FEATURE ANALYSES FOR GEODATABASE MAINTENANCE USING AERIAL IMAGERY AND LIDAR DATA

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Abstract: The maintenance of city geodatabase is an essential work. Parts of buildings may be removed or rebuilt in different periods so that the geodatabase should be timely updated. However, to renew all building models in a city scale is costly and time consuming. Change detection of building models for maintenance, thus, becomes a valuable alternative. In the geospatial area, airborne LIDAR data provides accurate elevation information, and aerial imagery shows rich 2D features. This investigation integrates the latest LIDAR data and aerial imagery to detect changed buildings for further reconstruction processes. Considering the geometric displacements between these two heterogeneous datasets, data registration should be done in advance. Traditional methods modified these local displacements through selected corresponding features. For the improvement of automation, this investigation implements a feature-based method to enhance data registration and change detection at the same time. The proposed scheme contains three steps: (1) feature detection, (2) data registration, and (3) change detection of existing building models. The first step detects linear features from aerial imagery and LIDAR data. These detected features provide the geometrical clues for the detection of building changes. The second step selects unchanged buildings for data registration. We also employ these features to compare with building models and fine-tune the registration results. The last step estimates changed buildings, which have different structure lines between models and used datasets. The preliminary results indicated that the feature-based concept could enhance the procedures of data registration and change detection with better performance.

1. INTRODUCTION

Following the urban evolution, to timely update residential conditions is an essential task for the geodatabase maintenance. Nevertheless, the establishment of an entire geodatabase requires huge efforts. From the cost point of view, the detection of changed buildings may provide an efficient way to maintain the geodatabase with focused targets. In addition, the benefit of change detection may also help the increment of maintenance frequency to monitor urban evolution and identify illegal buildings (Bouziani et al., 2010). Based on the above considerations, many studies have proposed different approaches using varied datasets including aerial imagery (Knudsen and Olsen, 2003), satellite imagery (Metternicht, 1999; Bouziani et al., 2010; Champion et al., 2010; Koc-san and Turker, 2012; Du et al., 2012), aerial imagery and airborne LIDAR data (Chen et al., 2012).

In the image analysis, the classification concept involves in the detection processes using multi-temporal images. Metternicht (1999) implemented a fuzzy approach to segment building areas with collected training sets and compare with satellite imagery by the spectral distribution. These changed areas were marked for the geodatabase maintenance. However, the used fuzzy sets may require the prior knowledge to collect suitable training sets for deriving better results. For this reason, Knudsen and Olsen (2003) considered the existing database to identify the spectral distribution within building areas from aerial images and generate training sets for supervised classification. The drawback is that their spectral analysis is limited to the surface characteristics of rooftops. The material factor of building rooftops may cause higher false alarm. Therefore, Bouziani et al. (2010) employed geometric criteria with numerical parameters from the existing geodatabase to segment building areas in latest satellite images for updating. Their limitation might be constrained by shadows and occlusions, which disturbed building shapes and caused higher segmentation errors in the image space. Besides change detection processes with image processing, Koc-san and Turker (2012) simultaneously conducted the classification and three-dimensional geometric criteria to identify changed buildings using satellite images and digital surface models (DSMs). The existing geodatabase provides initial building areas to analyse the spectral distribution and compute geometric parameters. The prior information then compares with new images for detection processes. From the reconstruction point of view, LIDAR data was integrated in the change detection processes for the estimation of elevation changes (Chen et al., 2012).

They considered the spectral information and the point distribution to identify changed buildings and reconstruct new buildings for updating.

According to the previous studies (Chen et al., 2012), the combination of high-resolution images and LIDAR data indicates a useful way of change detection for the geodatabase maintenance. Within their results, the multi-layer decision tree systematically collected building information from images and point clouds. In the decision processes, the detection of building locations and areas highly relates to the point distribution and the point density. Therefore, the used thresholds play important roles, which directly influence detection results. To reduce the constraints of used thresholds, this study proposed a feature-based analysis to detect building boundaries for comparison using aerial images and point clouds. The proposed scheme implemented the techniques of feature detection for aerial images (Lo and Chen, 2011) and LIDAR data (Lo and Chen, 2012) for change detection. Furthermore, the data registration (Lo and Chen, 2010) was also considered in the processes to reduce the data displacement. The existing geodatabase provides the initial locations of buildings for feature detection, and this study then identifies the changed buildings when the target boundary mismatches the detected linear features.

2. METHODOLOGY

This study contains three steps, which are (1) feature detection, (2) data registration, and (3) change detection of existing building models. The proposed scheme analyses the local distribution to detect features from aerial images and point clouds. Two detected results contain planimetric feature lines and three-dimensional structure lines to compare with existing building models for registration. The following step then refines the relative locations to compare with building geometries. These changed buildings are marked and used to update geodatabase. The workflow is illustrated in figure 1.

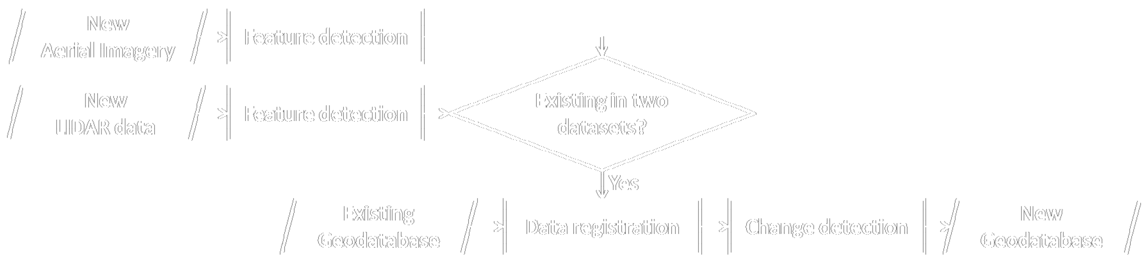


Figure 1: The workflow of proposed scheme

Feature Detection

To derive features for registration and change detection in an automatic way, this step implements the topological gradient analysis (TGA) (Lo and Chen, 2011) and the topological elevation analysis (TEA) (Lo and Chen, 2012) to identify linear features from aerial images and LIDAR data. Because each linear feature can be separated into several simple pieces, this study proposes a basic kernel to analyse the local distribution with a designed kernel in a 3 by 3 area (figure 2). Furthermore, the local distribution of each line should have small relief along the alignment and large relief cross the alignment. This step then bases on this concept to identify candidate feature grids using two directions, which are circular direction and radial direction (figure 3). For the improvement of feature detection processes, we designed twelve patterns to compare with local candidate grids instead of threshold operations. These designed patterns are illustrated in figure 4. After the candidate collection, this step derives image lines and 3D structure lines from aerial images and airborne LIDAR data for further steps.

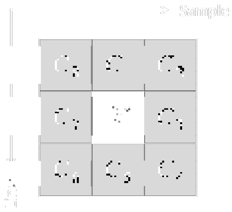
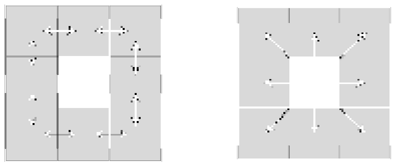


Figure 2: The basic kernel



(a) (b)

Figure 3: The analysed directions
(a) circular direction, (b) radial direction

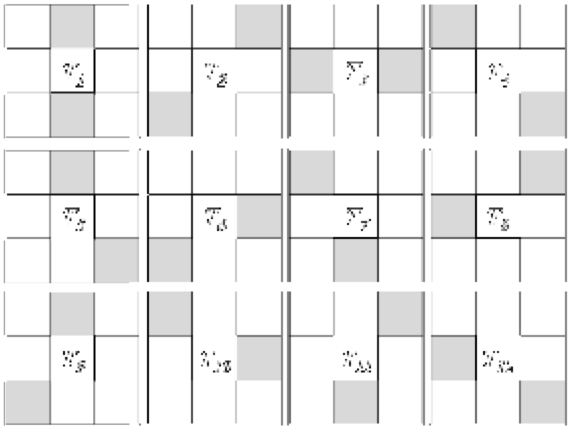


Figure 4: Designed patterns

Data Registration

The following part is to estimate the data displacement based on unchanged buildings in the geodatabase, aerial images, and LIDAR data. Because these heterogeneous datasets were captured from different sensors and production time, the data displacement may influence the results of change detection. For the consideration, this step selects some control points for the global registration. Due to each building boundary has its own specific geometry, figure 5 illustrates two different buildings with different parametric patterns in Hough space. So, these detected image lines and 3D structure lines are compared with existing building models to refine the global registration results.

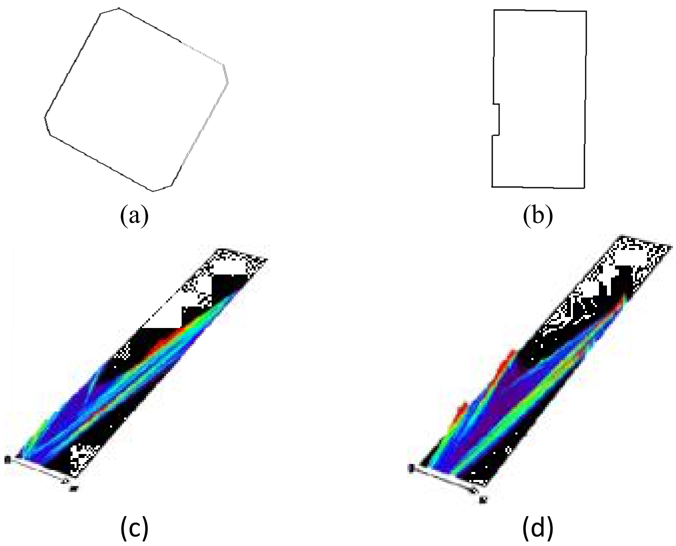


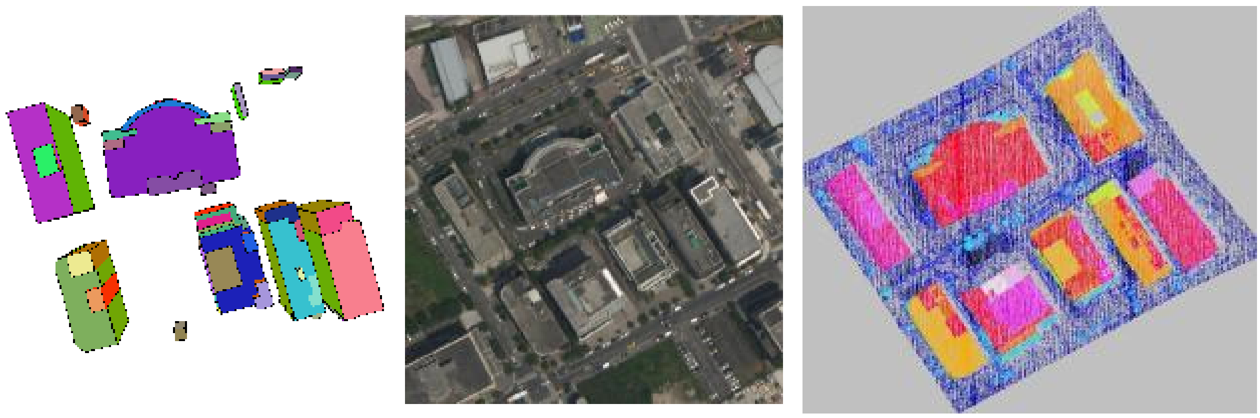
Figure 5: The parametric patterns of different buildings in Hough space
(a) building I; (b) building II; (c) Hough pattern I; (d) Hough pattern II

Change Detection

This step uses these registered features to compare with existing building models and identify changed targets by the geometric differences. In this part, we define that one totally changed building may have the different boundary and elevation of rooftop; one partially changed building may have unmatched structure lines or some removed sub-objects. According to the definitions, the proposed scheme identifies the elevation changes and boundary geometry to mark totally changed buildings first with an elevation threshold (H_{th}), an angle threshold (θ_{th}) and a number of structure lines (N_{th}). Note that the angle threshold plays the role to compare the orientation of detected lines with existing building models for change detection processes. The following step then identifies partially changed buildings with unmatched structure lines within the building boundary.

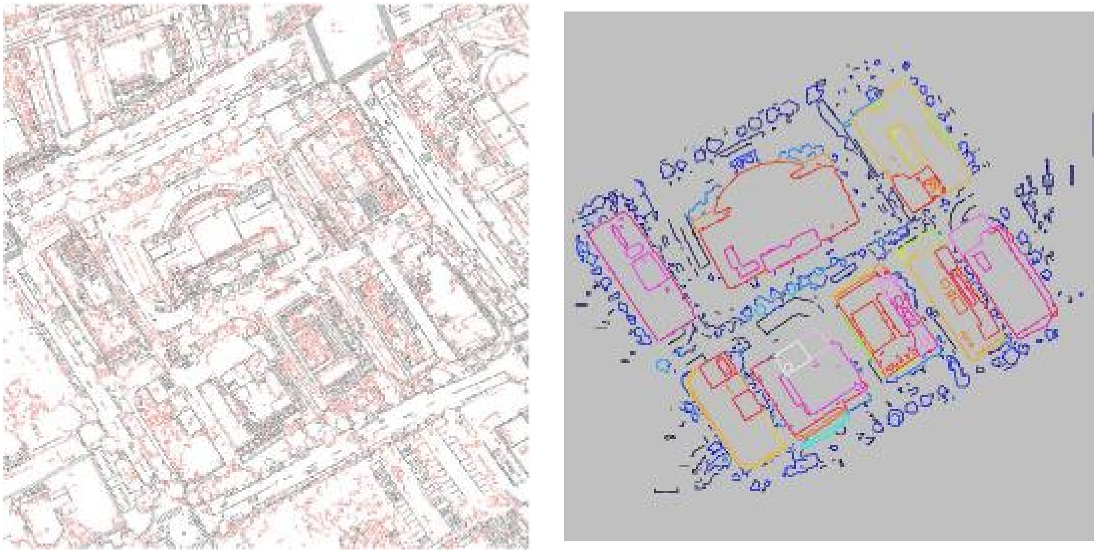
3. EXPERIMENTAL RESULTS

For the estimation of proposed scheme, this study selects Neihu district, Taipei city as the test area in Taiwan. The building models from existing geodatabase were produced using aerial stereopairs in 2007. Eleven buildings located in this area in 2007. The latest aerial image was captured with a 10 cm spatial resolution by DMC II in 2011. Leica ALS50 scanned the LIDAR data with the density of 10 points per square meters in 2011. The elevation range of point clouds is from 3.44 to 44.89 m. Figure 6 illustrates the used datasets including the previous building models, the latest aerial image and LIDAR data. After the processes, figure 7 shows the detected results of image edges and 3D structure lines. The proposed scheme then uses these features to identify the changed parts of previous building models. In the classified results, figure 8 uses red lines and green lines to indicate existing buildings and detected structure lines. The changed buildings and removed buildings are marked as yellow polygons and black polygons, respectively. Because there are some structure lines of cooler systems existing on rooftops, these buildings are regarded as changed parts. In addition, there are some ambiguities marked as red polygons because these objects only exist in aerial imagery. These three polygons thus are missed in the change detection processes because the detected features are inconsistent in the aerial imagery and LIDAR data. These three small targets only exist in the aerial imagery so that the proposed scheme cannot identify their conditions in the processes. The classification results are shown in table 1.



(a) (b) (b)

Figure 6: The used datasets in the test area
(a) previous buildings; (b) aerial imagery; (c) airborne LIDAR data



(a) (b)

Figure 7: The detected features from used datasets
(a) image edges; (b) 3D structure lines

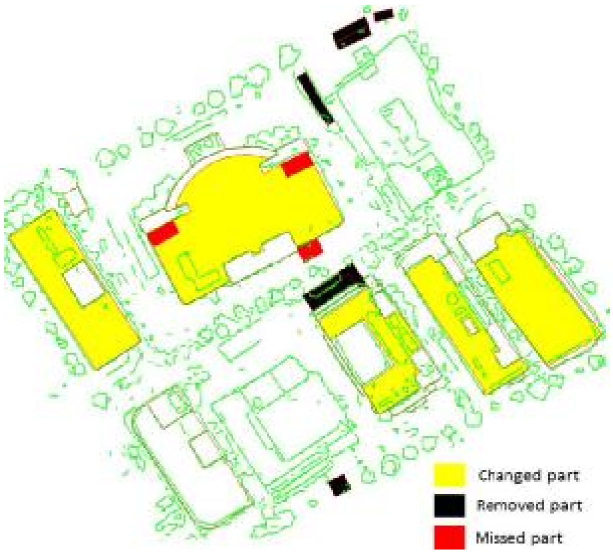


Figure 8: The detected results in the test area

Table 1: The classification results

Total polygons in the previous geodatabase	**44**
Changed parts	5
Removed parts	6
Missing parts	3
Unchanged parts	30
(Unit: polygon)	

4. CONCLUSIONS

The proposed scheme continued the previous works for data registration and change detection using detected linear features. The aerial imagery and airborne LIDAR data were integrated. In these preliminary results, the changed buildings and removed buildings were successfully identified so that the proposed scheme can update changed parts of the geodatabase in this small area. In the validation of preliminary results, 44 polygons were estimated for change detection. The proposed scheme successfully identified 41 polygons and missed 3 polygons. The missed parts were small objects and only existed in aerial imagery. For the new buildings, our future work will base on these detected structure lines to reconstruct building models and maintain the database.

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