

REVISION AND RECONSTRUCTION OF 3D BUILDING DATA BY INTEGRATING STARIMAGER/TLS IMAGERY AND COMPLEMENTARY DATA

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ABSTRACT:

Change extraction of building is needed to revise building data effectively. Many change detection algorithms use height difference analysis using temporal data such as LIDAR. However, remarkable changes of buildings cannot be detected in urban dense areas. On the other hand, building textures might change with higher possibility. However, the change cannot be detected due to influences of shadows and occlusion caused by nearby buildings in urban dense areas. Therefore, we have proposed a method to revise 3D building data by integrating texture change (roofs and walls) and 3D shape change of buildings using STARIMAGER/TLS (Three Line Sensor).

1. INTRODUCTION

Change extraction of building is needed to revise building data effectively. The change may be “shape change” of roofs and walls, “texture change” of roofs and walls or “attribute change” such as owner’s name. These changes occur due to reconstruction or demolition of the building. Many change detection algorithms use height difference analysis using temporal data such as LIDAR. However, remarkable changes of buildings cannot be detected in urban dense areas since most of the buildings are built on full lot size due to very small lot area. Therefore, when only building shapes are used for building change detection, a correctness of the change detection in dense area is lower than that in suburbs in many cases.

On the other hand, building textures might change with higher possibility. However, the change cannot be detected due to influences of shadows and occlusion caused by nearby buildings in urban dense areas. Though digital aerial photos and satellite images are used in existing research, these images have disadvantages such as occlusion and low resolution. Moreover, when only roof textures are used, all changes cannot be detected in images even if buildings change.

Therefore, we have proposed a new method to revise 3D building data automatically by integrating texture changing (roofs and walls) and 3D shape changing of buildings using STARIMAGER/TLS (Three Line Sensor) in this paper.

2. METHODOLOGY

At first, 3D building texture data, which is assumed as existing data, are prepared. The data include not only roof textures but also wall textures. If the data do not exist, they can be generated from TLS images, which are acquired at different time period than the TLS data for change detection.

Next, candidates of building shape changes are detected by using DSM of existing 3D building data and DSM generated from TLS image acquired for change detection. Approximate changes, which are probability of shape change in urban areas, are detected. This preliminary information is assigned to each building.

Then, existing 3D data are projected in TLS images. Building changes are detected by using the preliminary information and changes of textures in the TLS images. Not only roofs but also walls are referred in this processing. Building shadows are extracted from TLS images by using the temporal information of the data acquisition. TLS images are enhanced not to influence the texture change detection.

Moreover, when buildings with changes are detected in the existing TLS images, new 3D data are reconstructed at the same location by using initial values. The initial values are based on DSM generated from TLS images, a building template model and surrounding information.

3. STARIMAGER/TLS (THREE LINE SENSOR)

STARIMAGER/TLS (Three Line Sensor) is an optical sensor for aerial survey. TLS is composed of three linear CCD arranged in parallel, and it can acquire three images of each direction (forward, nadir and backward) at the same time as Figure.1 shows. The sensor is oriented on an aircraft perpendicularly to flight direction and scans the ground plane. Therefore, a triple stereo image of a ground object can be acquired.

TLS images are ultra high-resolution (spatial resolution: 3cm) images, and it can acquire triple stereo images at the same time. Additionally, TLS images have more advantages such as less influence of occlusion and information from roofs as well as walls.

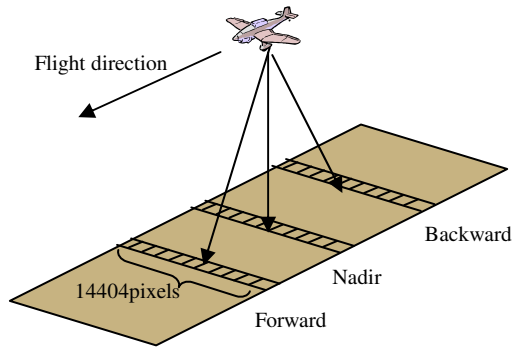


Figure. 1. Method of getting data with TLS

4. EXISTING 3D DATA

3D building texture data, which is assumed as existing data, are prepared beforehand. The data include not only roof textures but also wall textures. If the data do not exist, they can be generated from TLS images, which are acquired at different time period than the TLS data for change detection.

Additionally, 3D data with high representation are required to refer textures in TLS images correctly in this method. For example, Figure.2 shows a result of overlaying low-level 3D data on a TLS image. As this figure shows, the low-level 3D data cannot be referred corresponding texture correctly.

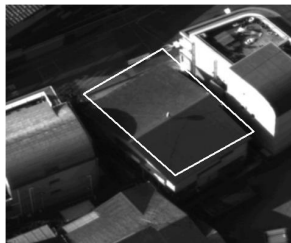


Figure. 2. Low-level 3D data

Therefore, high-level 3D data must be prepared such as Figure.3.

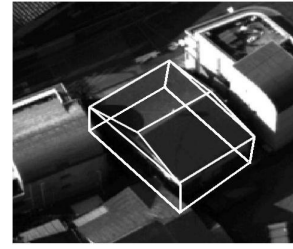


Figure. 3. High-level 3D data

Though many 3D data exist in urban areas, high-level 3D data such as TLS-scale 3D data exist seldom. Based on these, we have developed the snake-aided 3D data refinement method for this processing [1]. The followings show examples of the SNAKE-aided 3D data refinement (Figure.4-Figure.6).



Figure. 4. Refined 3D data



Figure. 5. Refined 3D data

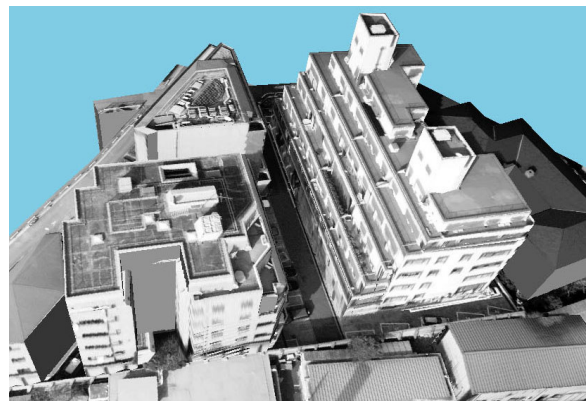


Figure. 6. Refined 3D data

5. CHANGE DETECTION

Urban dense areas have various sizes of buildings. Therefore 'coarse change detection' and 'fine change

detection' approaches are proposed in this paper. A first approach is to find candidates of building shape changes, especially height changes, for large buildings. A second approach is to detect candidates of building's shape and texture changes for small buildings.

5.1 Coarse change detection

Candidates of building shape changes are detected by comparing DSM (or height information) of existing 3D building data with DSM generated from TLS image. Coarse changes in urban areas are detected, which is probability of shape change. This preliminary information is assigned to each building.

In fact, when there is a building demolition, a building height is changed from an existing level to a ground level. When a new building is built up, the building height is changed along an opposite direction. Moreover, when a building is reconstructed, there are some changes of building height.

This method is effective to detect changes of large buildings such as department stores or multi stories parking lots, etc. in a viewpoint of processing time. However, most of small building changes cannot be detected since they are built on full lot size due to very small lot area. Therefore, fine change detection is applied to all buildings including these small buildings.

5.2 Fine change detection

Existing 3D data are projected into TLS images. Building changes are detected by using changes of textures in the TLS images and the preliminary information. Not only roofs but also walls are referred in this processing. Building shadows are extracted from TLS images by using the temporal information of the data acquisition. TLS images are enhanced not to influence the texture change detection. Details are described in the followings.

1) Decomposition

Existing 3D data are decomposed to roof polygons and wall polygons as Figure.7 shows. A classification of roofs and walls is done based on the roof model, which represents buildings by using roof boundaries, in the SNAKE-aided 3D data refinement processing.

2) Back-projection

These polygons are back-projected into visible TLS images; since occlusion, which is caused by surrounding buildings, can be guessed by a geometric processing. Generally, roof textures are back-projected to a TLS nadir image, and wall textures are back-projected to TLS forward / backward images. When non-textured polygons exist or TLS images do not have corresponding areas with polygons, they are not back-projected to TLS images.

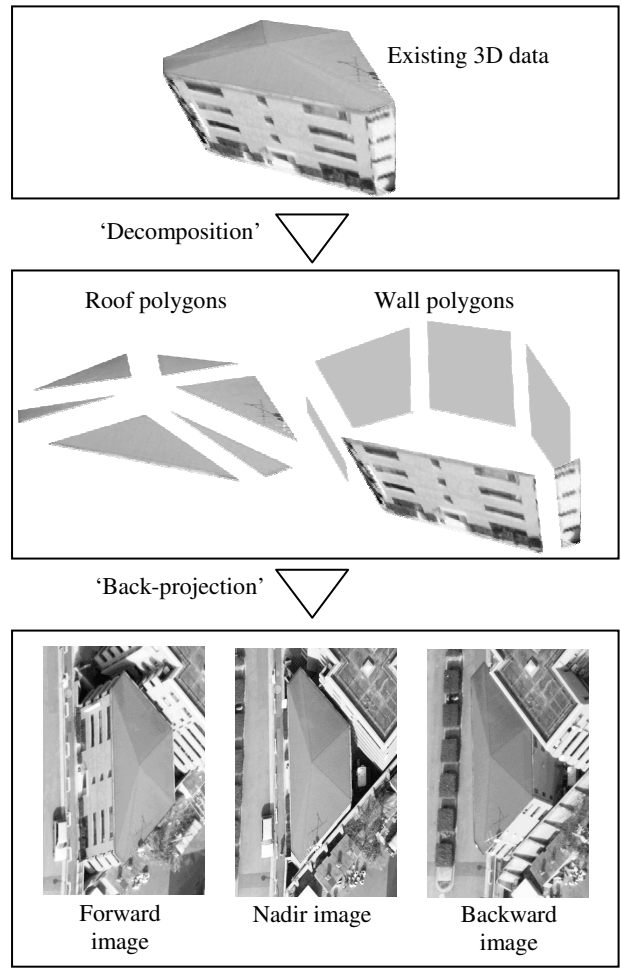


Figure. 7. Texture reference

3) Polygon based area correlation

A polygon based area correlation is calculated between existing 3D data and TLS images. An equation of the polygon based area correlation including parameters is described in eq.1.

$$C_{total} = (f_{\text{roof}} * C_r + f_{\text{wall}} * C_w) / (f_{\text{roof}} + f_{\text{wall}}) \quad (\text{eq. 1})$$

$$C_r = \sum_{k=1}^{N_r} (C_{rk}) / N_r$$

$$C_w = \sum_{k=1}^{N_w} (C_{wk}) / N_w$$

where

Crk : Correlation coefficient in each textured roof polygon

Cwk : Correlation coefficient in each textured wall polygon

Nr : Number of textured roof polygons

Nw : Number of textured wall polygons

f_{roof}, f_{wall}; Weight parameters

C_{total}; Result value for for change detection

A theory threshold value of a correlation coefficient in building change detection is not approximately 1.00.

However, actually, noises such as electric poles, electric cables and trees exist in textures in many cases, even if nadir images are used. Therefore, the threshold value of change detection should be set a lower value. In our preliminary study, a best threshold of building change detection is 0.8-0.9. Based on this processing, building demolition and reconstruction can be detected. The correlation coefficient is less value than the threshold, when buildings are disappeared or constructed (See, Figure.8). However, a case, which a new building is built up in a vacant lot, cannot be applied to this change detection algorithm, because initial polygons do not exist. In this case, lot boundaries obtained from GIS data can be used for this processing.

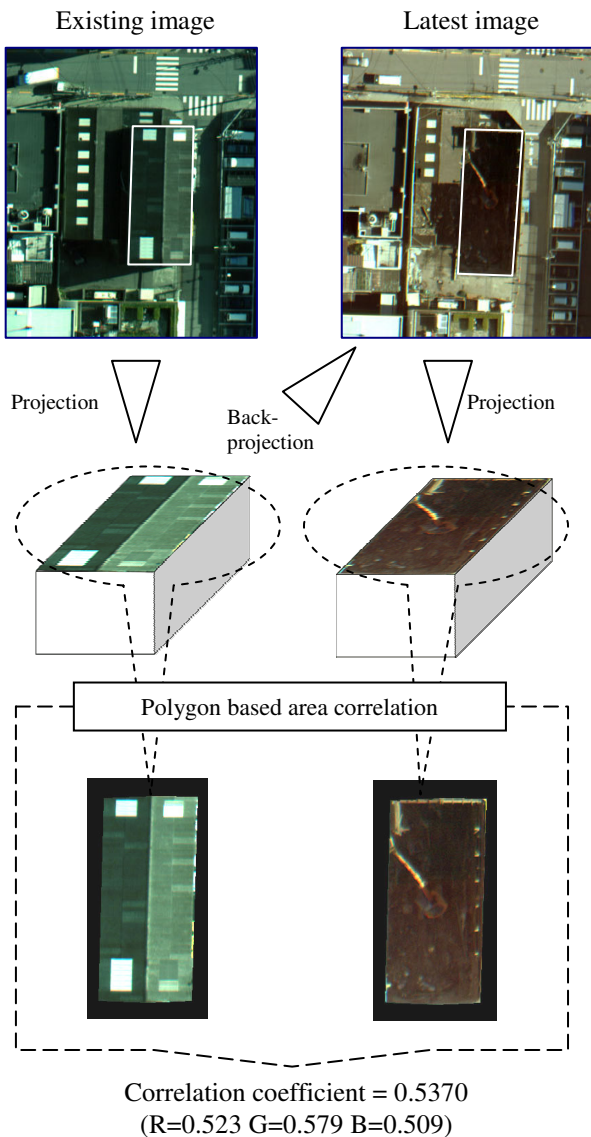


Figure. 8. Example of preliminary study (Comparison of roof polygon)

6. NEW 3D DATA CONSTRUCTION

While buildings with changes are detected in the existing TLS images, new 3D data are reconstructed at the same location by using initial values. The initial values are based on DSM generated from TLS images, a building template model and surrounding information. Based on this algorithm, a feature based matching is applied to reconstruct new buildings. However, especially in urban dense area, it is difficult to detect building boundaries due to a complexness of a building feature. Therefore, authors have developed the semi automatic matching based building extraction application. This application requires only polygon input manually in a single image without stereoscopic measurement, and it generates 3D data automatically, as Figure.9 shows [3].

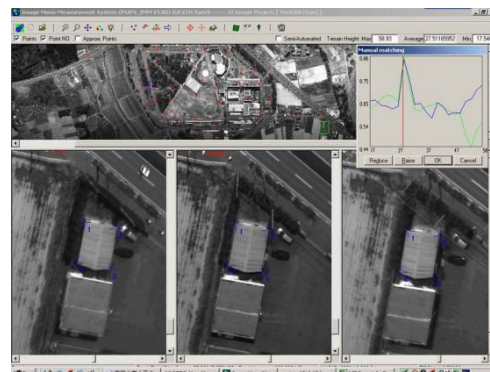


Figure. 9. Semi-automatic matching based building extraction application

7. CONCLUSION

The method of revision 3D building data by integrating texture change (roofs and walls) and 3D shape change of buildings using STARIMAGER/TLS (Three Line Sensor) is proposed in this paper. When high-level 3D data are prepared beforehand, this method is effective for automatic change extraction of 3D building data in urban dense areas.

8. ACKNOWLEDGEMENT

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