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Change detection of buildings using an airborne laser scanner

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Abstract

This study employed an airborne laser scanner to detect changes of buildings by acquiring a digital surface model (DSM) data of urban areas. Simple comparison between DSM data sets acquired at different occasions successfully detected building changes without omission errors. A CCD array image simultaneously acquired with the DSM data was also automatically orthorectified with the DSM data and indicated to help revise the building database efficiently.

Keywords: change detection; airborne laser scanner; building; digital surface model

1. Introduction

Local governments in Japan are mandated to collect taxes on real estate, including buildings in their jurisdictions. However, Japanese urban landscape is subject to dynamic changes due to new construction and reconstruction of urban features, especially buildings. Consequently, updating their GIS databases, especially detecting changes and revising the building data accordingly, is one of the most challenging tasks of the Japanese local governments.

2. Review of existing methods

The conventional method of detecting building changes employs aerial images and the manual photo interpretation technique (Lu et al., 1998). Due to the manual processes involved in such a change detection method, however, the detected changes inevitably include omission errors, and the whole process is both costly and time-consuming.

Automated approaches in detecting building changes or extracting building features from aerial or satellite images also have not yet reached the point where they can perfectly identify changes or buildings and assess the amount of omission errors in an a priori manner (Liow and Pavlidis, 1990; Murakami and Welch, 1992; Shi and Shibasaki, 1995). As long as there is a possibility of omission errors in the result of change detection, the worst scenario of an actual GIS database revision would require a manual inspection of the whole original images, which reduces the significance of applying automated approaches. On the other hand, as long as no omission errors are included in the result, removing commission errors can be made straightforward by manually eliminating them during the inspection process.

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Table 1
Specification of ALS employed in this study

Pulse rate	20 kHz
Scan rate	25 Hz
Scan angle	±30 degrees
Resolution	50 cm on the ground
Platform	Helicopter
Flying height	200–400 m above ground

The difficulty of detecting building changes from aerial or other optical images arises from the fact that the changes to be detected in a GIS database are not those of the optical surface characteristics of buildings, but those of 3D surface geometry or digital surface model (DSM) of urban areas, which cannot be directly observed through optical sensors. Deriving digital elevation model (DEM) data from stereo image pairs is the well established technology (Ehlers and Welch, 1987; Welch et al., 1998). In addition, many off-the-shelf commercial software applications for image processing provide such a capability as one of their functions that can be easily operated on PCs (Welch, 1990). Unfortunately, however, the DEM data generation method based on the stereo-correlation technique often fails to produce precise DSM data for densely populated building areas commonly seen in Japanese urban areas (Shi and Shibasaki, 1995). Consequently, a new approach is needed to detect changes of buildings in Japanese urban areas with few omission errors by directly measuring DSM of densely populated buildings.

Fig. 1. An aerial image of the study area, i.e., the central part of the city of Minokamo, Japan, taken in February 1996.

3. DSM acquired with laser scanning technology

Recent emergence of the airborne laser scanning technology has made it possible to generate DSM data with high vertical accuracy, up to approximately 10 cm, and high spatial resolution as small as less than 1 m (Ackermann, 1996; Axelsson, 1998; Lohr, 1998). Since many Japanese buildings and houses are designed based on a unit of approximately 2 m by 2 m in the horizontal directions and the building height per floor is approximately 2 m, it is expected that the current airborne laser scanning technology offers more-than-sufficient capability of detecting buildings. In addition, once the airborne laser scanner (ALS) is integrated with a CCD array sensor, simultaneous acquisition of DSM data and optical imagery would allow automated generation of orthoimages, which would be useful for manual inspection of detected changes.

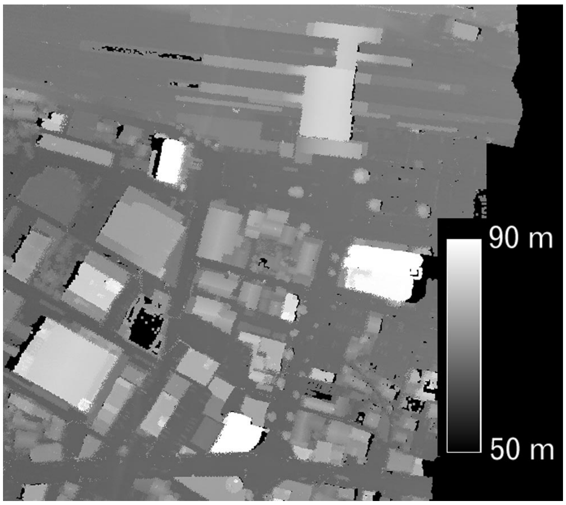

Fig. 2. An example of ALS data of the study area (acquisition date: August 19, 1998).

Fig. 3. A difference image generated by subtracting the ALS data acquired on October 21, 1996 from the one acquired on August 19, 1998. The white areas of the figure indicate that their elevation has become higher since the acquisition of the older data, while the grey areas indicate that their elevation has become lower than before.

The objective of this study is to validate the potential of an ALS for building change detection and orthoimage generation.

4. Specifications of the employed system

Considering the aforementioned unit size of typical Japanese buildings, the accuracies for the horizontal and vertical directions and the ground resolution of the ALS should be better than 1 m for the purpose of this study.

The ALS employed in this study was developed by Nakanihon Air Service of Japan. Table 1 summarises the basic specifications of the ALS. An accuracy validation study showed that it has the vertical accuracy of 10–20 cm and the horizontal accuracy of approximately 1 m (Murakami et al., 1998).

Therefore, the ALS is considered to satisfy the requirements of building change detection in Japanese urban areas.

5. Study area and acquired data

A study area was selected in the city of Minokamo, Japan (Fig. 1). It has a variety of typical Japanese urban features including tall buildings, a railroad station, and commercial areas mixed with densely populated residential houses and apartments. Thus, it presents a suitable area for the validation of the ALS for building change detection.

DSM data sets of the study area were acquired with the ALS for four times, i.e., on October 21,

Fig. 4. Changes detected in Fig. 3. The Fig. 3 image was transformed into a binary image with a threshold value of 1 m and then the noise was removed by using a simple noise reduction filter.

Fig. 5. An orthoimage generated from DSM and CCD array data, both of which were acquired on August 19, 1998.

1996, December 13, 1996, February 17, 1998 and August 19, 1998 (Fig. 2).

6. Change detection of buildings

Since the DSM data sets acquired with the ALS at different occasions have sufficient spatial accuracy and resolution, the building changes can be automatically detected by simply subtracting one of the DSM data sets from the others. One of the difference images thus generated is shown in Fig. 3. Although the edges of the buildings are present because of the horizontal error of the ALS, it clearly shows the changes of ground features. To help reduce the number of commission errors that need to be removed during a manual inspection process, the difference image of Fig. 3 was processed with a simple shrinking and expansion filter to remove edges of unchanged features. The amount of shrinking and expansion of the filtering process was determined in an a priori manner based on the horizontal error of the ALS. The result is shown in Fig. 4. Manual interpretation of and comparison between the aerial images taken in February 1996 and December 1998 confirmed that there is no omission error of building changes in Fig. 4. As long as no omission error is included in the result of change detection, manual inspection process can be concentrated only on the detected changes, which would reduce the time required to investigate the whole study area. These figures indicate the significance of acquiring DSM data with ALS repeatedly over the same area to detect building changes in urban areas.

7. Orthoimage generation

Changes detected in a difference image generally include commission errors such as changes of street

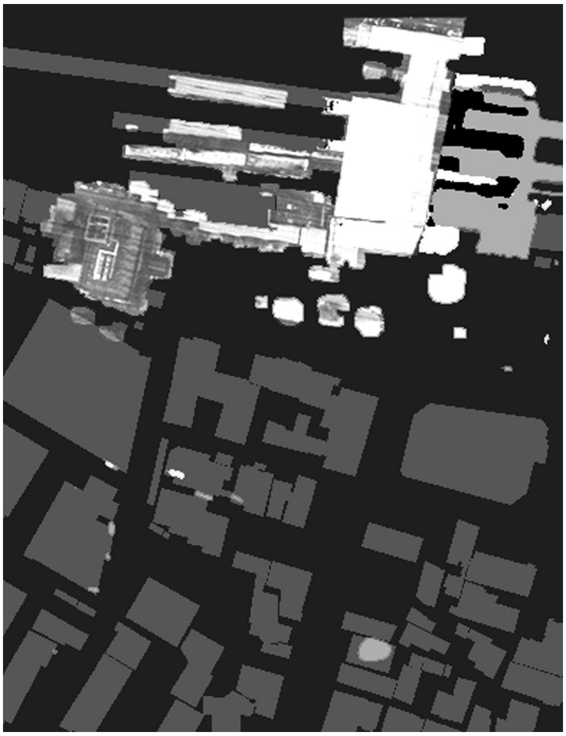

Fig. 6. An orthoimage of the study area overlaid with the change image of Fig. 4 and existing building database. Grey areas are building data in the building database. Only parts of the orthoimage where changes were identified during the change detection process are displayed to facilitate the database revision and inspection process by the operator.

trees. Removing these errors requires manual inspection, which would be facilitated with an orthoimage of the same area. By combining the position and attitude data of ALS and a CCD array sensor mounted on the same platform as the ALS, orthoimage generation would be a straightforward process by automatically locating the CCD detector corresponding to each sample of the position and attitude data. Fig. 5 shows an example of an orthoimage automatically generated by using a CCD image simultaneously acquired with the DSM data.

By merging the orthoimage with the change image shown in Fig. 4 and old building data derived from an existing building database, the details of the detected changes can be easily focused and manually interpreted to remove commission errors, such as street trees as shown in Fig. 6. Since the operator for manual inspection does not have to look at the whole orthoimage and only needs to focus on the areas where changes are detected, it can be said that the combination of the change image and orthoimage can reduce the total time required to revise a GIS database.

8. Conclusions

By using the ALS onboard a helicopter, this study demonstrated that building changes can be detected without omission errors by simply computing a difference image of DSM data acquired at different occasions over the same area.

It was also shown that removal of commission errors from detected changes with manual inspection can be made straightforward, and hence the time required of GIS database revision can be reduced by combining DSM data, orthoimage, and old GIS data. The high potential of the combination of an ALS and a CCD array was also demonstrated for automated generation of orthoimages, which would require more expensive processing with the conventional orthoimage production using aerial images.

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