

# AUTOMATIC BUILDING EXTRACTION AND 3-D CITY MODELING FROM LIDAR DATA BASED ON HOUGH TRANSFORMATION

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## ABSTRACT:

This paper proposes a new method of LIDAR data processing to automatically extract building and 3-D city modeling. This method exploits image processing technique including Hough transformation. The process of building extraction starts with DSM segmentation according to elevation values. Among these fragments, extracting process limits candidates of building fragments to those that have elevation higher than a specified threshold value and the DEM at the same location. Hough transformation is executed to boundary pixels of each candidate of building fragment and then fit to linear segments. Each fragment is polygonized with these line segments. After the extraction, 3-D-building model is created with these polygons such that each polygon has vertical wall from the top of building to the ground (DEM). Texture images are pasted onto each building, including walls. The most appropriate texture image is selected from aerial images according to geometry between building faces and external parameters of the photos. The method has been tested with LIDAR data of Shinjuku and Ginza area in Tokyo.

## 1. INTRODUCTION

Advances of information technology are changing the concept of map from simple 2-D space expression into 3-D real world model constructed in cyberspace. There are two main problems for 3-D model applications. The first one is how to express and define 3-D model for general use or specific applications. The other one concerns methods to build up 3-D model at a reasonable cost performance. This paper focuses on the method to build up 3-D city model with LIDAR data.

The most typical commercialized method of 3-D city modelling with LIDAR data simply stands up buildings and houses in 2-D map with height values of footprints that fall into building polygons. This method, however, cannot express details of building shape, since building polygons in 2-D map simply trace outside boundaries of buildings. Another type of 3-D city model expression uses original LIDAR DSM. This type of 3-D model can express the details of city, but the amount of data tends to be too large and hard to manage or view in PC without special devices.

This paper presents an automated method for 3-D city model production with LIDAR data and aerial photo images, which can be applied to production of 3-D map for infrastructure. First, LIDAR DSM image is divided into fragments where DSM pixels have almost the same elevation value. Hough transformation extract straight lines and curves of building boundaries and constructs them into 3-D shapes. Extracted polygons are shaped into prisms with planar walls and aerial photo images are pasted onto each faces of building model as texture images according to geometrical information. Thus building models are more realistic with detail of shapes and texture images.

This paper first overviews the strategy of building extraction and construction and introduces building extraction with Hough transformation. Some experimental results with tests are presented in the following section with LIDAR data of Shinjuku and Ginza area in Tokyo, Japan.

## 2. THE STRATEGY OF THE METHOD

The strategy of the proposed algorithm consists of two parts. The first part is building extraction where building polygons are extracted from DSM and aerial photos. The second part is 3-D modelling where 3-D-building model is created with these polygons such that each polygon have vertical wall from the top of building to the ground.

### 2.1 Building Extraction

The schema of the algorithm is shown in Figure 1. This method treats DSM data as “image”, and exploit image processing technique including Hough transformation. As pre-processing, LIDAR data are converted in raster format and DEM is extracted by minimum filtering. Details of the image processing sequence are as follows.

**2.1.1 DSM Segmentation:** The process of building extraction starts with segmentation, where raster DSM is divided into fragments where DSM pixels have almost the same elevation value. Among these fragments, extracting process limits candidates of building fragments to those that have higher elevation more than a specified threshold value and the DEM at the same location. Jaggies around DSM masks are cleaned up with morphological dilation and erosion. A DSM fragment extracted here is called “DSM masks”. To avoid extraction of trees, cars and other objects, city block polygons in existing digital map data can be applied to omit DSM masks outside the polygons.

### 2.1.2 Edge Extraction:

Edge Extraction of the DSM image is executed with some edge operator, such as Canny operator or other zero-crossing operators. If DSM resolution is too poor to extract edge lines, aerial photo images can be used alternatively. In resultant edge image, each edge should be thinned into 1-pixel width edge lines.

**2.1.3 Masking:** Masking operation eliminates edges which does not overlap DSM mask. The remaining edges are used for boundary extraction in the following processes.

**2.1.4 Hough Transformation:** Hough transformation is executed to edge pixels in the masked edge image and straight lines are extracted as candidates of building boundaries.

**2.1.5 Line Segmentation:** The extracted straight lines are divided into line segments at the crossing points. After that, line segments that go through the DSM mask are eliminated.

**2.1.6 Polygon Tracing:** The line segments around a DSM mask are traced to form a polygon. If some parts around the DSM mask have no line segments, DSM mask boundary segments are used.

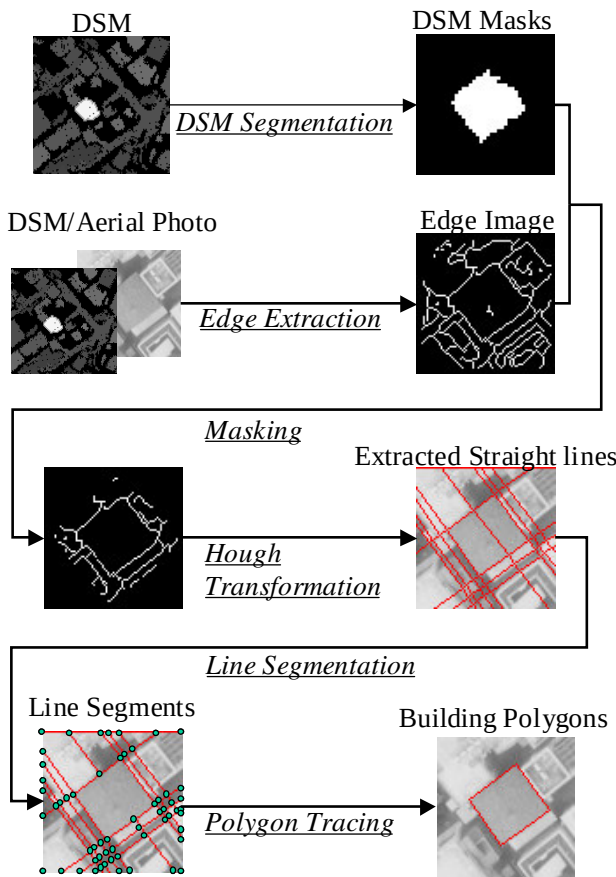


Figure 1. The schema of building extraction

## 2.2 3-D Modelling

After the building boundary extraction, 3-D-building model is created with these polygons such that each polygon forms the top of building with the elevation of corresponding DSM mask. Vertical walls from the top of building to the ground (DEM) are attached to the polygons. Texture images are pasted onto each building, including walls. The most appropriate texture image selected from aerial images according to geometry between building faces and external parameters of the photos as shown in Figure 2. External parameters of the photos can be directly measured by GPS/IMU systems, or calculated by aerial triangulation. Aerial photos provides texture images of good

quality if they are captured with large overlap and sidelap (such as 80% and 60% ). Figure 4. shows a sample of a 3-D model with texture images cut and pasted from aerial photos.

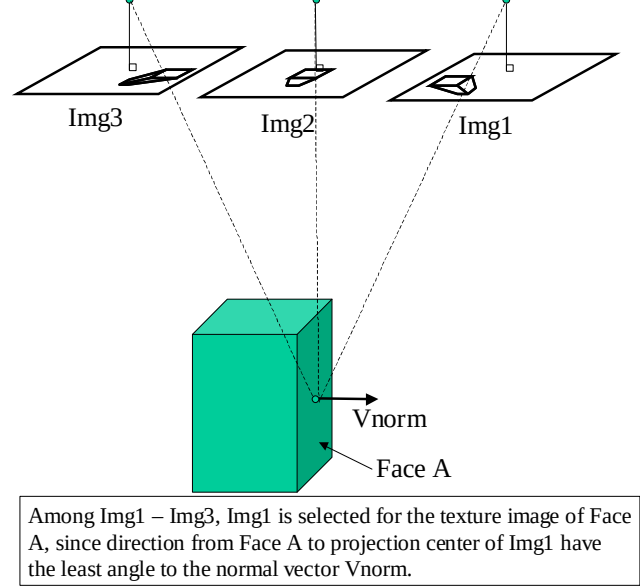


Figure 2. The schema of texture image selection

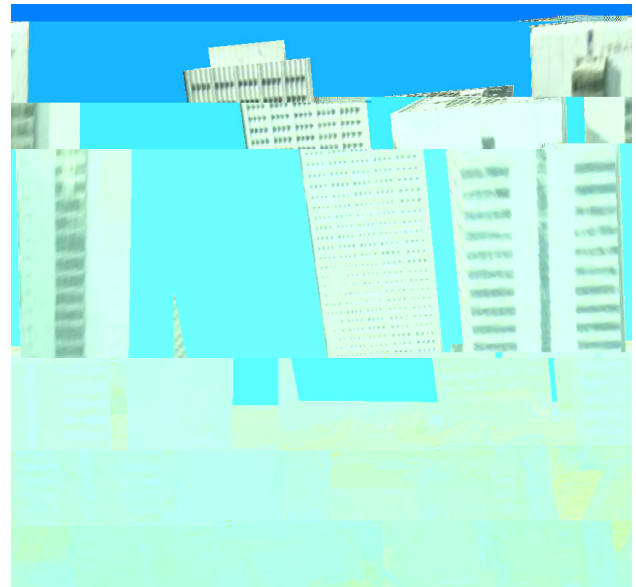


Figure 3. A 3-D model with texture images cut and pasted from aerial photos

## 3. EXPERIMENTAL RESULTS

We have applied the above algorithms to LIDAR data and aerial images of Shinjuku and Ginza area in Tokyo (50-cm resolution). ALTM2033 of Optech is used as LIDAR sensor. A prototype program has been developed as an application that works on Windows2000-based personal computer.

Figure 4 shows the DSM image and the extracted polygons of the test site of Shinjuku area. Figure 5 shows a sample of 3-D city model of Shinjuku area. This figure shows that texture images on the wall area are pasted around the building, as well as the top of the buildings. Figure 6 shows another sample of 3-D city model of Ginza area. For both models, the processing time is about 2 hours for 1km<sup>2</sup> with a Pentium IV processor.

The 3-D model enables visibility analysis from each viewpoint of aerial photos. This realizes true orthoimage creation based on the re-created DSM from extracted building polygons. Figure 7 shows a sample of a true orthoimage of Shinjuku area (Oda et. al., 2004).

#### 4. SUMMARY AND FUTURE WORK

A method for automatic building extraction and 3-D city modelling has been presented and demonstrated with LIDAR data of Shinjuku and Ginza area in Tokyo. This method can

produce 3-D models with texture images and the processing time is about 2 hours for 1km<sup>2</sup> with a Pentium IV processor. This method now cannot express inclined roofs. This will be attained by segmentation of DSM which can distinguish inclined area as fragments

#### .References

Oda, K., W.Lu, Uchida, O., Doihara, T., Triangle-based visibility analysis and true orthoimage generation, ISPRS2004, Commission III, PS WG III/8.

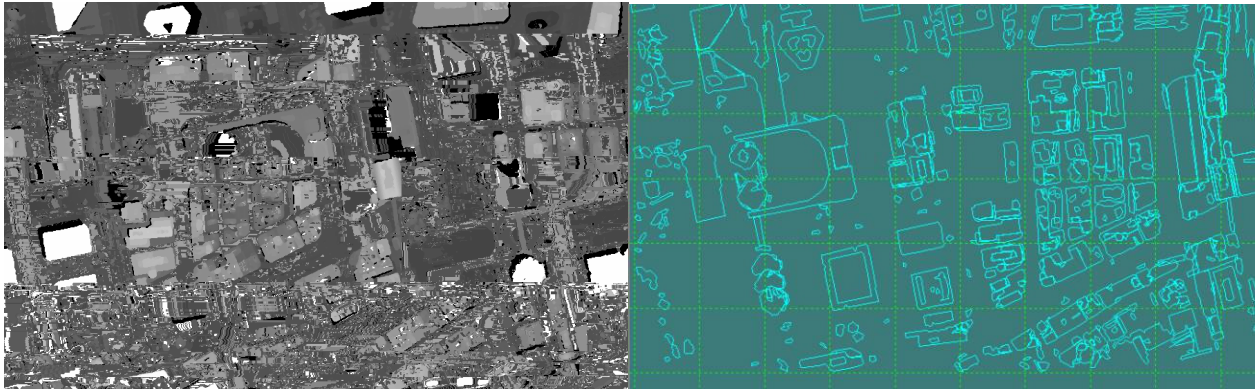


Figure 4. DSM image (left) and extracted polygons with LIDAR data (Shinjuku area)

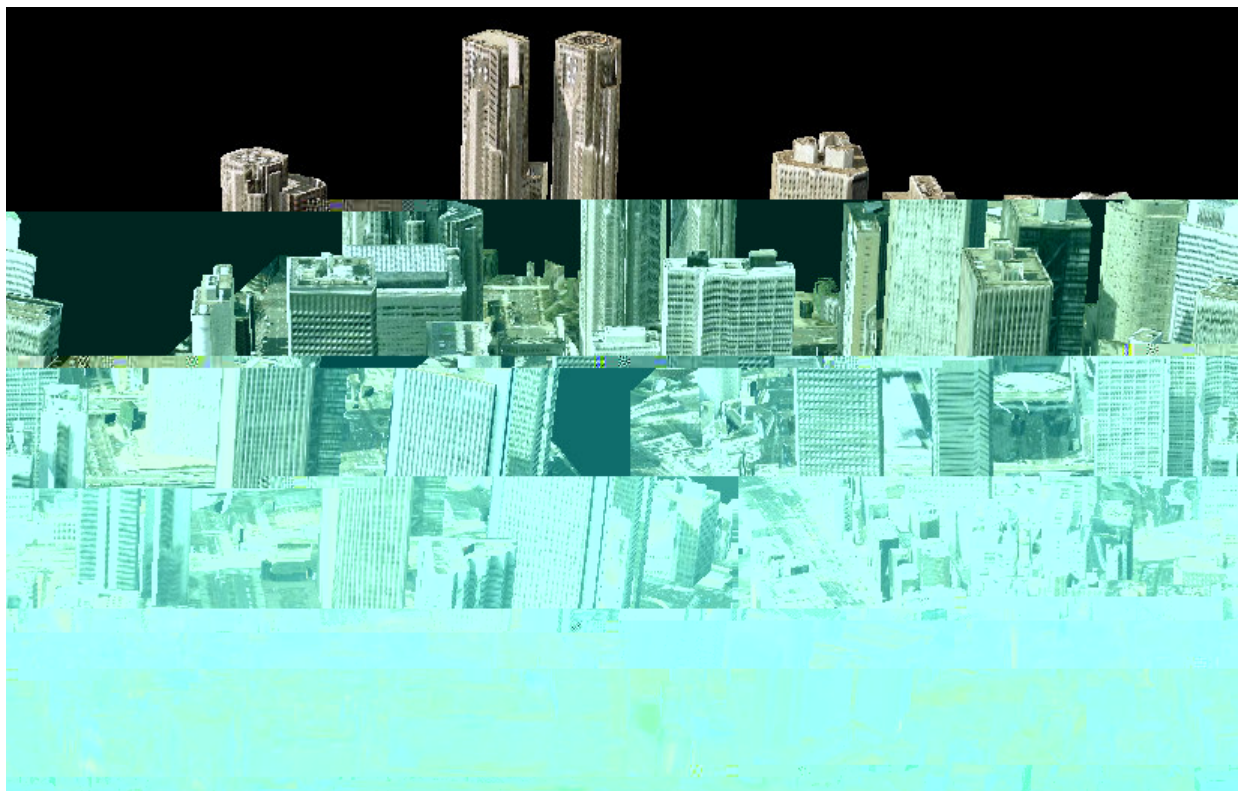


Figure 5. A sample of 3-D city model processed from LIDAR data and aerial images. (Shinjuku area)





Figure 6. A sample of 3-D city model processed from LIDAR data and aerial images. (Ginza area)

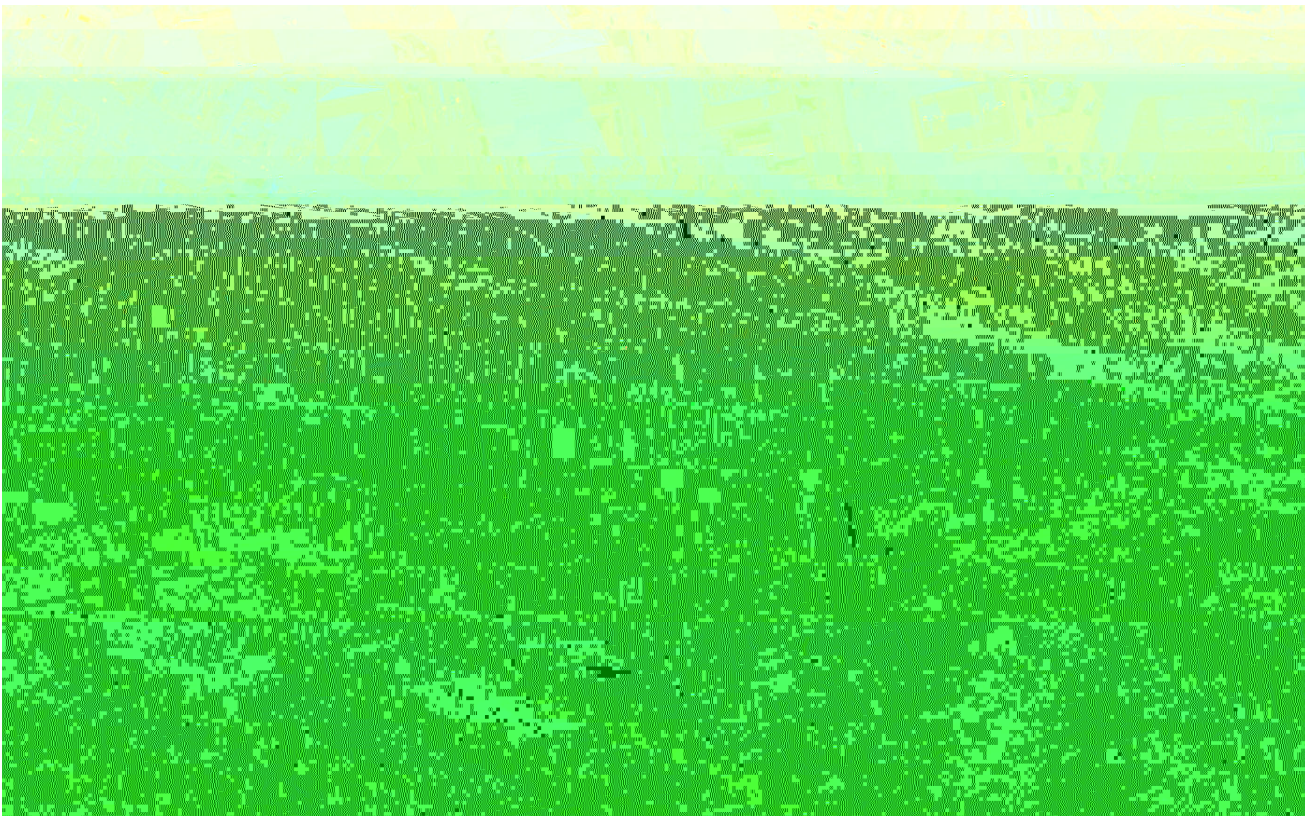


Figure 7. A true orthoimage of Shinjuku area.