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Generation of the Orthoimage with the Correction of Building Occlusion

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Abstract

Geospatial Information Systems (GIS) have been employed to systematically manage and design land use in urban areas. This has increased the need for more accurate vector and raster data. In Korea, 1/1,000-scale digital maps are used as vector data for the facility management in urban areas. This has increased the need for large scale orthoimages. Orthoimages generated from aerial imagery can provide accurate information, making possible the more effective city management. However, there is a large problem in using the orthoimages, i.e., currently available conventional orthoimages have not been generated based on Digital Elevation Model (DEM) that takes into account the building heights. So this causes the displacements of building image in large scale orthoimages. The present study is an attempt to generate the large scale orthoimages based on building DEM. The semiautomatic building extraction method can detect building outlines by mouse clicking on either building roofs or corners. Building DEM, based on the outline and calculated building height, was used to produce the large scale orthoimages with the corrected building occlusion.

Keywords : *geospatial information system, digital map, orthoimages, DEM, semiautomatic building extraction, building occlusion*

1. Introduction

It is estimated that, in the middle of the twenty-first century, up to 70% of global citizens will live in urban areas. This accelerated urbanization will require a greater need for urban orthoimages along with a higher reliance on Geographic Information System. Orthoimages not only provide topographic information but can also be employed in other mapping applications.

Conventional photographs are taken by the images projected through the perspective center which inevitably produces image displacement due to terrain relief, camera position and rotation, and other factors. Since conventional orthoimages have been generated from terrain DEM without consideration of building DEM, the building displacement in those images cannot be corrected. Thus, large scale orthoimages have to be corrected for this displacement. These images are available with large scale digital maps in urban areas densely crowded with buildings.

According to Amhar and Ecker (1995), more than 8% of the image pixels were erroneously produced in orthophotography generation due to building height. A building DEM requires the detection of outlines showing building shapes. To do this, automatic and semiautomatic building extractions are usually used. However, in cases where automatic extraction is performed directly from the aerial images, accurate building outline extraction is very difficult because of shadow, roof color, and neighboring trees making it hard to discern building roofs.

To overcome this problem semiautomatic building extraction was utilized in this paper. When a roof texture was homogeneous, automatic building outline detection was performed by mouse-clicking on a part of the roof. To construct the building outlines when the texture was non-homogeneous, a computer program was developed to search out corner points by clicking spots near corner points. The resultant corner points were processed by image matching to calculate the building heights. Gross errors were removed and the remaining height values were averaged and stored as the final building height. The building DEM was generated by taking into account building heights and outlines, and the generated DEM was

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combined with the terrain DEM to include buildings and terrain heights in the same DEM. Large scale orthoimages were generated by correcting building displacement caused by building height.

2. Semiautomatic Building Extraction

Automatic building outline extraction is necessary and indispensable in automating the digital photogrammetric process. In actual aerial images, however, building shadow or neighboring trees can reduce gray value difference between buildings and the surrounding background making automatic building extraction difficult and ineffective. As a solution, this study led to the development of a computer program which enabled the human operator to analyze gray value distribution within given threshold range by clicking a part of the roof. Edge following, based on the analyzed gray values distribution, was used in detecting building outline (Fig. 1(a)). To locate the interested corner points in the detected outline, the curvature (cos r_j) was calculated on all the points constituting the outline so as to search out points with significantly higher curvature variations as follows:

$$\cos r_j = \frac{(r_i - r_{i+j})(r_i - r_{i-j}) + (c_i - c_{i+j})(c_i - c_{i-j})}{\sqrt{(r_i - r_{i+j})^2 + (c_i - c_{i+j})^2} \cdot \sqrt{(r_i - r_{i-j})^2 + (c_i - c_{i-j})^2}}$$

where r_i and c_i refer to the rows and columns of the points on the outline. The curvature of each point was calculated by extending interval (INTER) j from the point. Variation in INTER values can control the detected number of points with higher curvature.

Since the building outline search could fail due to nonhomogeneity of roof gray values, the corner points were searched by means of a spiral search on neighboring areas by mouse clicking on the building corner vicinity (Fig. 1(b)). For corner points detection, the Förstner interest operator was used with a threshold weight (1.5) and roundness measure (0.75). A 5×5 pixel window and the 2×2 Robert gradient operator were incorporated to compute the gradient (Yoo *et al.*, 1996).

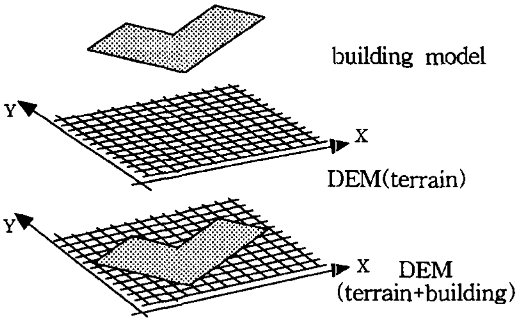
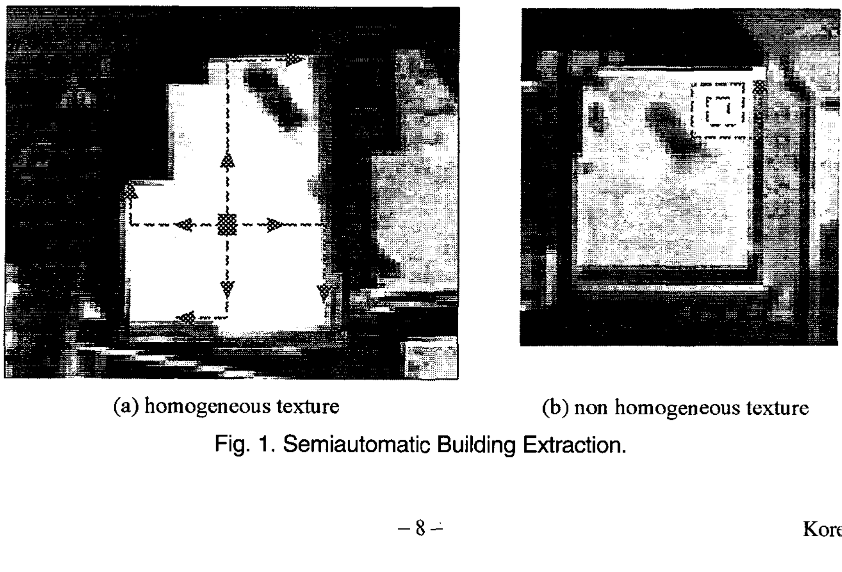


Fig. 2. Overlaying Building DEM on Terrain DEM.

3. DEM Generation

Image matching was conducted on building corner points from the left image by semiautomatic building extraction in order to locate conjugate points in right images and to obtain building heights based on a bundle adjustment (Yoo *et al.*, 1996; Yoo *et al.*, 1999). Since several corner points were detected on one building, height values of all the corner points were screened to remove points with gross errors, and the average of the remaining height values was determined as the final building height value. Since most building roofs in the urban areas are flat in Korea, the average value can be used. The calculated building height value and outline were incorporated in generating building DEMs, which was combined with terrain DEM. To prevent interpolation from occurring near the building outline, building and terrain DEMs were overlaid and the building height value was defined as the elevation for grid points within the building, while terrain elevation value was allocated to those outside the building (see Fig. 2).



(a) homogeneous texture (b) non homogeneous texture

Fig. 1. Semiautomatic Building Extraction.

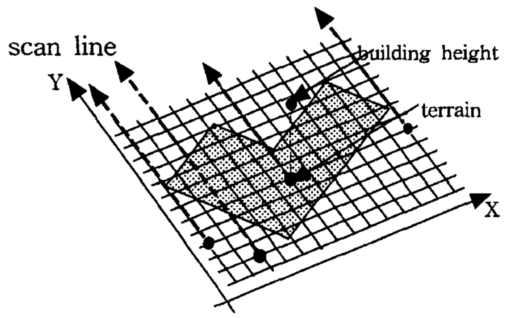


Fig. 3. Scan Lines for the Calculation of Grid Elevation.

In order to identify the grid locations within and outside the building, the number of points that intersect with the building outline was calculated along the scan line as shown in Fig. 3. When the number of intersected points was odd, they were determined to be interior points, while even-numbered points were classified as exterior points. The building height value was allocated as the elevation value for interior points, and terrain height value was defined as the elevation for exterior points.

4. Orthoimage with Corrected Building Occlusion

Aerial image usually include building displacement due

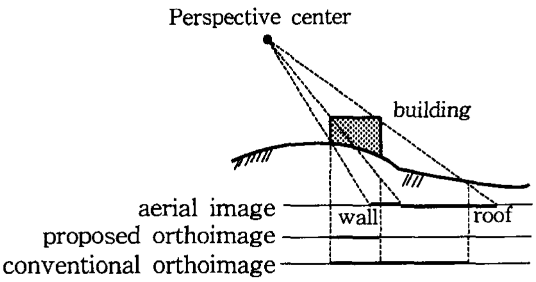


Fig. 4. Proposed Orthoimage Comparing to the Coventional Orthoimage.

to building heights. Since this displacement occurs around the principal point of a photograph, the building position must be moved based on the DEM. In conventional orthoimages, building image displacement remains as can be seen in Fig. 4.

Whereas the building DEM can be employed to correct this displacement, as the proposed orthoimages show. To explain the correction procedure, the geometrical relation between the perspective center and building outline in aerial images was expressed by using the collinearity condition for the building displacement correction based on the DEM. Fig. 5 shows the process of defining occlusion area

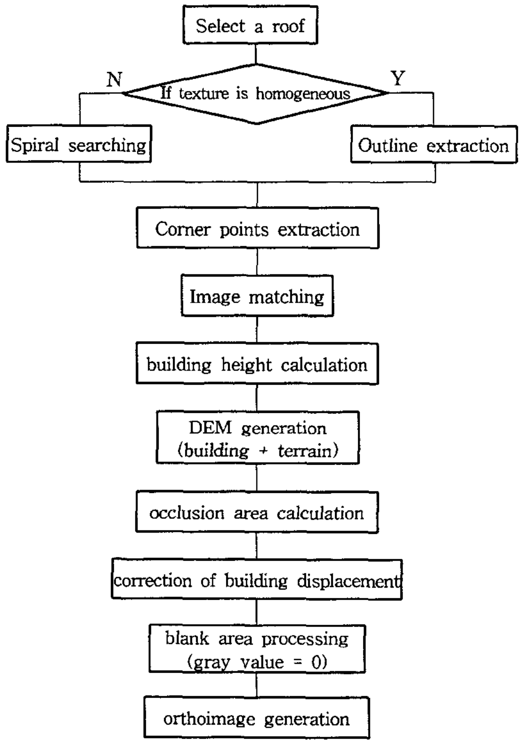


Fig. 6. Flow Chart of the Proposed Method for Orthoimage Generation.

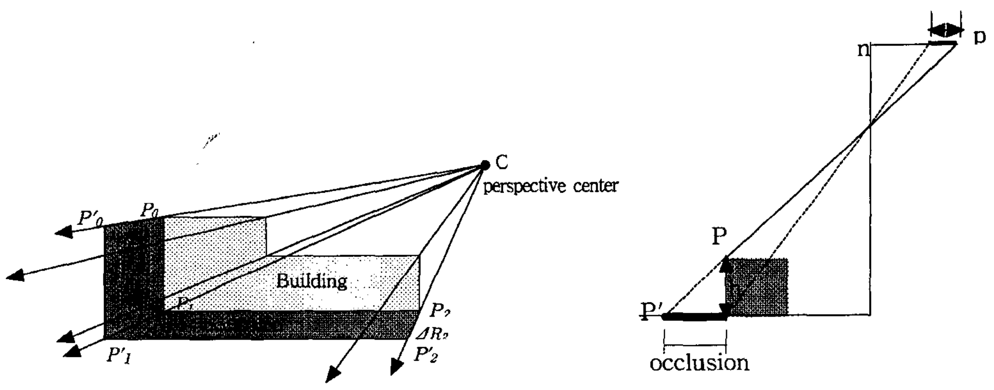


Fig. 5. Occlusion Area.

in aerial images due to buildings. The occlusion area appeared blank when the building roof was moved to the true position, and filled it with black color.

Generally, occlusion area refers to the area that is invisible from an arbitrary view point due to building height. The occlusion area of the building in Fig. 5 is the area represented by P_0, P_1, P_2, P'_0, P'_1, and P'_2, where the position of P_i can be identified by the elevation value of the building outline, and P'_i position can be calculated by using terrain DEM, P_i, and perspective center. The coordinates for the calculated occlusion area were used in orthoimages generation to help perform blank area processing.

The above mentioned orthoimage generation procedure was coded into a computer program. Visual C++ was used and the flow chart of the generation procedure is shown in Fig. 6.

5. Experiment and Discussion

5.1 Building Extraction

The digitized aerial image at scale of 1:3,000, over the region of Changwon city was used as the test data for generating of orthoimage with corrected building occlusion.

Fig. 7 represents building detection in case of homogeneous gray values. It is important to notice that detection results varied depending on tolerance value differences. To obtain the distribution of roof gray values, the average of the gray values in a 3×3 window centering around the mouse-designated point was defined as a reference value to which surrounding gray values were compared. The tolerance (TOL) is a threshold value allowed to vary as the difference between the reference and neighboring gray values change. The resultant building outline was employed in detecting interested points needed for image matching. The curvature of the pixels constituting the outline was calculated in order to detect corner points with drastic curvature variation. The INTER variable was used to exclude points with insignificant low curvature and to detect points with higher curvature such as corner points of building.

Refer to Fig. 7, there may be some problems with building outline extraction when the targeted roof has structures or roof gray values with excessive differences due to shadows or other factors. Thus this method was limited to the case where gray values were judged as homogeneous. As a solution to this problem, building corners were detected one by one when the roof was overshadowed and gray value distribution was irregular. To facilitate designating corner points accurately, spiral searching was automatically performed by mouse-clicking near corner points. The results are presented in Fig. 9, where black crosses refer to mouse-click spots and white points refer to the spots detected as corner points. The semiautomatic building extraction proposed in this paper was evaluated by detecting corner points in a test area.

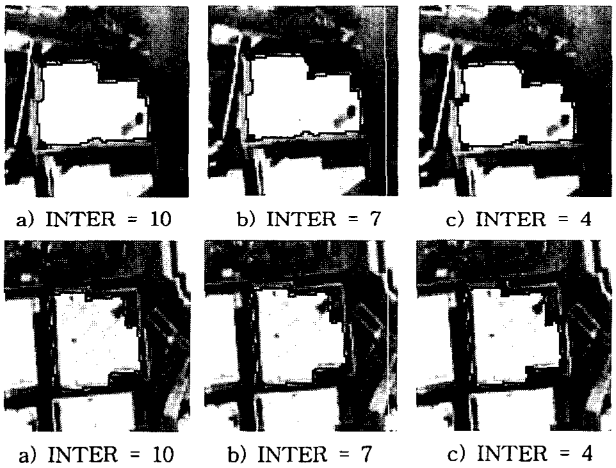


Fig. 8. Extracted Corner Points According to the INTER Variation (for homogeneous texture).

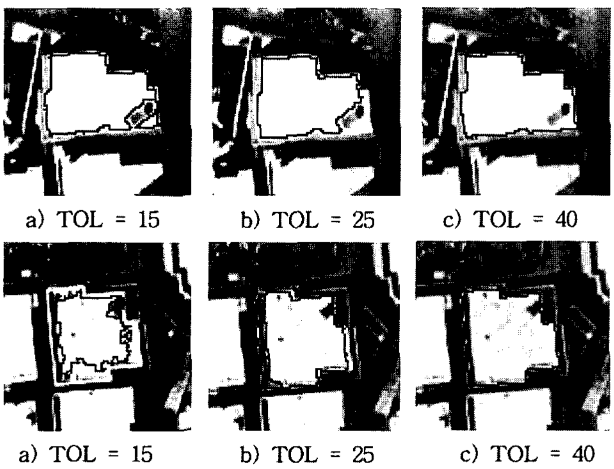


Fig. 7. Detected Building Outlines According to the TOL Variation (for homogeneous texture).

Fig. 9. Extracted Corner Points (for non homogeneous texture).

These detected points were used in image matching to obtain exact building heights.

5.2 DEM Generation

The corner points of building detected as interested points from the left image of stereo pair provide the reference window required for image matching. The reference window was obtained for each of the corner points to calculate its epipolar line. Cross correlation matching was used to find conjugate points in the right image, and a bundle adjustment was employed to find building heights. Since several corner points were present in one building, gross errors ($\geq 3\sigma$) were removed from the building height values, and the average of the remaining values was determined as the final building height value for flat roofs. The building height values and outlines were utilized to generate the DEM of the buildings, which then was combined with terrain DEM. To ensure that the building shape would not look smooth, steps were taken to prevent interpolation from happening near the building outline. As the result, generated DEM showed the building shape clearly (see Fig. 11).

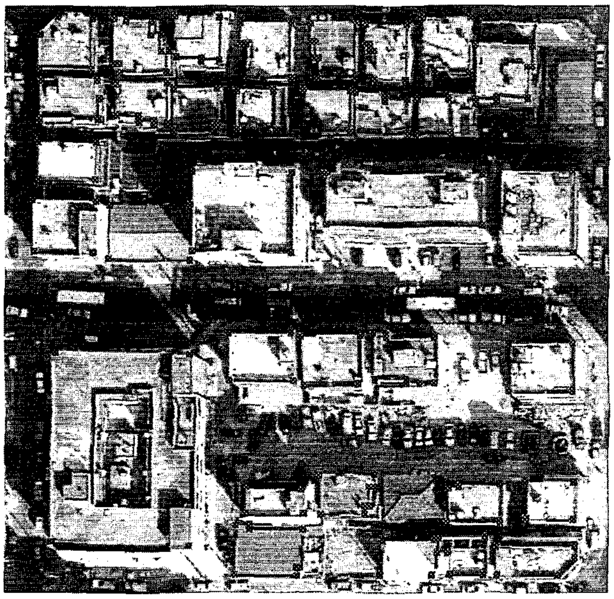


Fig. 10. Extracted Building Corner Points in the Test Area.

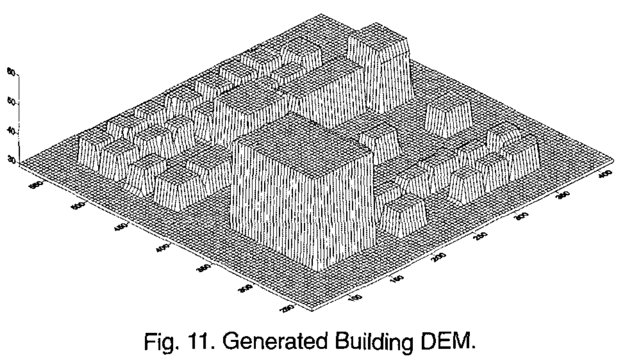


Fig. 11. Generated Building DEM.

5.3 Large Scale Orthoimage Generation

If building outlines and heights were not considered in large scale orthoimages, the building position in digital map at scale of 1:1,000 would be different from that in orthoim-

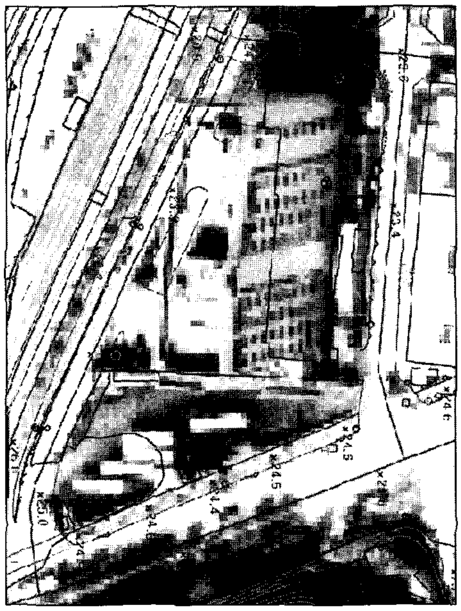


Fig. 12. Overlap of Orthoimage and Digital Map.

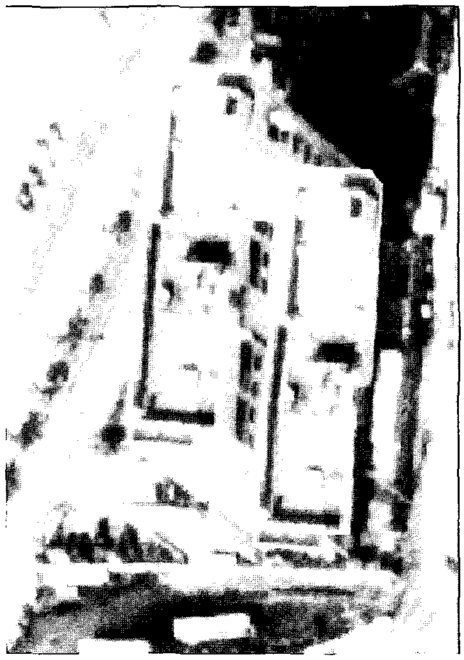


Fig. 13. Double Mapped Image.

ages, as can be seen in Fig. 12. As a solution to this problem, this study extracted building outlines and generated building DEM in order to correct relief displacement due to building heights. Fig. 13, however, shows a problem with this method: double mapping of the same building took place and the building shape still remains at the original position from which it had been moved. To eliminate this faulty mapping, the occlusion area was defined based on the perspective center of the photographs, the building height and the outline, and the blank area due to building displacement was filled with black color (see Fig. 14). The orthoimage of the test area generated by the proposed method in this study is presented in Fig. 15.

Fig. 14. Orthoimage from Corrected Building Image Displacement.

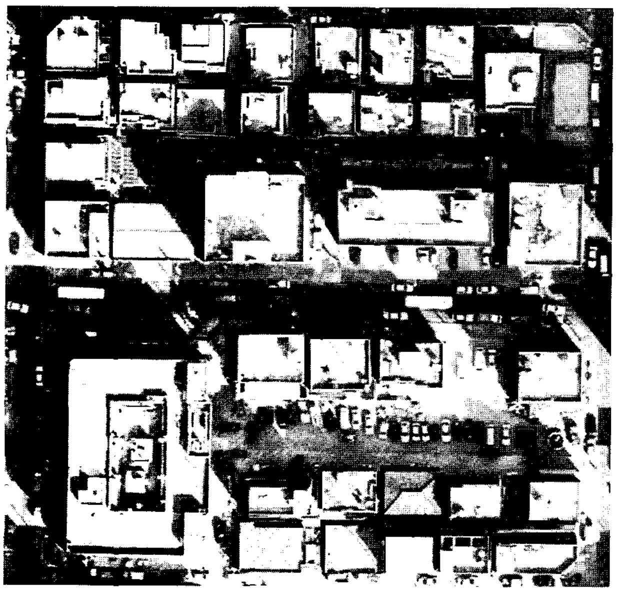


Fig. 15. Generated Orthoimage of the Test Area.

6. Conclusion

As the urban concentration of population continues to strain the expanded demand on social infrastuctures, the need for effective urban planning and management becomes pressing. In particular, GIS is an attractive alternative technology that can be used to handle urban growth which has produced massive amounts of data that cannot be effectively managed with conventional technology. Effective urban area management based on GIS necessitates large scale digital maps consisting of raster data showing details of the urban areas and can be overlaid with digital vector maps. Currently available raster data include aerial images and high-resolution satellite imagery that can be used in the near future. The major problem with large scale orthoimage generation based on aerial images is the modeling of buildings located in urban areas. To do this, exact information of building outlines and heights is needed. In an attempt to automatically extract building DEM in urban areas, many studies have been undertaken which have generated Digital Surface Models based on Airborne Laser Mapping in order to extract building shapes and positions automatically. The present study, however, focused on large scale orthoimage generation using aerial images alone.

Semiautomatic building extraction with two functions that may be selected depending on the gray value patterns, was performed to obtain building DEM. One function, based on gray value differences, was to search out the building outline by mouse-clicking a part of the roof in case the gray values of the roof were homogeneous. The other function was to search out the corner points one by one in case where the roof gray value distribution was irregular and the former method is not available. However, since the latter method is time and labor consuming, a computer program was written and utilized to automatically search out the corner points by the mouse-clicking on the areas near the points.

The corner points obtained from the left image by outline extraction were used as interested points for image matching, and cross correlation matching and bundle adjustment were adopted to calculate building heights. The resultant building heights and outlines were used in building DEM generation.

Building DEM and the perspective center of aerial images were used to define occlusion areas produced by buildings. Displacement due to building height was corrected in order to move the buildings into their true positions; the remained double mapped original building image was assigned as blank area and filled with black color.

Hopefully, future research efforts will focus on ways to fully automatize building extraction by using data produced by new technologies such as Airborne Laser Mapping. In addition, though the occlusion areas are filled with black color in this study, future studies should be made to minimize the black filled areas by using the proper techniques such as the image mosaics, etc.

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