DETECTION OF BUILDING CHANGES FROM LIDAR DATA AND AERIAL IMAGERY

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ABSTRACT: Change detection for land cover is an important work in the geo-information field. Traditionally, change detection is usually done by using multi-temporal images through the spectral analyses. Those images provide two-dimensional spectral information without including 3D shape in the third dimension. Among others, building models are the prominent object in the 3D world. As the availability and quality of emerging LIDAR (Light Detection and Ranging) systems that make the acquisition of shape information convenient, we include LIDAR data and aerial images to detect the changes of building models. The proposed scheme comprises four major parts: (1) data pre-processing, (2) detecting changes on old building areas, (3) treatment for unchanged buildings, and (4) finding new or changed buildings in the rest areas. The first step performs the spatial registration for the three types of data. In addition, we remove ground and vegetation areas. In the second step, we include LIDAR data and aerial images in the area of old buildings to detect changes. In the third step, if a building model is reckoned as unchanged, we mark the area in LIDAR to ensure finding new or changed buildings the next step. For the rest areas, we search for new or changed buildings by using mathematical morphology. The test site is located at Hsin-Chu city of north Taiwan. The old building models were acquired in 2002. The aerial images were acquired in 2005 with 12cm resolution. The LIDAR point clouds were also acquired in 2005 with a density of 1.5pts/m^2. Preliminary results indicate that the result of detecting building changes by proposed scheme may reach high fidelity.

1. INTRODUCTION

The location and the shape of buildings are not only needed in city management, but also receive many emerging industrial's respect recently. Cyber city provides more spatial information than the traditional two-dimensional maps. It also provides the functionality to comprehensively integrate all information. But inevitably, Cyber city also has the same issue with traditional map regarding the timely requirement. Therefore the effective revision of spatial data becomes urgent. As change detection is an important step in data updating, some methods used the multi-temporal high-resolution imagery, detects changes by the spectrum difference or uses supervise classification to discover the building position to carry out the comparison for change detection (Knudsen and Olsen, 2003). In seeking the building position by the supervise classification, it would be unreliable when the non-building spectrum information and the building spectrum information are similar. If the new building's roof spectrum information is not similar with training area, it may wrongly discover the new building. Furthermore, using spectrum information to detect change doesn't consider the situation when the difference occurs in shape instead of color.

The method of change detection can mainly be divided into two categories. The first is to perform classification firstly then compare the surface difference between two periods. The second is directly determining change by the difference between two data sets. A number of researches, such as Knudsen and Olsen (2003), Matikainen *et al.* (2004), Walter (2004a), and Walter (2004b) belonged to the first category. This category is highly depending on the classified results. In addition the threshold of deciding change is difficult to choose. The second category (Murakami *et al.*, 1999; Jung, 2004) is unable to know the land category because no classification is used. It is also observed that trees often cause mistakes in many researches.

Instead of the spectrum imagery that often used in the past, many change detection methods using LIDAR data are proposed. One of the methods used the DSMs (Digital Surface Model) produced by different period of LIDAR data to detect changes (Murakami *et al.*, 1999). Girardeau-Montau *et al.* (2005) directly used point-to-point position relations for change detection. Walter (2004b) used LIDAR data in an object-based classification to determine the land-use category after the observation of land phenomenon. Matikainen *et al.* (2004) divided LIDAR point cloud into homogeneity area, and then extracted information to discover the building area for change detection. In the majority of researches, the old data set is often the vector map (Knudsen and Olsen, 2003; Matikainen *et al.*, 2004), LIDAR data (Girardeau-Montau *et al.*, 2005; Murakami *et al.*, 1999), or aerial imagery (Jung, 2004). On the other hand, change detection that used 3D model as earlier period building data are rarely reported. The objective of this paper is to detect building changes by using old building model with new LIDAR data and aerial imagery. The workflow of this investigation is shown in Fig.1.

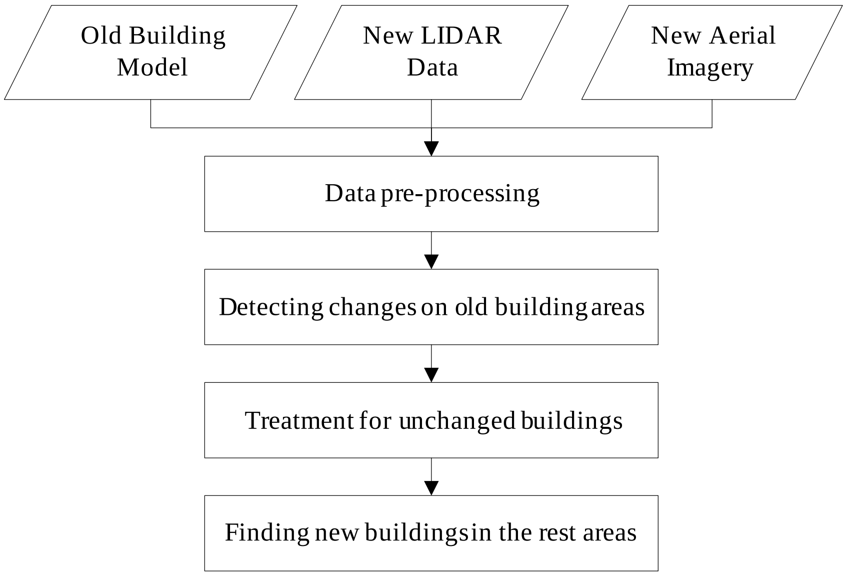


Fig.1. The workflow of investigation

2. DATA PRE-PROCESSING

Firstly, we use LIDAR data to produce DSM and DTM. Then three major steps are included in this part: (1) data registration, (2) occlusion removing, and (3) removements of ground and vegetation areas. Considering the differences of coordinate systems among three data sets, it is necessary to perform registration. Before we use multi-spectra information to discover vegetation areas, we need to do true-orthorectification for images. It includes detect occlusion to avoid double mapping (Chen *et al.*, 2006). Because ground and vegetation usually result in wrong detection, we remove ground and vegetation areas in LIDAR data and aerial images.

We measure control points and select the mapping functions to register the three data to the same coordinate systems. There are plane registration and elevation registration. The plane registration takes the imagery coordinate system as the reference. The elevation registration takes the LIDAR coordinate system as a reference. The plane registration tests affine transformation with respect to 2D shifts. The elevation registration tests two equations, the first one contains the scale and translation parameters as expressed in equation 1. The second equation has a translation as expressed in equation 2, where Z is in the LIDAR coordinate system, z is in the building model or the imagery coordinate system, S is the scale parameter, and T is the shift parameter.

$$Z = S \cdot z + T \tag{1}$$

$$Z = z + T \tag{2}$$

We use H-buffer to detect the occlusion areas (Chen *et al.*, 2006). We then subtract DTM from DSM to generate nDSM. For those parts lower than 2m in the nDSM is considered as ground areas. We then use the multi-spectral information to produce NDVI and through ISODATA classification to identify vegetation areas.

3. DETECTING CHANGES ON OLD BUILDING AREAS

We use building model and the DSM to remove vegetation and ground to locate the unchanged building. We then mark the unchanged building areas in next step and retain changed buildings. We use building corner coordinates to calculate coplanarity parameters A, B, C in equation 3. We then calculate the height difference between the one extracted from DSM with respect to the fitting plane.

$$Z = AX + BY + C \tag{3}$$

We set a $\pm$3m threshold for height difference to discriminate changed and unchanged pixels. Because the building edges in DSM are not distinct, we use morphology to remove 2m area around building edges.

The workflow of determining changes is shown in Fig.2. We examine the changed pixel number in every polygon firstly. If it reaches 50% of the polygon or the area bigger than 25m^2, a change is assumed. Then we use vegetation indexmap generated in first step to determine if the polygon is vegetation occluded or not. As the vegetation area in polygon more than 60%, we take the polygon as vegetation occluded. If not, we use ground indexmap produced in first step to determine demolished buildings. When the ground area in polygon is more than 60%, we recognize the polygon demolished, or the polygon is new or internal-changed.

If changed area under 50% and smaller than 25m^2, we then assume the unchanged pixel number in polygon. As unchanged area reaches more than 80%, the polygon is recognized as unchanged. Otherwise the polygon will be checked if it is vegetation occluded or demolished. If neither, we recognize the polygon as undetermined.

4. TREATMENT FOR UNCHANGED BUILDINGS

In this step, we exclude the DSM area of unchanged buildings that have been determined in the last step. We ensure that the buildings discovered in the following step are new or changed.

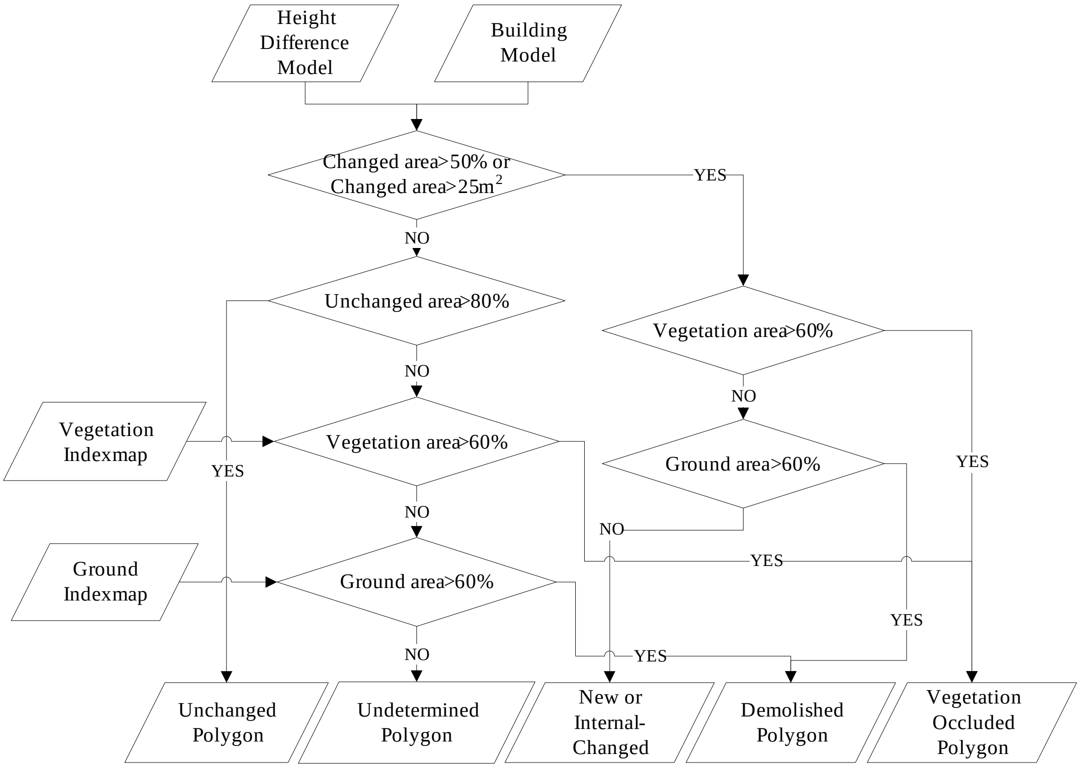


Fig.2. The workflow of change determination

5. FINDING NEW BUILDINGS IN THE REST AREAS

Because we have excluded the vegetation, ground area and the unchanged buildings region, it can be considered the rest areas as new or changed buildings. However, there also has some linear noises and small region. So we use morphology opening to remove the noises. Finally, the result is considered the new and changed buildings.

6. EXPERIMENT AND RESULTS

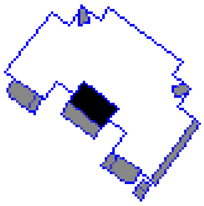
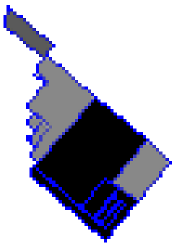
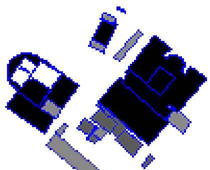
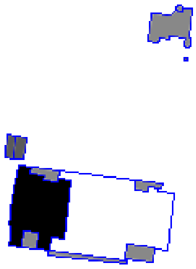
The test site is located at Hsin-Chu city of north Taiwan. The old building models are prismatic ones, which were acquired from 2002 data set. The aerial images were acquired using an UltraCam-D aerial digital camera in 2005/6 with 12cm resolution. The LIDAR point clouds were acquired using Leica ALS50 with a density of 1.5pts/m^2 also in 2005/6.

In plane registration of building model with imagery, the RMSE of the affine transformation is 0.190m when 5GCPs and 35ICPs are used; and the RMSE of the 2D shifts transformation is 0.192m when 11GCPs and 35ICPs are used. In plane registration of LIDAR with imagery, the RMSE of the affine transformation is 0.393m when 11GCPs and 35ICPs are used; and the RMSE of the 2D shifts transformation is 0.392m when 10GCPs and 35ICPs are used. There isn't much difference between the two registration functions, so we choose 2D shifts transformation. We test two functions in the elevation registration. The first contains the scale and translation parameters as expressed with equation 1 and the second has a translation parameter as expressed with equation 2. In the registration of building model with LIDAR, the RMSE is 0.878m for equation 1 when 19GCPs and 38ICPs are employed. The RMSE is 0.875m for equation 2 when 14GCPs and 38ICPs are used. In the elevation registration of Imagery with LIDAR, the RMSE is 1.040m for equation 1 when 8GCPs and 35ICPs are used. The RMSE is 1.081m for equation 2 when 6GCPs and 35ICPs are used. The results of two transformations are also similar, so we choose a translation parameter as expressed in equation 2.

In Table.1, there are four typical areas in the test site. The building in (a) is unchanged. A changed and a demolished building are included in (b). Case (c) has a new building in upper part of image, an unchanged in left part of image, a rebuilt in right part of image, and some small buildings. Case (d) has a new building in upper-left part of image, a demolished in middle-left part of image, and two unchanged in lower and upper-right part of image.

We may observe that all changes can be found in these areas. However, it still has some commissions. There are five reasons that cause commission errors. Firstly, because of the additional objects on the roof, like standpipes or air conditioners, were not included in the building model. The changed and undetermined polygons in (a), the undetermined polygons in (b), and the changed polygons in the left part of (c) are examples. Secondly, because we remove the areas close to edges, the remaining pixels are insufficient to determine the status, especially small polygons. For example, there are small polygons recognized as undetermined in four areas. Thirdly, the partly occluded by tree may cause insufficient information such as the polygon in lower part of (c) recognized as undetermined. Fourthly, the imprecise of produced DSM causes the polygon recognized as changed in (d). Fifthly, the vegetation detection can not apply when the area is occluded, so the new and changed building we found could be a tree. For example, the new object we found in upper part of (d) may be a tree.

Table.1. Change determination and finding new and changed buildings results

	(a)	(b)	(c)	(d)
Old Aerial Image				
New Aerial Image				
Change Determination (B: changed, W: unchanged, LG: undetermined, DG: vegetation occluded and demolished)				
New and changed buildings (White areas)				

7. CONCLUSION

In this study, we have proposed a scheme to detect changes in old building models with new LIDAR and aerial imagery. With the method, the changed buildings can be found mostly. Most errors are caused by the imprecise of the original building models. So if the data sets can accurately describe the real world, the proposed method may achieve higher accuracy. Besides the incompleteness of building models, there are some other data set can't accurately describe the real world. For example, the DSM interpolation error from sparse LIDAR points should be improved.

It would be a positive idea to use discrete LIDAR point clouds instead of DSM to alleviate the interpolation error. The spectrum information of aerial imagery can also be used to refine the resultant, not just used in the vegetation detection.

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