FEATURE INTEGRATION FROM AIRBORNE IMAGERY AND LIDAR POINT CLOUDS

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ABSTRACT: Airborne imagery and LIDAR point clouds are complementary in terms of the geometric contents, so the integration of these two heterogeneous data sets is an important task in geospatial technologies. Airborne imagery has high horizontal accuracy for edges but its elevation is implicit. Lidar point clouds have higher elevation accuracy than airborne imagery but its edge is not clear. Thus, the proposed method integrates single imagery and LIDAR point clouds to reconstruct 3D building models.

The proposed scheme comprises five major parts, (1) Lidar data pre-processing, (2) determination of image feature extraction area of interest, (3) feature extraction, (4) data integration, and (5) 3D model reconstruction. In the Lidar data pre-processing, we obtain the initial boundaries via the method of elevation slicing, get the roof patches based on plane-fitting technique and analyze the Lidar data to generate models height. The initial boundaries are projected to the image space for the determination of an image work area in the second step. In the third part, we detect the edges in the image work area to find the candidate edges. In the fourth part, the back projected Lidar data is used to search for the precise edges. Each edge is vectorized to get line segments. Then, we project the line segments to object space to reconstruct 3D building models.

The proposed method is validated using manual measured 3D building models as reference data. The test data include (1) DMC aerial imagery with a spatial resolution of 17cm, and (2) Lidar point clouds from Leica ALS 50 with a spatial resolution of 10 points/m^2. The experimental results indicate that the reconstruction may reach high accuracy.

1. INTRODUCTION

The cyber city is an essential task in the three dimensional world for city planning, management, disaster prevention, and many other applications. Building reconstruction is one of the major part in the cyber city modeling. Nowadays, there is enormous information, such as aerial images, LIDAR (LIght Detecting And Ranging) data, radar image, map and so on. Since there are subtle discrepancies among different data, lots of researches proposed the approaches of integrating different data for building reconstruction. Lidar data and imagery are used in the building reconstruction frequently. Brenner (2005) proposed the combination between lidar data and airborne imagery can increase the quality and automation in building reconstruction.

There are many researches about feature extraction in Lidar data and imagery for building reconstruction; however, the judgement of building type and parameters are difficult. Habib et al. (2003) proposed the three dimension building reconstruction with line feature from stereo images. Teo et al. (2005) introduced the approach of elevation slicing and boundary regulation to determine the building roof and reconstruct the building via LIDAR data. Zhang et al. (2005) reconstructed 3D building models and map the texture with digital map, lidar data and video image sequence. Wu et al. (2010) introduced a linear registration algorithm for lidar point clouds and aerial images without orientation parameters. Habib et al. (2010) generated the complex polyhedral building models by integrating stereo-aerial imagery and lidar data.

Heterogeneous data have different characteristics; therefore, integration is important in various data. In order to describe the three dimensional world distinct, airborne imagery and lidar point clouds provide the most suitable sources. Thus, this paper proposes an approach that integrates the features extracted from lidar point clouds and airborne imagery. Digital images with high spatial resolution provide sharp edges, while the elevation is implicit. On the other hand, LIDAR data provide high accurate elevation but the planimetric resolution is lower. Therefore, the proposed method takes one aerial image and LIDAR data with the advantages of the two complementary data sets to reconstruct buildings.

The proposed scheme comprises five major parts, (1) Lidar data pre-processing, (2) determination of image feature extraction area of interest, (3) feature extraction, (4) feature integration, and (5) 3D building model reconstruction. First step, we find the building part from lidar data and then, generate the roof patch to discriminate the roof type. Building initial boundaries are extracted from roof patches and building heights are determined from lidar data analysis. Second step, the initial boundaries are back projected to image space for the determination of an image work area. The detected edges in the image work area are regarded as the candidate edges in the third part. In the fourth part, Lidar data are back projected to search for the precise edges. Each edge is vectorized to get line segments. Then, we project line segments to object space to reconstruct the 3D building models.

2. PROPOSED METHODS

The proposed method integrates the features extracted from LIDAR data and airborne imagery to generate the building initial boundary and building height. Flow chart of proposed methods is shown in figure 1.

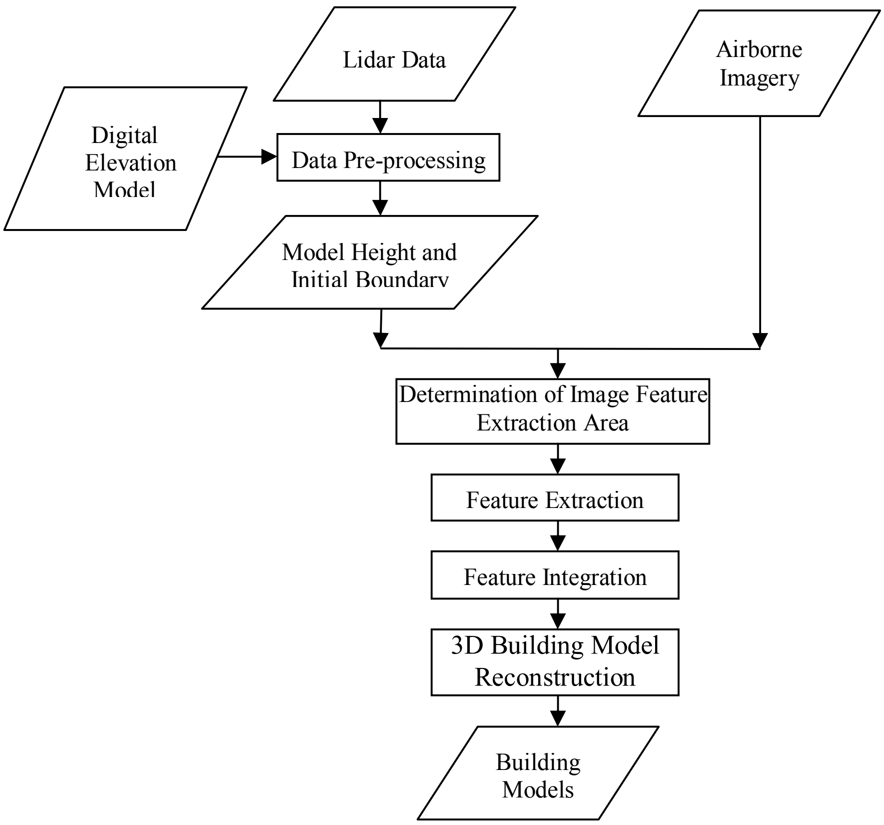


Figure 1 Flow chart of proposed methods

2.1 Lidar Data Pre-processing

Lidar data pre-processing comprises three parts, (1) TIN (Triangulated Irregular Network) construction, (2) roof patches construction, and (3) building height analysis. Finally, we can get the building initial boundary and model heights.

2.1.1 TIN construction: All the lidar point clouds are constructed to Delaunay triangulation network which is shown in figure 1. The triangulation network has two criteria: (1) maximum-minimum angle and (2) no point is inside the circumcircle of any triangle [Golias and Dutton, 1997]. After triangulation networked constructed, the normal vector in each triangle is calculated for wall filtering. If the angle between the horizontal plan and normal vector is large, then, we regard it as wall construction and filter it.

2.1.2 Roof patches construction: The co-plans are analyzed from triangulation network. We use the region growing [Rottensteiner, 2003] to segment the plan. In the region growing, the growing starts from a seed element and the surrounding elements are judged whether the characters between itself and seed elements are close enough. If the characters are similar, the element will be judged to same class. The plan equation can be calculated from each class. If two classes are adjacent and the planes are inclines, we regard the roof patches as a pitched roof and cross the roof plans to get the intersecting line.

2.1.3 Building height analysis: The heights of lidar point clouds in roof patches are calculated to determinate the height of initial building boundaries which are generated from roof patches. The three dimension coordinate of ridge in pitched roof are derived from the intersecting line.

2.2 Determination of image feature extraction area of interest

The initial boundaries are back projected to the image with collinear condition equations to find the correspondent part in the image. Since there is lots of information in the image, we open a buffer according to the initial boundaries to get the feature extraction area.

2.3 Feature Extraction

The features we extracted in this part is feature lines. We utilize Canny edge detector [Canny, 1986] to detect the feature lines which satisfy three requirements: (1) good detection, (2) good localization, (3) minimal response.

2.4 Feature Integration

The feature lines which in the buffer are complex could contain roof wall and shadow. Those are difficult to discriminate which one is the real boundary. We open a buffer along the initial boundaries to get the lidar point clouds on the roof line. Those lidar point clouds are projected to the image for assisting us to recognize the real boundary.

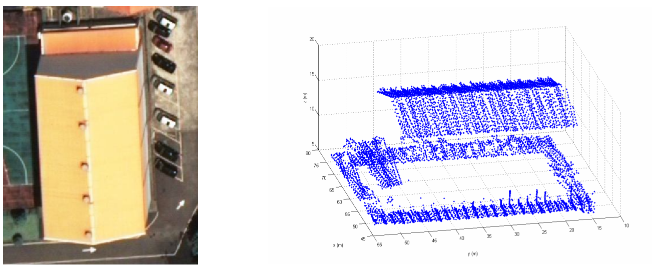
Due to the different resolutions between two data, we open a search window on the lidar points projected to the image space. If the edges are in the search window, then, we will regard it as the candidate edges. After the correspondent edges found, the edges are vectorized to the line segments via Hough transformation [Hough, 1962].

2.5 3D Building Model Reconstruction

The line segments are crossed to each other to generate the intersection points which mean the roof corners. Now, we already have the Eops of airborne image, image coordinates of roof corners, and model heights so we use the ray tracing to determine the roof coordinates in the object space. Finally, we can get the three dimension coordinates to reconstruct the building model.

3. EXPERIMENTS AND RESULTS

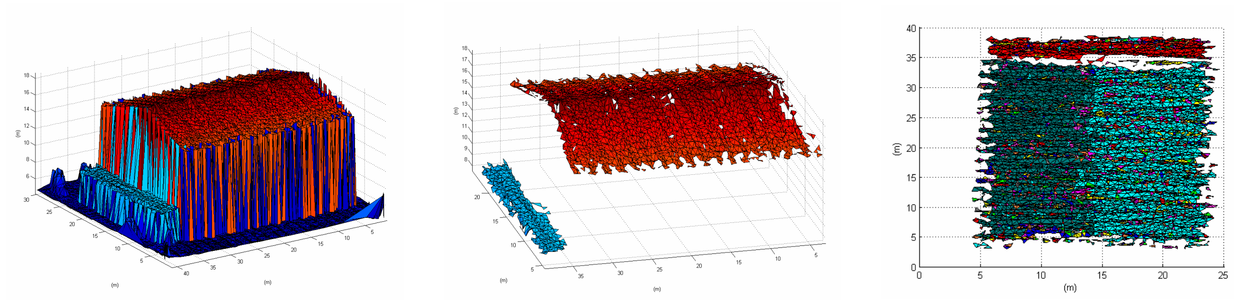
The data were obtained from DMC images and ALS 50 point clouds in the test. The resolution of the airborne image is 17cm and the average of LIDAR points is 10pt/m^2. The different data sources are showed in figure 2. The test data contain a pitched roof and a flat roof.



(a) (b)

Figure 2 Test Data
(a) Airborne imagery (b) Lidar point clouds

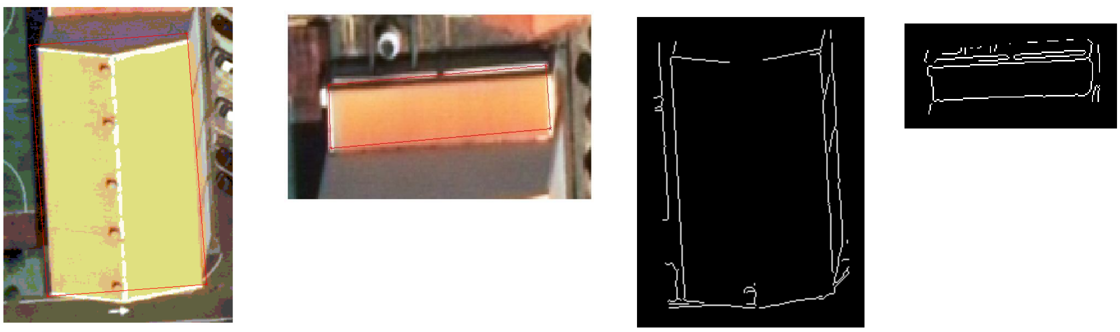
In the first part, lidar-preprocessing, the lidar point clouds are constructed to the TIN and the wall constructions are filtered. After filtering the wall constructions, region growing make the similar roof patches as the same class. The TIN construction, TIN construction without wall construction and the roof patches after region growing are shown in figure 3.



(a) (b) (c)

Figure 3 Results of lidar-preprocessing
(a)TIN construction (b) TIN construction without wall construction (c) Roof patches after region growing

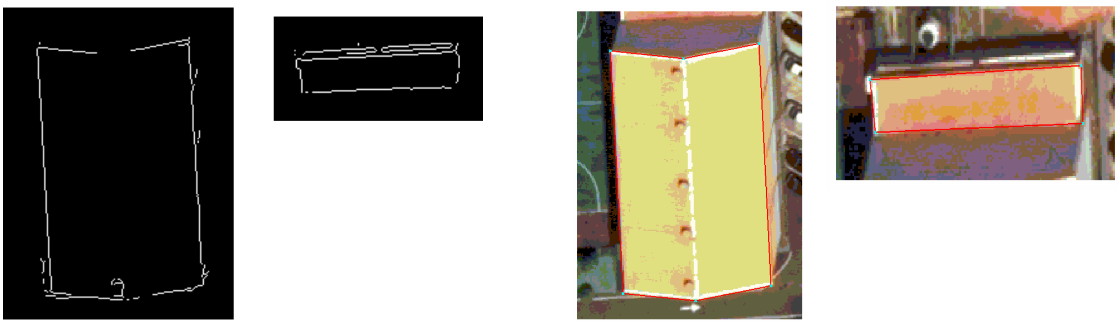
According to the roof patches, we can determine the initial boundaries and building height. Then, the initial boundaries are back projected to the airborne image with Eops and collinear condition equations. Based on the boundaries, we can open a buffer and detect the edges in the buffer. The initial boundaries and edges in the buffer are shown in figure 4.



(a) (b)

Figure 4 Edges detection based on the initial boundaries
(a) Initial boundaries in the image(b) Edges in the buffer

There still are lots of edges in the buffer. In order to find the real edges, we back project the lidar points to the image to help us to find the candidate edges. Hough transformation vectorizes the edges to the line segments and the line segments intersect to each other to generate the intersecting points. The candidate edges and line segments are shown in figure 5.



(a) (b)

Figure 5 Adjusted building boundaries in image space
(a) Candidate edges (b) Line segments composed of candidate edges

From the image coordinates of intersecting corners and model heights, we can determine the three dimension coordinate of roof corners via ray tracing. The reconstructed building model is shown in figure 6. The root mean square error (RMSE) between the determined coordinates and the stereo measurement of 3D building model are shown in table 1. The statistic heights in the flat roof are more accurate than the heights in the pitched roof. The image coordinates are the majorly factor to affect the horizontal coordinate so form the figure 5(b), the corners are similar to the real corners in image; hence, the planimetric errors are similar.

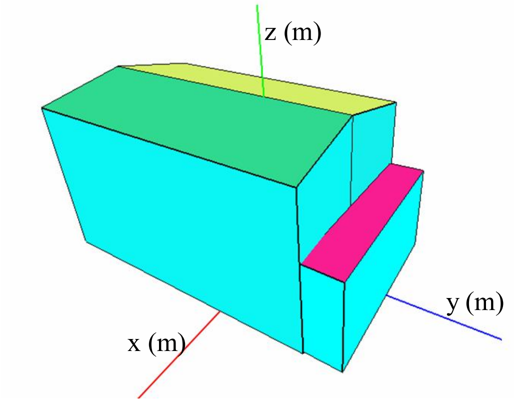


Figure 6 Reconstructed building model

Table 1 RMSE of building corners in object space

Construction	$RMSE_X$ (m)	$RMSE_Y$ (m)	$RMSE_Z$ (m)
Flat roof	0.373	0.156	0.118
Pitched roof	0.129	0.451	0.538

4. CONCLUSIONS AND FUTURE WORKS

A method that integrates lidar data and airborne imagery has been proposed. The accurate building boundaries may be located by the proposed method three dimensionally. The proposed method has a good performance in data integration. Since the integration between lidar point clouds and imagery provides degree of freedom for computational adjustment, the least squares solution is thus suggested in the future.

5. ACKNOWLEDGMENT

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6. REFERENCES

Brenner, C., 2005. Building reconstruction from images and laser scanning, International Journal of Applied Earth Observation and Geoinformation, 6(3–4), pp. 187–198.

Canny, J., 1986. A Computational Approach to Edge Detection, IEEE Transactions on Pattern Analysis and Machine Intelligence, 8(6), pp. 679-698.

Golias, N.A. & Dutton, R.W.,1997, “Delaunay Triangulation and 3D Adaptive Mesh Generation”,Finite Element in Analysis and Design, 25, pp. 331-341

Habib, A., Lee, Y. and Morgan, M., 2003. Automatic Matching and Three-Dimensional Reconstruction of Free-Form Linear Features from Stereo Images, Photogrammetric Engineering and Remote Sensing, 69(2), pp. 189-197.

Habib, F., R. Zhai, M. Li, and C. Kim, 2011. 3D Generation of Complex Polyhedral Building Models by Integrating Stereo-Aerial Imagery and Lidar Data, Photogrammetric Engineering & Remote Sensing, 76(5), pp. 609-623.

Hough, P.V.C., 1962. Methods and Means for Recognizing Complex Patterns, U.S. patent, 3,069,654.

Teo, T.A., Chen, L.C., Liu, J.K., and Hsu, W.C., 2005. Buildingreconstruction From Lidar Data Using Iterative Regularization Approach,Proceedings of Asian Conference on Remote Sensing, Nov. 7-11, Hanoi,Vietnam, CD-ROM.

Rottensteiner, F., & Briese, Ch., 2002. A New Method For Extraction In Urban Areas From High-Resolution LIDAR Data , ISPRS, vol. XXXIII, pp. 295-301, Graz, Austria.

Wu, H., Y. Li, J. Li, and J. Jong, 2010. A Two-step Displacement Correction Algorithm for Registration of Lidar Point Clouds and Aerial Images without Orientation Parameters, Photogrammetric Engineering & Remote Sensing, 76(10), pp. 1135–1145.

Zhang, Y.J., Zhang, Z.X., Zhang Z.Q., and Wu, J., 2005.3D Building Modelling With Digital Map, Lidar Data and Video Image Sequence, The Photogrammetric Record , 20 (111), pp. 285–302.