Fusion of LIDAR Data and Aerial Images for Building Reconstruction

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Abstract: From the view point of data fusion, we integrate LIDAR data and digital aerial images to perform 3D building modeling in this study. The proposed scheme comprises two major parts: (1) building block extraction and (2) building model reconstruction. In the first step, height differences are analyzed to detect the above ground areas. Color analysis is then performed for the exclusion of tree areas. Potential building blocks are selected first followed by the refinement of building areas. In the second step, through edge detection and extracting the height information from LIDAR data, accurate 3D edges in object space is calculated. The accurate 3D edges are combined with the already developed SMS method for building modeling. LIDAR data acquired by Leica ALS 40 in Hsin-Chu Science-based Industrial Park of north Taiwan will be used in the test.

Keywords: LIDAR, aerial image, data fusion, building model, digital terrain model, digital surface model

1. Introduction

In the recent years, more and more applications ask for 3D city models, such as urban planning and landscape visualization. Building models are the objects of highest interest in 3D city modeling. Research of building reconstruction nowadays aims to develop an automatic method from the present data. For the developments in sensor technology, LIDAR (LIght Detecting And Ranging) offers a new efficient data acquisition method for measuring urban objects in three dimensions (Wehr & Lohr, 1999). The key point of our research is the data fusion. The principal idea is to combine LIDAR data with aerial images for the reconstruction of building models. The research of building reconstruction presented in the following is solved in two steps. First, building blocks are to be extracted from the area of interest. That means the process will localize each building block. Second, we aim at the individual building block and detect the straight 3D lines followed by building reconstruction process.

2. Building Block Extraction

The extraction of building blocks includes three steps: (1) preprocessing of LIDAR data, (2) preprocessing of aerial images, and (3) data fusion.

1) Preprocessing of LIDAR data

The procedure starts from resampling the discrete points of LIDAR data into regular grid as DSM and DTM (Briese et al, 2002). Then we detect the above ground area by analyzing the height difference (Alharthy & Bethel, 2002). The above ground areas mainly consist of buildings and trees. We then use color information from aerial images to eliminate tree areas and retain building areas in the next step.

2) Preprocessing of aerial images

In this step, supervised classification is selected to extract the tree areas in the aerial image. We classify the image into four parts: (1) trees, (2) shades of trees, (3) man-made structures, and (4) shades of man-made structures. After the classification we combine the first two parts as tree areas and last two parts are the non-tree areas.

3) Data fusion and Building Blocks Detection

Referring to data fusion, the first step is to register the multiple data sets. In our research, exterior orientation parameters of aerial images are modeled first by using ground control points to register with LIDAR data. Using the parameters, LIDAR points in the object space (E, N, H) can be projected back to the image space (x, y). In the next step, all the pixels of above ground areas detected in the previous process are projected back to classified image. If the pixels of above ground are located at the tree area, the pixel is eliminated. After this step, a great part of trees are removed from above ground area. Then we group the remaining pixels into regions as candidate building blocks. By using the minimum building size as a threshold value, we exclude the small blocks. Through shape analysis, these blocks that do not meet the shape of man-made building are excluded. In the last step, surface roughness is analyzed for the remaining blocks to further identify the buildings.

3. Building Model Reconstruction

After extracting building blocks, each individual building block is isolated. Then we reconstruct the model from individual building block. Most of the buildings can be represented by a set of straight lines. The main work of our research is to detect straight lines from the data (Haala & Brenner, 1999). Our method of building modeling is to estimate the approximate edge from LIDAR data first. Based on the rough edges, we detect precise 3D edges in image space. Approximate edges in single building block are obtained by a Laplacian filter. The approximate edges with precise height information from LIDAR data are projected into aerial image to mark the working area for precise edge detection. At the same time, index image is generated which stores height information. Through the edge detection, straight lines in image space are detected. With the image coordinates (x, y) and the height information (Z) from index image, we can calculate the 3D edges in object space (X, Y, Z) by employing exterior orientation parameters.

The accurate 3D edges are combined with the already developed Split-Merge-Shape, SMS method (Chen & Rau, 2003) for building reconstruction.

4. Experiment and Result

The LIDAR data used in this research are of an area located in Hsin-Chu Science-based Industrial Park of north Taiwan obtained by Leica ALS 40 system. The discrete LIDAR points were classified into ground points and surface points previously. The average density of LIDAR data is about 2 points per square meter. The ground resolution of aerial image is 10cm per pixel.

In the extraction of building blocks, surface points from LIDAR data are resampled into raster form as DSM with a pixel size of 1m. The ground points are resampled as DTM with same resolution. The height threshold between DSM and DTM to detect above ground area is 3m. After color analysis, area of blocks is constrained with a minimum size of $30m^2$. After shape and height analysis, more then 95% buildings are accurately extracted, only 3 of 79 buildings in our test area are not detected. The steps of building blocks extraction for a subarea are demonstrated in Figure 1.

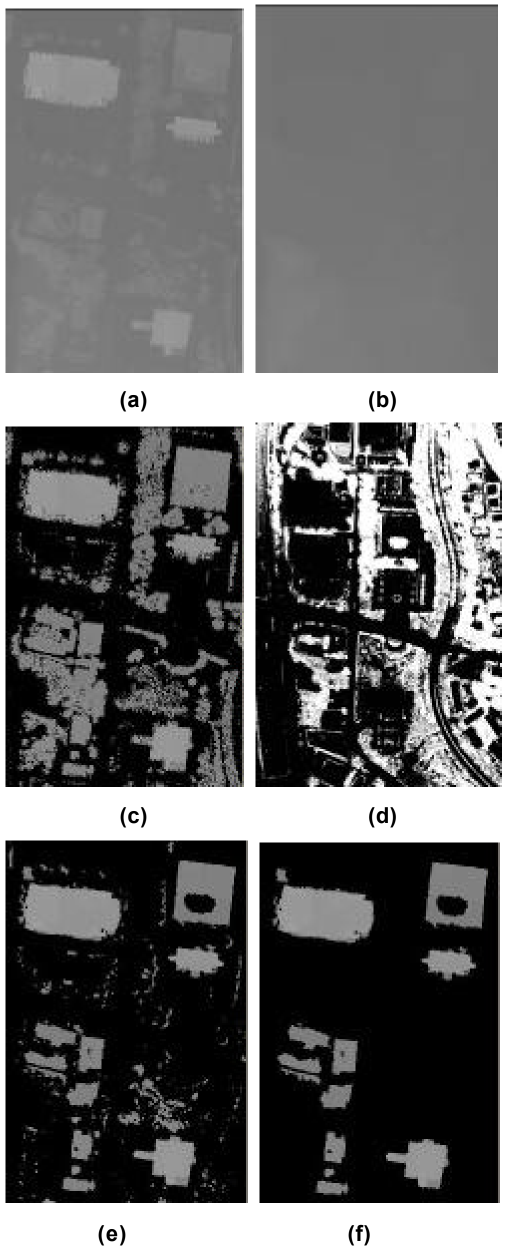
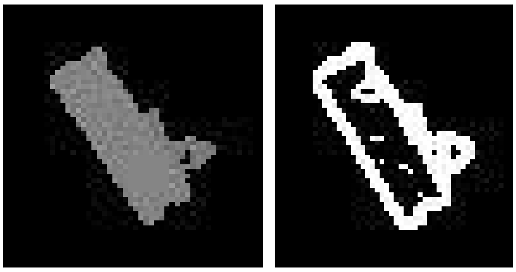


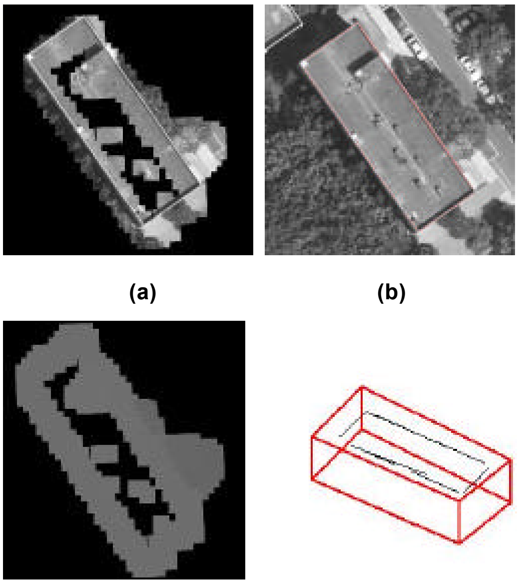
Fig. 1. Steps of building blocks extraction, (a) DSM, (b) DTM, (c) Above ground areas, (d) Classified image (white: tree, black: non-tree), (e) Above ground areas after color analysis, (f) Result of building blocks extraction.

In the step of building reconstruction, single building block is extracted, and edge is approximately detected. The edges are then projected into aerial image to mark working area for straight edge detection. Through edge detection, the precise edges are combined with the height obtaining from index image that can be projected into object space. After combining the 3D lines with SMS method, the building model can be reconstructed. Comparing the coordinates of 16 roof corners in the reconstructed models with the corners measured from stereo pairs, the rms errors are 0.48m, 0.41m, 0.64m in the X, Y, Z components, respectively. Steps and results are shown in figure 3 and 4.



(a) (b)

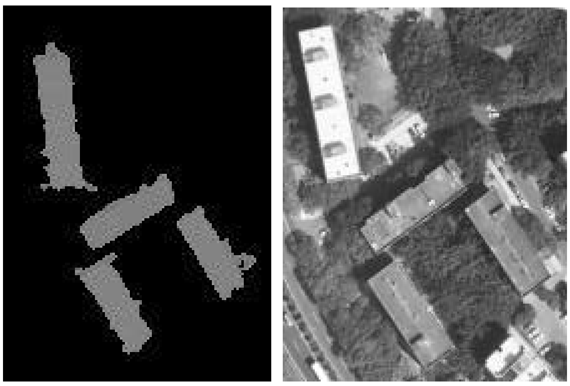
Fig. 2. Rough edge estimation from LIDAR data, (a) Single building block, (b) Approximate edges in building block



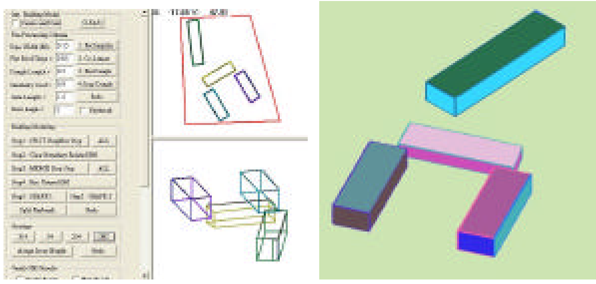
(a) (b)

(c) (d)

Fig. 3. Precise edge detection of aerial image, (a) working area in aerial image, (b) detected straight edge (red lines), (c) index image (gray level shows the height information), (d) 3D lines in object space



(a) (b)



(c) (d)

Fig. 4. Building models, (a) Building blocks in test site, (b) test area in aerial image, (c) SMS method, (d) Result of building models.

5. Conclusions

We have presented a scheme for the extraction of building blocks and building modeling by performing fusion of LIDAR data and aerial image. The result from the test site shows the potential of the automatic method for building reconstruction. More than 95% buildings are correctly detected by our approach. The building models generated by our method take the advantage of high horizontal accuracy from aerial images and high vertical accuracy from LIDAR data. Comparing the models reconstructed by our method with the measured roof corners from stereo pairs, the rms errors in horizontal and vertical are less than 1m. However, in this investigation, we only consider flat roof buildings. Multiple level roofs are not considered in the procedure. The improvements of the scheme for treating more complex buildings are the major works in the future.

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