

POTENTIAL OF AN AIRBORNE LASER SCANNER SYSTEM FOR CHANGE DETECTION OF URBAN FEATURES AND ORTHOIMAGE DEVELOPMENT

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ABSTRACT

The Kobe earthquake in 1995 demonstrated an urgent need of developing a change detection mapping system of buildings with high temporal accuracy to save people from damaged buildings. An airborne laser scanning system (ALSS) is considered to have the potential of meeting such a need of detecting building changes in 3D shape because of its capability of direct measurement of ground elevation and short turnaround time.

This study employed the data acquired by ALSS at three different occasions to detect changes of buildings in 3D shape. Images generated from a simple processing of these ALSS data clearly showed building changes without omission errors, the detection of which, otherwise, would require intensive manual airphoto interpretation. The combination of a CCD array sensor with the laser scanning system also indicated the potential of ALSS for automated orthoimage development, even though the current system developed in this study still needs further improvement in image displacement correction.

1 INTRODUCTION

At the Kobe earthquake that occurred in January 1995, more than 4,000 people were killed with damaged buildings. 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 immediately after the earthquake, which prevented prompt rescue operations. Good weather conditions after the earthquake allowed the Geographical Survey Institute (GSI), the national 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 400 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 damaged buildings.

Difficulty of finding damaged buildings through manual interpretation of vertical airphotos also prevented adequate detection of damaged areas (Sekiguchi, 1996). In addition, the ground truth conducted later revealed that only 12 % of the damaged areas had been successfully depicted in these maps. Consequently, a new technology that allows automated mapping of damaged areas with high temporal accuracy and sufficient information content is needed for far quicker response to this kind of disasters.

What we need to map in damaged areas is the change of

ground features, especially buildings that would influence most on people's lives. Here, building change should be defined as the change of 3D shape, not of the surface characteristics in order to make it meaningful for damaged building detection.

In addition, as far as building change is concerned, there needs to be a reference data set that would allow the comparison between before and after an event, i.e., a disaster. In this context, damaged area mapping should be based not on special mode of actions designed only for disaster responses, but on an extension of ordinary business practices mandated to the public sector, in which the urban landscape is periodically monitored to ensure a good reference data set.

Japanese urban landscape is subject to dynamic changes due to the construction and reformation of 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. Local governments in Japan are mandated to collect real estate taxes in their jurisdiction. One of the information contents required in this business practice is to detect changes of 3D building shape to renew the amount of tax to be collected. Consequently, an efficient change detection method with high temporal accuracy and sufficient information content would provide reference data sets for both damaged area detection and real estate tax collection.

Recent development of an airborne laser scanner system (ALSS) has opened a new way of directly measuring elevation or developing a digital surface model (DSM) with high vertical and temporal accuracies (Ackermann, 1996;

Flood and Gutelius, 1997). Since the ALSS measures DSM directly, it allows direct comparison of two data sets acquired at different occasions to detect 3D shape changes. On the other hand, images obtained through optical sensors like CCD arrays and aerial cameras are subject to changes of illumination conditions and line of sight direction of sensors, which would make the change detection process complicated and leave uncertainties on omission errors.

In addition, if ALSS data and CCD array imagery are successfully combined to develop digital orthoimagery, the manual inspection process for the detected changes would become straightforward and significantly reduce the time required for GIS database revision.

The objective of this study is to validate the potential of ALSS for building change detection and of orthoimage development.

2 SYSTEM REQUIREMENTS AND SPECIFICATIONS

Many Japanese buildings and houses are designed based on a unit of 3 m by 3 m in horizontal directions and the building height per floor is approximately 3 m. Therefore, the accuracies for the horizontal and vertical directions and the ground resolution of the ALSS should be better than 1 m.

The ALSS employed in this study was developed by Nakanihon Air Service Co., Ltd. Table 1 summarizes the basic specifications of the system. A preliminary accuracy validation of the system showed that the ALSS has the vertical accuracy of 10-20 cm and the horizontal accuracy of 1-3 m (Murakami, et al., 1997a). After the initial validation, some system upgrade, including the improvement of laser ranging device sensitivity and the detection of platform position and attitude, was conducted to improve the three dimensional accuracies of ALSS data. After this system upgrade, the horizontal accuracy was improved to approximately 1 m (Murakami, et al., 1998).

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 |

3 STUDY AREA AND AQUIRED DATA

A study area was selected in the city of Minokamo, Japan (Figure 1). 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. Thus, it presents a

suitable area for the validation of ALSS for change detection.

A helicopter was employed as the platform of ALSS to acquire elevation data of the study area at different occasions for change detection as shown in Table 2. The data taken on October 21, 1996 is shown in Figure 2.



Figure 1. An airphoto of the study area, i.e., the central part of the city of Minokamo, Japan. The airphoto was taken in February 1996.

Table 2. Information on the data acquired with ALSS.

(Weather: Clear, Flying speed: 45-55 km/h)

| Date | Flying Height | Code in the text |
|----------------|---------------|------------------|
| Oct. 21, 1996 | 200 m | Oct96 |
| Dec. 13, 1996 | 200 m | Dec96 |
| Feb. 17, 1998* | 250 m | Feb98 |

*: Feb98 was acquired with the upgraded system and has better spatial accuracy.

4 CHANGE DETECTION OF BUILDINGS

Assuming that the ALSS data sets acquired at different occasions have sufficient spatial accuracy, the building changes in 3D shape can be detected by simply subtracting one of the data sets from the others. Differential images generated by subtracting one of the

data sets in Table 2 from the others are shown in Figure 3. Although the edges of the buildings are present especially in the image generated from Oct96 and Dec96 because of the insufficient spatial accuracy of the system, changes of buildings can be easily and clearly identified.

In addition, by simply transforming the image of Figure 3b into a binary image and reducing the noise with an image filtering operator, the changed areas can be successfully extracted without omission errors as shown in Figure 4. This enables the human inspectors to concentrate only on the detected changes and to reduce the time required for interpreting the whole input image.

The subimages of Figure 3a around two of the detected changes were enlarged and shown in Figures 5 and 6 together with a ground photo and a pair of airphotos, respectively, to understand the actual changes occurred in these areas. These figures show that the changes of buildings can be easily detected by acquiring ALSS data repeatedly over the same area. And the same operation would be applied to detect damaged buildings in case of disasters by comparing the latest ALSS data with the one acquired immediately after the disaster. In other words, local governments can be well prepared for disasters like the Kobe earthquake by regularly acquiring ALSS data and updating their GIS database.

This leads to an idea of an urban DSM database of local governments to improve the efficiency of their operations at both ordinary and emergency.

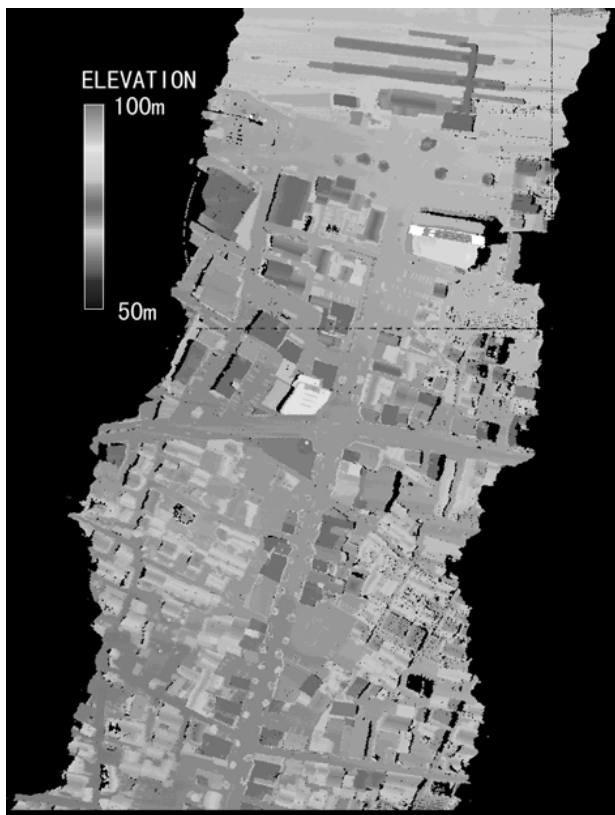


Figure 2. An example of ALSS data of the study area (Acquisition date: October 21, 1996).



a)



b)

Figure 3. Differential images generated by subtracting one of the ALSS data sets from the others. White parts of the figure indicate that their elevation has become higher since the acquisition of the older data: a) Differential image between Oct96 and Dec96; and b) Differential image between Oct96 and Feb98.



Figure 4. Changes detected from Figure 3b. The Figure 3b image was transformed into a binary image and then the noise was removed from a simple noise reduction filtering.

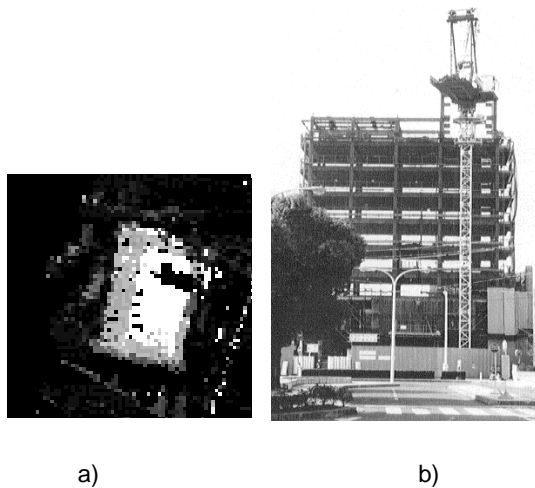


Figure 5. A building under construction that is identified in Figure 3: a) a part of Figure 3 where a change is identified between Oct96 and Dec96; and b) a photo of the building under construction taken from the ground in February 1997.

5 ORTHOIMAGE DEVELOPMENT

With a DSM or DEM data, developing orthoimagery would be a well established process even in the conventional photogrammetry. However, by utilizing the position and attitude data employed to transform the raw laser scanner data to a DSM data and by installing a CCD array sensor in the same platform as the laser scanner, orthoimage development process would become far automated with minimum human intervention.

Figure 7 shows an example of CCD array images acquired along with the laser scanner data, and an

orthoimage automatically generated by using the DSM data simultaneously acquired with the CCD image. Although the displacement correction needs far more improvements to be of use for operational purposes, this approach has a high potential that would significantly reduce the time and cost required for orthoimage development compared to the conventional photogrammetric approach.

6 CONCLUSION

By employing the ALSS on board a helicopter, this study demonstrated the potential of the ALSS technology for the detection of urban building changes in 3D shape with high temporal accuracy and without complicated data processing or omission errors. Local governments would be well prepared for both efficient GIS database revision and the detection of damaged buildings in case of disasters without requiring special mode of actions.

The orthoimage developed in this study also suggested the high potential of the combination of a laser scanning system and a CCD array for automated development of orthoimage, although the image displacement correction needs further improvement.



a)

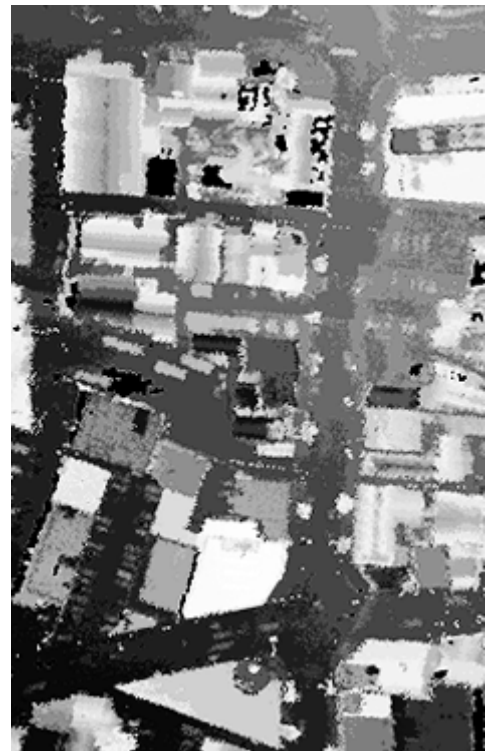


b)



c)

Figure 6. A reformed house identified in Figure 3: a) an airphoto taken in February 1996; b) an airphoto taken in January 1997; and c) a part of Figure 3 where the change is identified.



b)



a)



c)



d)

Figure 7. Development of orthoimage from a DSM data and a CCD array image: a) the airphoto of the area for the orthoimage development; b) the DSM data employed for the orthoimage development; c) the original CCD array image; and d) orthoimage developed from b) and c).

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