# GENERATION OF DIGITAL ORTHOPHOTO FOR URBAN AREA USING DIGITAL BUILDING MODEL

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**KEY WORDS:** Digital Orthophoto, Radial Sweep Algorithm, Surface Reconstruction, Interest Points, Building Model.

## ABSTRACT

Generating digital orthophotos for urban areas has been limited because of their natural complexity. Problems arise with the existence of a group of buildings standing side by side and with different patterns. This study aims at the generating digital orthophotos for urban area through the modeling of the building. Modeling of a building was done by first estimating building height from interest points matching, radial sweep algorithm, and surface reconstruction technique. Then combined with an existing digital map, more accurate building height estimating was done to create a digital orthophoto for urban area.

## 1 INTRODUCTION

It has been difficult technically to create a digital orthophoto for urban area because of their natural complexity. Especially estimating building height was most trouble making processes of all. Ebner and Heipke (1988) proposed an integration solution for image matching and object surface reconstruction. Lang and others (1995) and Haala (1995) dealt with problem of automated building extraction from aerial images. Amhar and Ecker (1996) proposed an integrated solution for the problems of 3D man-made objects in digital orthophotos. They classified image into classes and performed separate rectification for terrain and building area to generate othophotos. This paper presents a method about the generation of orthophoto for urban areas through the accurate mapping of building. The accurate building boundary information has obtained from the existing digital maps.

## 2 APPROACH

Our scheme to generate digital orthophoto for urban area is illustrated in Figure 1.

- Construct TIN model using distinct points such as the corner of buildings , a road crossing, and so on.
- Initial DEM generation using piecewise Lagrange interpolation and setting up the initial building height.
- Extract the building layer from existing 1:5000 digital map.
- Determine centroid coordinate of each building layer.
- Determine the building height using surface reconstruction method.
- Generate 3-D object file.

- Generate digital orthophoto from a modeling of building.

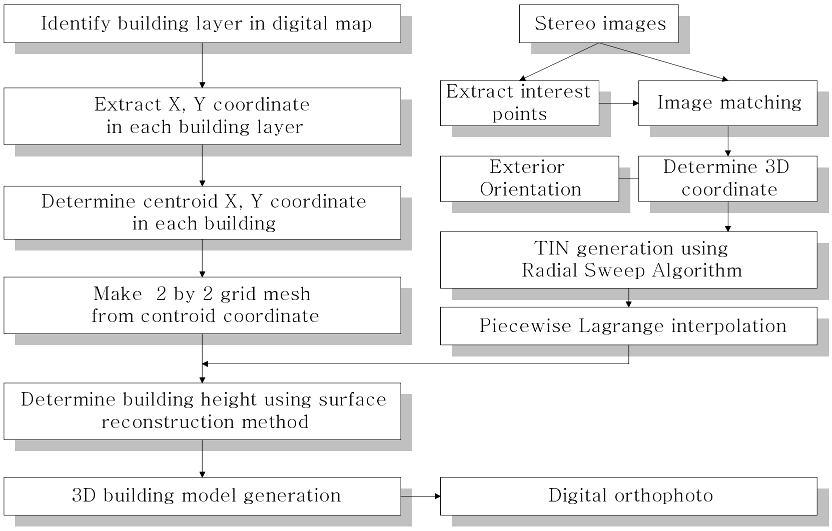



Figure 1. Flow chart for generating orthophotos for urban areas.

## 2.1 Construction of a TIN using interest points

First we applied Förstner interest operator (Förstner and Gülch, 1987) to extract the distinct points in a 5x5 or 7x7 window by using the slant of brightness. After the distinct points have been extracted, radial sweep algorithm is applied to construct a TIN of the 3D coordinates. Detail procedures for this process is shown in Figure 2. Initial DEM for building is used in surface reconstruction process since this process is nonlinear and required initial values. Initial value of surface reconstruction is obtained by piecewise Lagrange interpolation of a TIN.

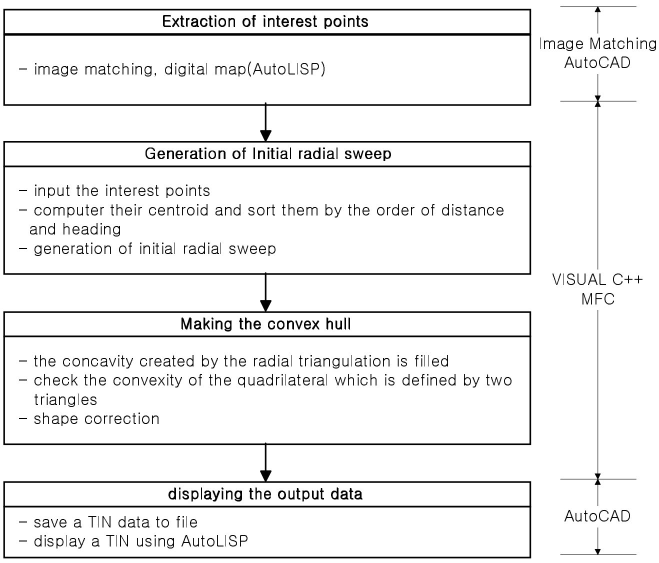



Figure 2. radial sweep algorithm(RSA)

## 2.2 Surface reconstruction

Image density (intensity) of aerial images is formed under the influence of characteristics of object surface. Relationship between density value assigned to the object surface element and the corresponding image density value can be formulated following equation (1). In this paper, we assumed that we have already known exterior orientation parameters, and select the method of getting the solution by putting the height value as an unknown quantity.

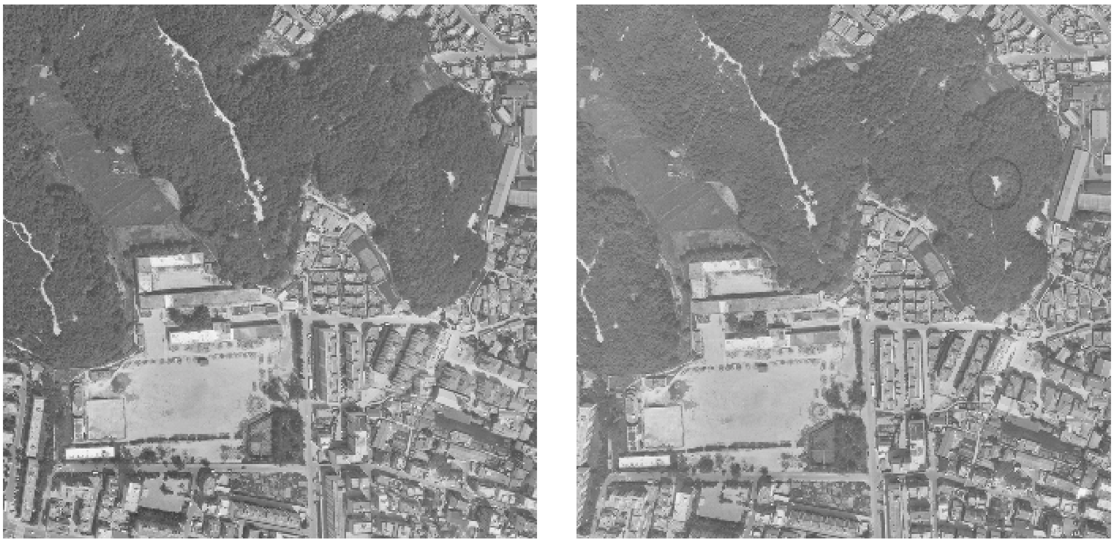
$$v = G - Tr[d(x_p(Z, P), y_p(Z, P))] \tag{1}$$

where $G$ : the unknown density value assigned to the object surface element
$Tr$ : radiometric image transformation
$Z$ : the height of the grid points of the geometric surface model
$P$ : the orientation parameters
$d(x_p, y_p)$ : image density value is computed from the neighboring density value by e.g. bilinear interpolation

## 3. CREAATION OF TIN AND BUILDING EXTARCTION

### 3.1 Constructing a TIN and surface interpolation

Aerial images of test area are shown in Figure 3. Our test area shows the typical urban scene of Korea. Several group of building blocks represents apartment complex. Individual houses and school district are also visible in the image. Black textured area represents surrounding mountainous terrain. The status of test area mapping is summarized in Table 1.
We applied interest point operator and extracted about 12,000 interest points. About 30% of extracted points were selected for matching purposes. This was done by calculating cross correlation coefficients. When the cross correlation coefficients using 11x11 window size were over 0.7, we select those points for matching. We created TIN using those selected points.



(a) Left image (406) (b) Right image (407)

Figure 3. Aerial images of test area

| Test area | Photo scale | Focal length | The size of pixel | Flight height |
|---|---|---|---|---|
| 406 | 1:6,000 | 152.85mm | 32µm ×32µm | ≈876m |
| 407 | 1:6,000 | 152.85mm | 32µm ×32µm | ≈876m |

Table 1. The states of the test area

We performed piecewise Lagrange interpolation using 3 points of each triangle to interpolate the points inside the triangle. If the $i$ th triangle is named $T_i$ on the given area, interpolation function on the three point $P_{0i}$, $P_{1i}$ , $P_{2i}$ of $T_i$, $h_{1i}(x, y)$ can be represented as (2).

$$h_{1i}(x, y) = f(P_{0i}) \cdot \Phi_{i0}(x, y) + f(P_{1i}) \cdot \Phi_{i1}(x, y) + f(P_{2i}) \cdot \Phi_{i2}(x, y) \tag{2}$$

Figure 4 shows the result of interpolation using 1m interval in equation (2).

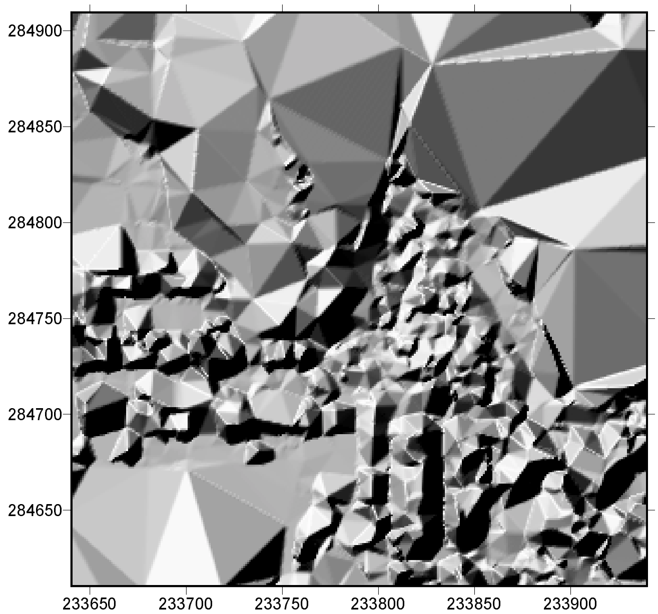



Figure 4. Initial value for surface reconstruction using a 1m interval.

### 3.2 Building extraction

It is critical to determine accurate building height to create ortho image of the building. To efficiently perform this process we first put some assumption on the size of buildings. For our study area the smallest size of building is assumed to be 4m. We constructed 2m × 2m grid around the centroid of the buildings. The building boundaries are obtained form existing 1:5,000 digital map of the study area.

The total number of extracted building from the digital map was 70. Six extracted buildings among them are not generated properly because the boundary area is out of the blueprint area. The layer code of building layer of digital map is shown in Table 2. Digital map of the test area is shown in Figure 5.

| Layer code | Contents |
|---|---|
| 4110 | Not classified |
| 4111 | Building except houses |
| 4112 | Houses |
| 4113 | Tenement house |
| 4114 | Construction |
| 4115 | Apartment |
| 4116 | Building without walls |
| 4117 | Green house |
| 4118 | Temporary building |
| 4119 | The boundary of clustered houses |

Table 2. The code of building layer in digital map

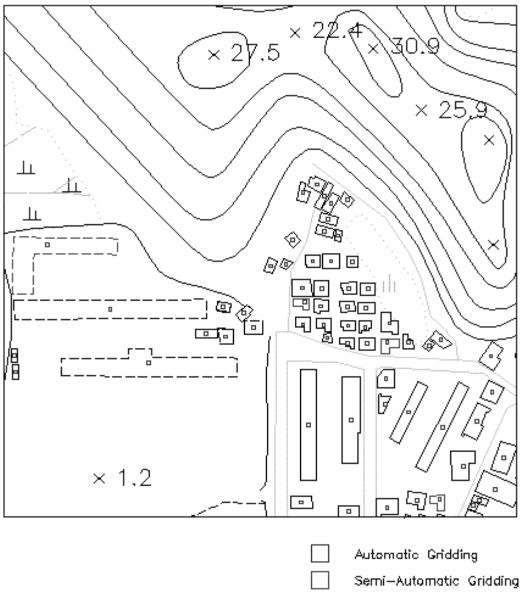



Figure 5. 2m × 2m grid generation from each building centroid

## 4. GENERATION OF DIGITAL ORTHOPHOTO OF BUILDING

### 4.1 Determination of building height

Building height was determined by surface reconstruction with the initial building height. The pixel size was 32㎛, corresponding to approximately 0.2 m on the ground. In surface reconstruction process the actual size of object surface element (OSE) was 0.2 m. We defined 25 OSE inside the 1m x 1m grid. Total number of OSE in the original 2m x 2m, therefore, is 100.

In each mesh node point (total 9 in the 2m x 2m grid), we can calculate corresponding Z values. These calculated values may be different. We assumed that the top of the building is flat and used average value of calculated Z as a representative height for the building. Figure 6 represent DEM and building height. The brighter the image is, the higher the elevation is.

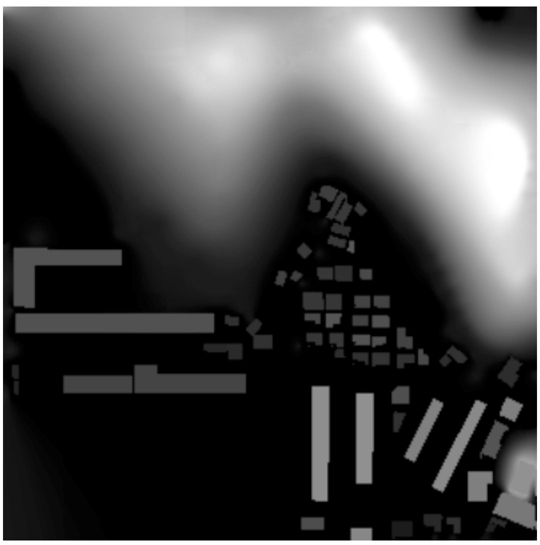
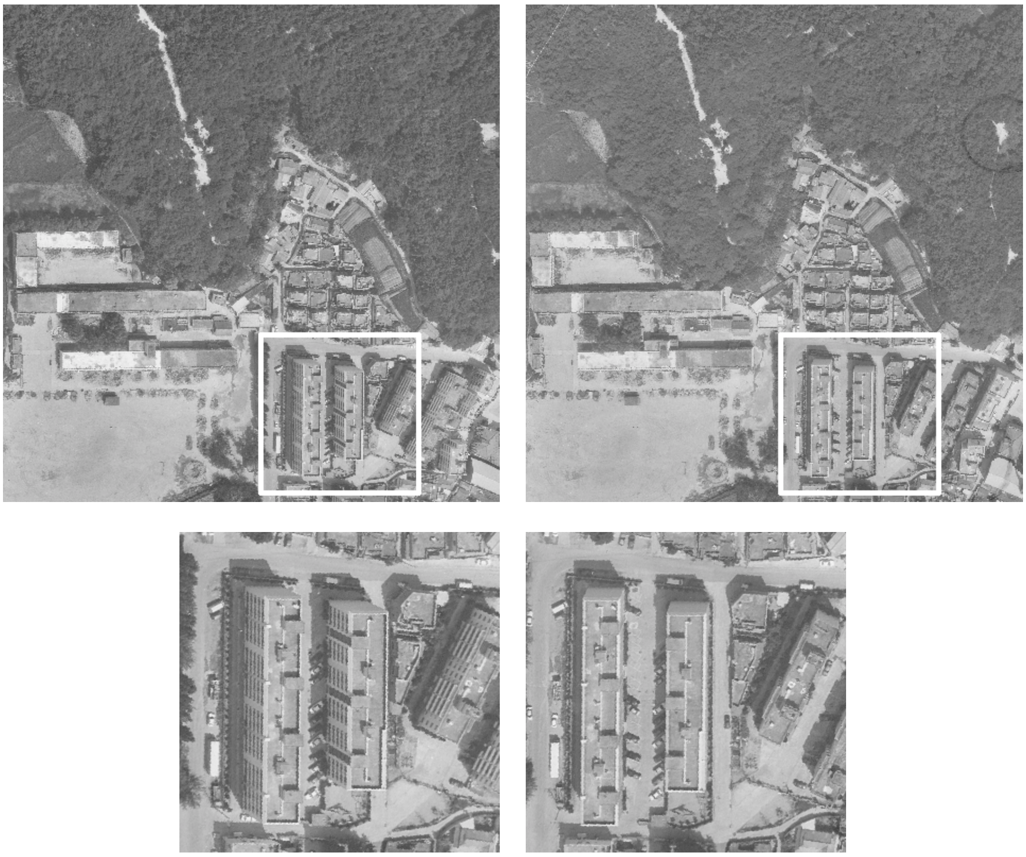


Figure 6. DEM and Building Height Map

### 4.2 Generation of orthophoto

Figure 7 shows a orthophoto of the test area without considering building model. Since the shape of the building was not properly modeled, the displacement of building was not correctly adjusted. Figure 8 shows improved version of Figure 7 by considering building model. The black areas around the building represent occlusion area. There was no corresponding gray values in the original image, we assigned 0 gray values for the occluded areas.

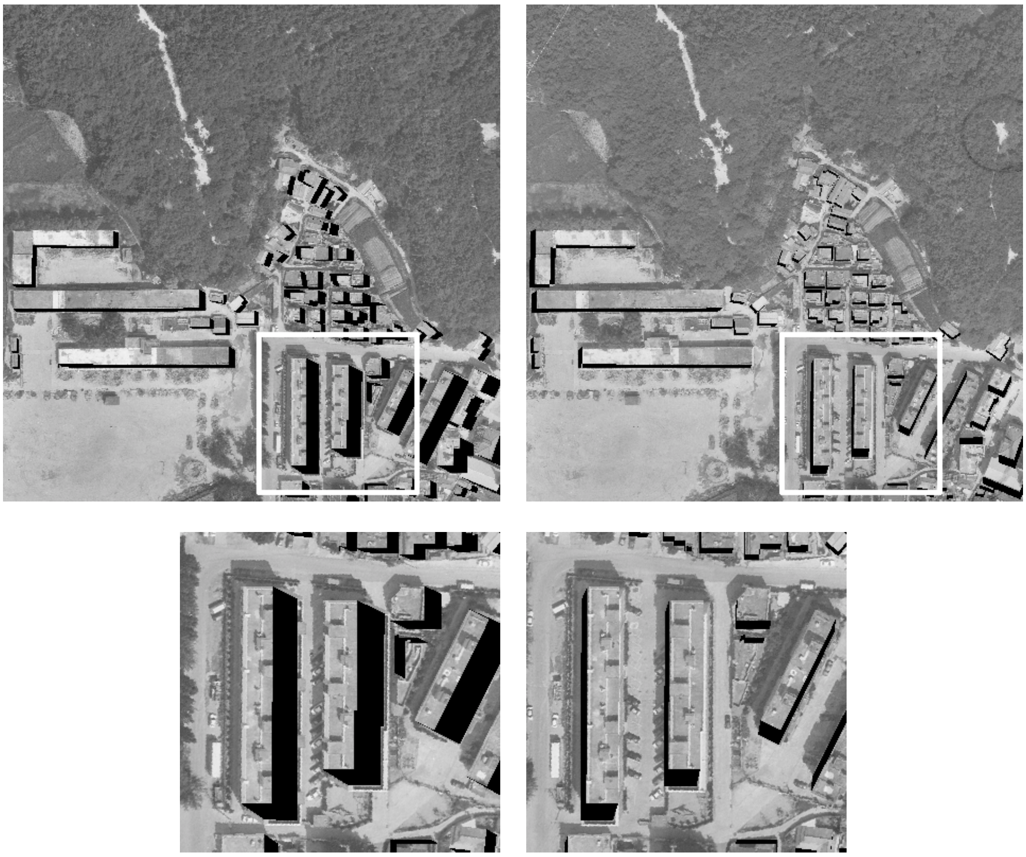


(a) Left (b) Right

Figure 7. Orthophoto generated without considering building layer

### 4.3 Accuracy assessment of building height

We checked the height accuracy of our processed digital building model by comparing with height values measured by the analytical plotter. Results show that height difference between digital building model and the height values measured by the analytical plotter ranges from –1.564 m to 3.291 m with ± 0.889m RMSE.



(a) Left (b) Right

Figure 8. Orthophoto with occlusion areas

## 5. CONCLUSIONS

Successive application of algorithms such as interest points matching, radial sweep algorithm and surface reconstruction technique made it possible to reconstruct the surface, especially building. The proposed method used a building boundary information from a digital map, and therefore the constraints for the shape of the building were reduced. We were able to reconstruct the buildings effectively with this combined method.

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