for the accuracy assessment of the ALSS.

4. DATA ACQUISITION

A helicopter was employed for the platform of ALSS to acquire elevation data of the study area with different flight parameters as shown in Table 2. The data taken on October 21, 1996 at the flying altitude of 250 m is shown in Figure 2.

Table 2. Information on the Data Acquired with ALSS (Weather: Clear sky, Flying speed: 45-55 km/h)

Date (1996)	Flying Altitude	Flying Direction	Acquisition Period
Oct. 21	200 m	South to North	2 minutes
Oct. 21	250 m	South to North	2 minutes
Oct. 21	300 m	South to North	2 minutes
Dec. 13	200 m	South to North	2 minutes
Dec. 13	300 m	East to West	30 minutes

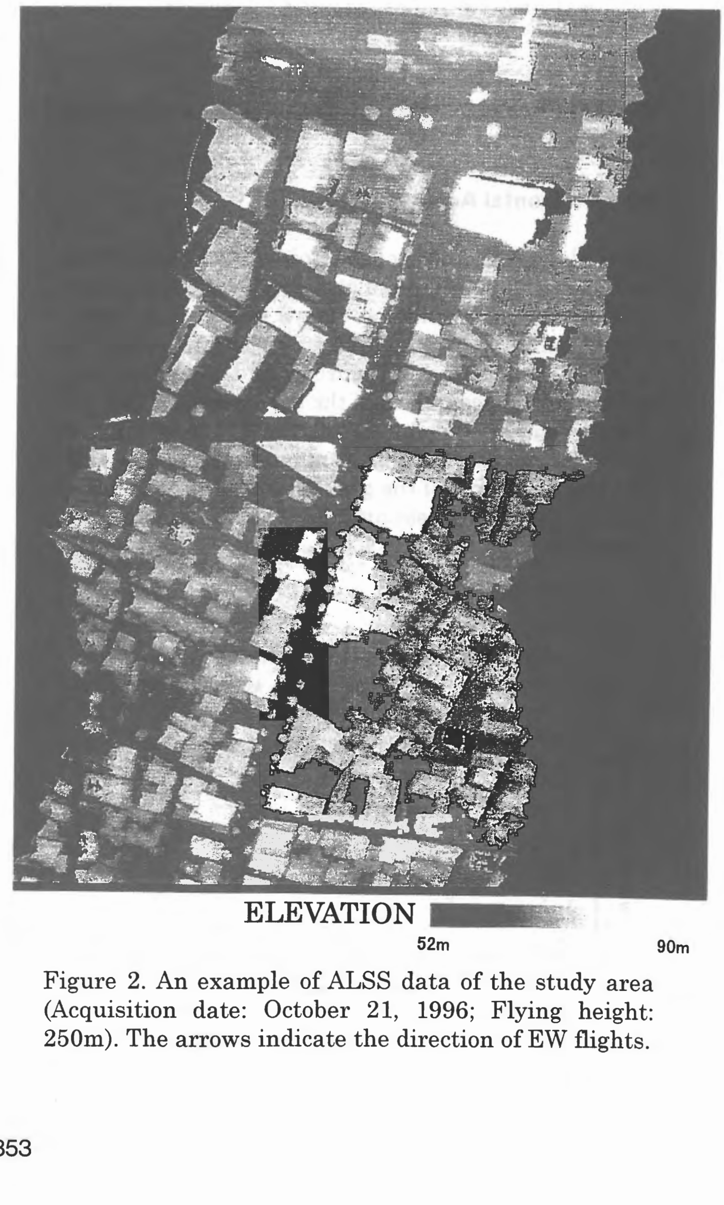


Figure 2. An example of ALSS data of the study area (Acquisition date: October 21, 1996; Flying height: 250m). The arrows indicate the direction of EW flights.

5. ACCURACY ASSESSMENT

The acquired data were assessed with the control points shown in Figure 1.

5.1 Vertical Accuracy

A total of 9 vertical control points derived from manhole tops were employed for vertical accuracy assessment by comparing the elevation values between the control points and ALSS data. The result is shown in Figure 3 and the standard deviation is approximately 20 cm. Figure 3 indicates bias in the errors proportional to the flying height of the platform.

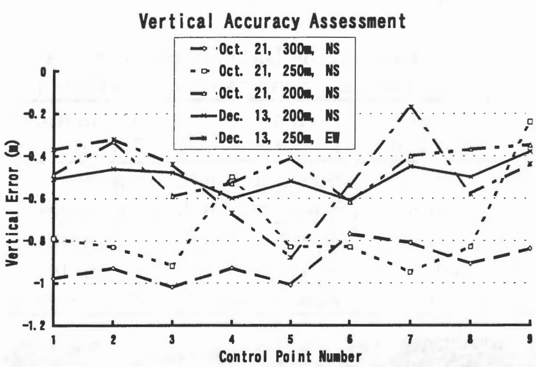


Figure 3. Vertical accuracy assessment result for ALSS data.

5.2 Horizontal Accuracy

Spatially well-defined control points like corners of the buildings and bare ground areas were selected as the horizontal control points as shown in Figure 1. These control points were compared with the ALSS data. The result is summarized in Figures 4 and 5, which show the horizontal accuracies of the east-west and the north-south directions, respectively. The total accuracy of the horizontal directions is approximately 1 m (S.D.). The wavy patterns of the graphs of Figures 4 and 5 indicate that the sensor attitude was not accurately detected.

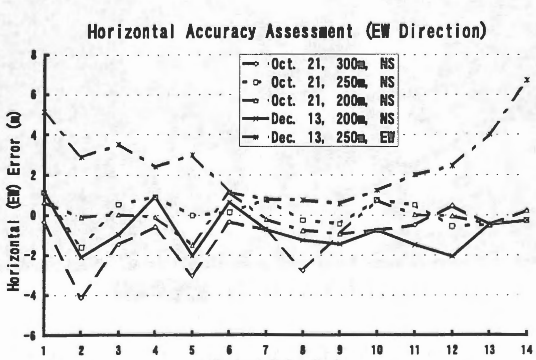


Figure 4. Horizontal accuracy assessment result for ALSS data in the east-west direction.

5.3 Temporal Accuracy

The temporal accuracy was assessed by the time needed to measure an area of 2 square km and to process the acquired data. The measurement time was 30 minutes and the processing time was 2 hours with a PC (Pentium, 133 MHz).

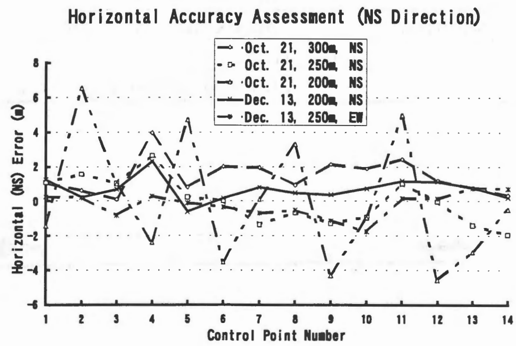


Figure 5. Horizontal accuracy assessment result for ALSS data in the north-south direction.

6. CHANGE DETECTION OF BUILDINGS

Japanese urban landscape is subject to dynamic changes due to the construction of new roads and buildings. Updating GIS databases, especially of roads and buildings, is one of the most challenging tasks of local governments to keep up with practical needs of their daily businesses like real estate taxing and underground facilities management.

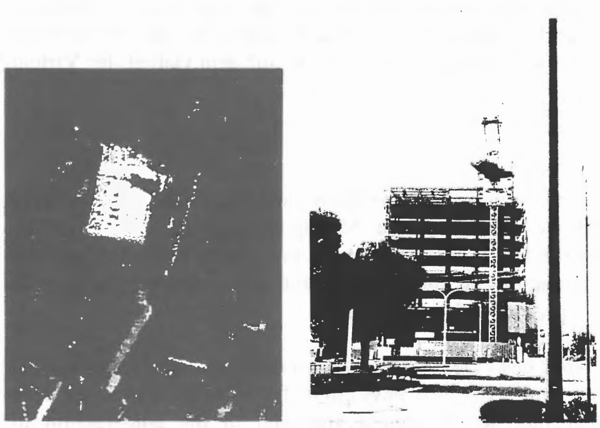
Thus, the high temporal accuracy of the ALSS data is a great advantage over the conventional photogrammetric approaches. This idea leads to change detection of urban areas, especially buildings by directly comparing the ALSS data sets acquired in different occasions. The ALSS data sets listed in Table 2 were acquired in two different occasions separated by 53 days, i.e., October 21 and December 13, 1996. An image generated by subtracting the former data set from the latter is shown in Figure 6. Although the edges of the buildings are present in the image, two changes of buildings can be easily and clearly identified. The image of Figure 6 around these changes were enlarged and shown in Figures 7 and 8 together with a ground photo and a pair of airphotos, respectively to understand the actual changes occurred in these areas.

7. SUMMARY

By employing an ALSS on board a helicopter, this study demonstrated the potential of ALSS technology for the accurate measurement of 3D urban features as well as the detection of urban building changes with high temporal accuracy. This result is considered to make ALSS eligible for the detection of collapsed buildings in case of disasters.
However, the system developed in this study requires significant improvements in the attitude control or

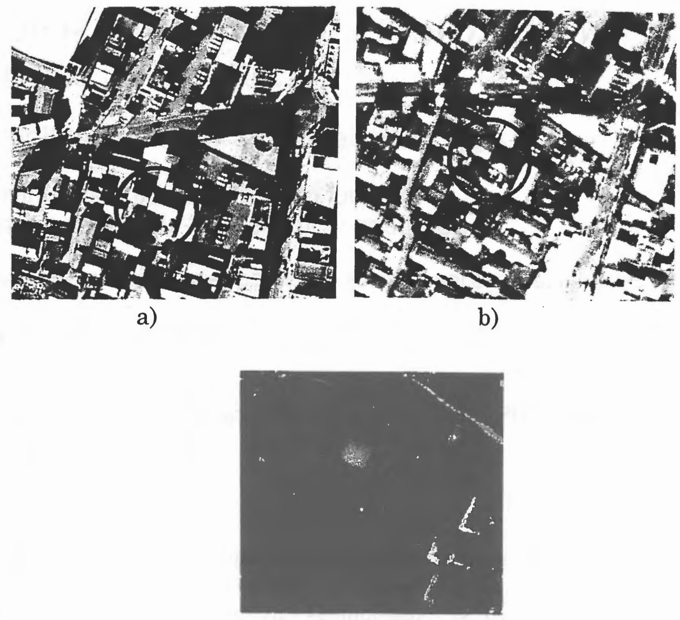
accurate attitude information acquisition. Such improvement is expected to reduce the horizontal errors of the ALSS data.

Figure 6. A differential image generated by subtracting one of the two ALSS elevation data sets from the other acquired in October and December 1996. White parts of the figure indicate that their elevation has become higher since the acquisition of the older data.



a) b)

Figure 7. A building under construction that is identified in Figure 6: a) a part of Figure 6 where a change is identified; and b) an photo of the building under construction taken from the ground.



a) b)

c)

Figure 8. A reformed house identified in Figure 6: a) an airphoto taken in February 1996; b) an airphoto taken in January 1997; and c) a part Figure 6 where a change is identified.

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