3D BUILDING INFORMATION EXTRACTION FROM A SINGLE QUICKBIRD IMAGE

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ABSTRACT:

Today's commercial high resolution satellite imagery such as IKONOS and QuickBird, offers the potential to extract useful spatial information for geographical database construction and GIS applications. Recognizing this potential use of high resolution satellite imagery, KARI is performing a project for developing Korea multipurpose satellite 3(KOMPSAT-3). Therefore, it is necessary to develop techniques for various GIS applications of KOMPSAT-3, using similar high resolution satellite imagery. As fundamental studies for this purpose, we focused on the extraction of 3D spatial information and the update of existing GIS data from QuickBird imagery. This paper examines the scheme for rectification of high resolution image, and suggests the convenient semi-automatic algorithm for extraction of 3D building information from a single image. The algorithm is based on triangular vector structure that consists of a building bottom point, its corresponding roof point and a shadow end point. The proposed method could increase the number of measurable building, and enhance the digitizing accuracy and the computation efficiency.

KEY WORDS: Building height extraction, single image, High resolution satellite imagery, QuickBird, Triangular vector structure, GIS application

1. INTRODUCTION

Extraction of 3D building information from high resolution satellite imagery is one of the most active research topics. There have been many previous works to extract 3D information based on stereo analysis, including sensor modelling (Croitoru, A., 2004, Jin, X., 2005). Practically, it is not easy to obtain stereo high resolution satellite images. On single image performance, most studies applied the roof-bottom points or shadow length extracted manually to sensor models with DEM (Digital Elevation Model) (Willneff, J., 2005 and Croitoru, A., 2004). It is not suitable to apply these algorithms for dense buildings. At this point of view, an effective research was made by Lee(2006), which applied projecting shadow regions. However that method cannot be applied to buildings, of which the shadow end is not observable. We aim to extract 3D building information from a single satellite image in a simple and practical way. To measure as many buildings as possible, in this paper, we suggested a new way to extract building height by triangular vector structure.

2. PREPROCESSING

2.1 Test Data

In our approach, we used the QuickBird imagery as a high resolution satellite image. The QuickBird system launched in October 2001 collects about 61 cm class panchromatic and 2.5 m multispectral stereoscopic data covering a surface area of 16.5 km x 16.5 km. QuickBird images are available with 3 levels of processing: Basic, Sstandard and Orthorectified according to correction level. Standard level, which we used, is provided under radiometric corrections detectors-oriented distortions and geometric corrections according to a given type of map projection. Its positioning accuracy is 23m CE 90% and 14m RMSE under given RPC (Rational Polynomial Coefficients) information.

We used 1:1,000 digital maps to register geometrically QuickBird imagery and the DSM (Digital Surface Model) from airborne Lidar (Light Detection and Ranging) points data to evaluate the accuracy.

2.2 Rectification

To guarantee compatibleness with the other GIS data, QuickBird image was rectified using commercial software by manually extracted GCPs (Ground Control Points). A total of 37 control points were extracted between the QuickBird image and digital map. Among these points, 18 were used as GCPs, and 19 as ICPs (Independent Check Points). We tested the accuracy of rectification through three software programs: SOCET SET 5.2, PCI Geomatics and ERDAS IMAGINE 9.0. The Multi-Sensor Triangulation module in SOCKET SET showed the highest accuracy, 73.1 cm RMSE. For our approach, we used the result rectified using SOCET SET, in which the original RPC parameters could be refined with linear equations and precise GCPs.

3. BUILDING HEIGHT EXTRACTION

To estimate the height of buildings conveniently from single image, we proposed the semi-automatic extraction method based on the triangular vector structure. Its basic concept comes from the fact: the triangle consisting of each building's bottom point, its corresponding roof point and the shadow end point are always similar to one another in a single satellite image, because the altitude of the satellite and the sun is high enough to be considered that their projection angles are in parallel. Figure 1 and Figure 2 show the principal. In the figures, triangle A and B are similar triangles that consisting of the same angles vector. Therefore we can estimate the relative height of the building from measuring the length of any side or observing one point and one side of the triangle from the satellite image.

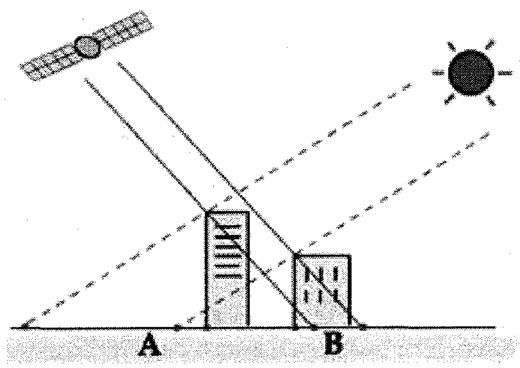

Figure 1. Parallel ray of the sun and satellite

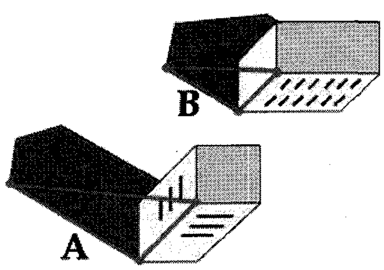

Figure 2. Similar triangles on satellite image

At the first step of this approach, we extracted the reference triangle whose three vertices are distinguishable. Then, the triangles of each building were measured using the reference triangle. Lastly, the building heights were estimated from the known proportional constant such as the sun elevation angle. It's very simple and easy to perform because it's not necessary to get extra data or compute the sensor model. We coded a simple program as an interface for these processes using the Microsoft Visual C++ .NET.

3.1 Assumption

Our practical test was performed based on three assumptions as follows.

1) The building of interest stands on the flat ground.

2) In the scene, there are one or more buildings that are observable from the following three points: a roof point, its corresponding bottom point and the shadow end point.

3) In other buildings, one or more sets must be observable among the following sets: a roof point and its bottom point on the side, a roof point and its shadow end point, a roof edge and portion of its corresponding shadow edge.

If these conditions are not satisfied, the building height can not be estimated.

3.2 Reference Triangle Determination

To define the reference triangle in the scene, a proper building must be chosen and measured. As shown in Figure 3, to be selected as a reference triangle, point *A* (roof point), *B*(bottom point) and *C*(shadow end point) should be observable from an edge of the building. The reference triangle is determined by digitizing three points *A, B, C*. Then, the angles and side lengths are registered to our interface. For more stable estimation, it is better to use multiple reference buildings. If more than one building is measured as the reference, the mean triangle in proportion to each side length is determined.

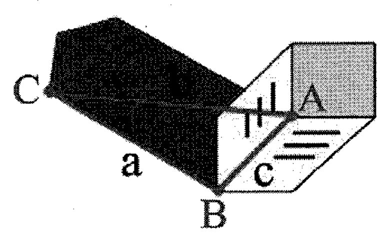

Figure 3. Conceptual diagram of reference triangle

3.3 Building Height Measurement

The way to embody the measurement in our program is as follows. When the user selects and clicks a roof point of a building using the curser, the program regards the position as point *A* of the triangle and fixes the position as a vertex of the roof. Then, as the user drags the mouse along, the triangle is displayed bigger or smaller by the reference triangle. Through the position of the building bottom and shadow, user can determine the right size of the triangle and end the measurement of the triangle. The measured triangle is registered with the position, the length of each side, and label number. Because the triangular angle is fixed by the reference one, it is easy to digitize and measure. And, if at least one point on the building bottom or the shadow edge is observable, it is possible to measure the building height.

After the measurement of building triangles, we can estimate the building height using the known proportional constant. The proportional constant can be decided by choosing one among the sun elevation angle, the satellite viewing angle in the metadata of satellite images, and the known height of a building in the scene. If you know the height of a building in the area of interest, you can calculate the ratio between the height and the length of any triangle side. Otherwise, you can apply the tangent function value of the sun elevation angle for side *a* in

Figure 3, and the satellite viewing angle for side *b* in Figure 3.

4. EXPERIMENTAL RESULT

To evaluate the suggested method, we applied it to a QuickBird image, which has the sun elevation angle 30.2°, the mean satellite elevation angle 59.4°. The test area was about 1.5×1.7 km^2 in Daejeon, South Korea. There were a lot of tall business buildings of various shapes and high-rise apartments as shown in Figure 4. We defined all buildings in the test area to the targets. As the result, 165 buildings were measured and the accuracy was evaluated by comparing them with Lidar DSM data.

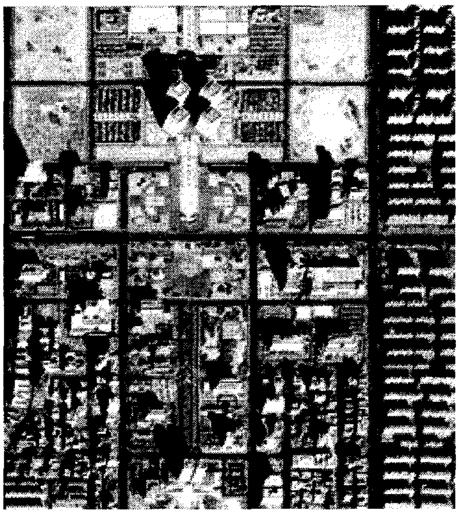

Figure 4 Test area

4.1 Comparative Performance Evaluation

We compared the number of observable buildings between previous methods and the proposed approach. Commonly, in previous researches, the length of building side or that of building shadow was measured, or the roof and shadow end line were used to estimate the building height. So we counted the number of observable buildings in each case, as follows.

- case 1: measure the length of building side
- case 2: measure the length of building shadow
- case 3: measure the roof and the shadow, as suggested by Lee, T. (2006)
- case 4: proposed method

Table 1. Number of observable buildings

	Case 1	Case 2	Case 3	Case 4
Observed	135	107	155	159
Unobserved	31	59	9	6

Following figures are examples showing the performance of the propose method. As shown in Figure 5 and 6, the proposed method can measure the buildings with different roof shape and bottom shape. And there is no need to digitize the edge of buildings alike, in Figure 6 and 7. In addition, like the parking building in Figure 8, it is possible to measure a building, when the end of shadow is distinguishable because a roof point and part of shadow edge can define the triangle. When the user digitizes the measuring points, the error can be decreased by wrong manual clicking because the triangle structure restricts the permissible angle. Unobservable buildings in our method are those which do not show even a small part of the bottom and the shadow as Figure 9.

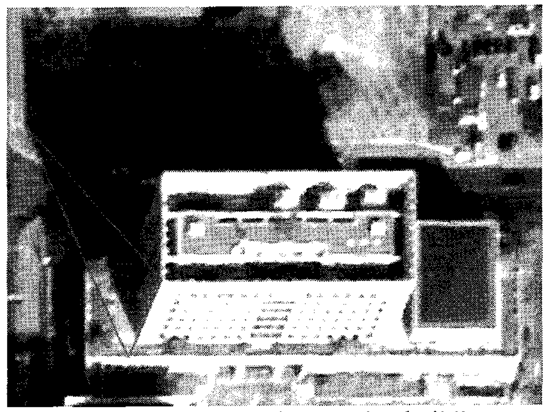

Figure 5. Example of measuring building

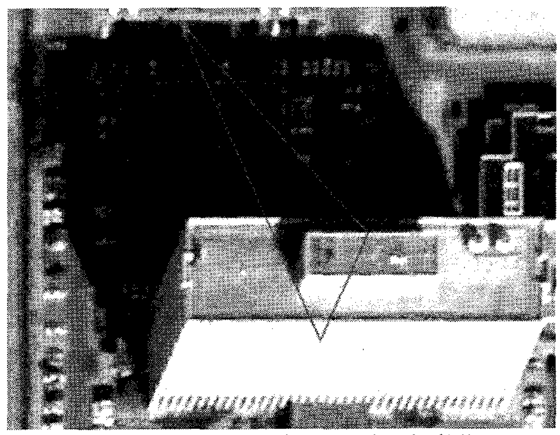

Figure 6. Example of measuring building

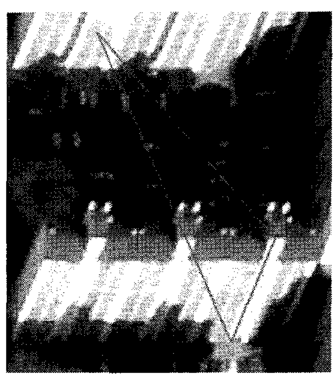

Figure 7. Building example

Figure 8. Building example

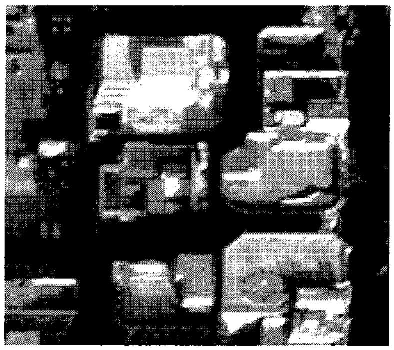

Figure 9. Example of unobservable building

4.2 Accuracy Assessment

According to comparison with Lidar DSM, RMSE of our approach was 0.91m, and the maximum error was about 3 m. The height of buildings tended to be estimated longer than Lidar data because the test area was a bit slant to the direction of the shadow.

5. CONCLUSIONS

In this paper, we examined rectification by updating RPCs, and suggested a convenient semi-automatic extraction method of 3D building information from a single QuickBird image. The building height estimation algorithm was based on triangular vector structure. The proposed method could increase the number of measurable buildings, compared to previous works, and enhance the digitizing accuracy and the computation simplicity. Apart from the advantages, our approach is not suitable for slope areas and needs individual manual work for each building.

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