# A Study on Automatic Extraction of Buildings Using LIDAR with Aerial Imagery


Young-jin Lee
ETRI(Electronics and Telecommunications Research Institute)
161 Gajeong-dong Yuseong-gu, Daejeon 305-350, Korea
yjinlee@etri.re.kr

Woosug Cho
Department of Civil Engineering, Inha University
253 Yonghyun-dong Nam-gu, Incheon 402-751, Korea
wcho@inha.ac.kr

Soo Jeong, Kyung-ok Kim
ETRI(Electronics and Telecommunications Research Institute)
161 Gajeong-dong Yuseong-gu, Daejeon 305-350, Korea
soo@etri.re.kr, kokim@etri.re.kr



**Abstract:** This paper presents an algorithm that automatically extracts buildings among many different features on the earth surface by fusing LIDAR data with panchromatic aerial images. The proposed algorithm consists of three stages such as point level process, polygon level process, parameter space level process. At the first stage, we eliminate gross errors and apply a local maxima filter to detect building candidate points from the raw laser scanning data. After then, a grouping procedure is performed for segmenting raw LIDAR data and the segmented LIDAR data is polygonized by the encasing polygon algorithm developed in the research. At the second stage, we eliminate non-building polygons using several constraints such as area and circularity. At the last stage, all the polygons generated at the second stage are projected onto the aerial stereo images through collinearity condition equations. Finally, we fuse the projected encasing polygons with edges detected by image processing for refining the building segments. The experimental results showed that the RMSEs of building corners in X, Y and Z were ±8.1㎝, ±24.7㎝, ±35.9㎝, respectively.



**Keywords:** LIDAR, Building Extraction, Airborne Laser Scanning.


## 1. Introduction

In photogrammetric practice, manual digitizing with stereo image is a typical way of extracting building. Since manual building extraction is very costly and time consuming, an automated procedure is in great demand. However, this is one of the most difficult tasks in digital photogrammetry. It could be said that automatic building extraction using LIDAR data has certain advantage over traditional photogrammetric technique when spatial resolution of the LIDAR data is high enough to extract buildings. The purpose of this investigation is to develop a robust procedure that reconstructs building by fusing LIDAR data with panchromatic aerial image.

## 2. Algorithm for Building Extraction

Building extraction algorithm that proposed in this paper is divided into three stages by form of used data. At the point level process, we eliminate gross error and extract building candidate points from LIDAR point data. At the polygon level process, we separate building polygon and non-building polygon and establish relationship of inclusion among polygons such as apartment rooftop and elevator tower on the apartment rooftop using area condition. At the parameter level process, we extract building boundary using edge information with projected encasing polygons. Figure 1 shows the process of proposed building extraction process.

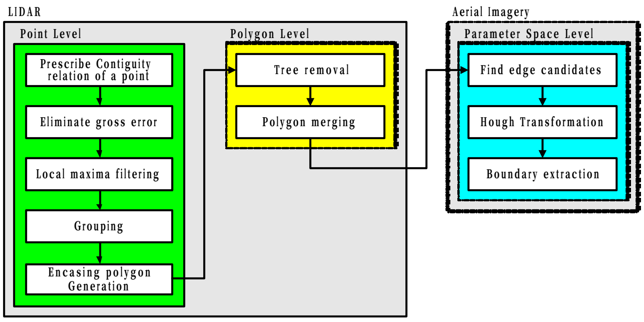


**Fig. 1. Proposed building extraction process.**

### 1) Point level process

1. Contiguity relation of a point

When process LIDAR point data directly, it is essential to prescribe contiguity relation of a point for improvement of data processing speed. In this study, we divide the object area into lattice and then, each lattice have index of points that exist in relevant space of the lattice, and each point have index of lattice that the point located in. Direct processing of point data is available at the fast speed using index of each point and lattice.

2. Eliminate gross error

To remove gross error, we find gross error candidates using statistical technique and then, find and remove isolated points among these candidates.

3. Extraction of building candidate points

It is possible to separate buildings candidate points from LIDAR data using assumption that building is higher than surrounding. In this study we use local maxima filter to extract building candidate points.

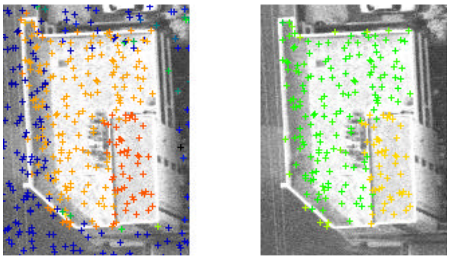


**Fig. 2. Building candidate points.**

4. Grouping

The purpose of grouping is to classify all the building candidate points into groups as on the same rooftop. This process is accomplished at the fast speed using predefined contiguity relation.

5. Generation of encasing polygon

We use encasing polygon algorithm that apply minimum distances condition to make polygon with building points.

**2) Polygon level process**

1. Tree Removal

To remove tree polygon we apply several constraints such as area and circularity. Remove polygons that have smaller area than predefined minimum area of building and have complex boundary using circularity.

2. Polygon merging

The purpose of polygon merging is to establish relationship of inclusion among polygons such as apartment rooftop and elevator tower on the rooftop using area condition. Figure 3 shows the result.

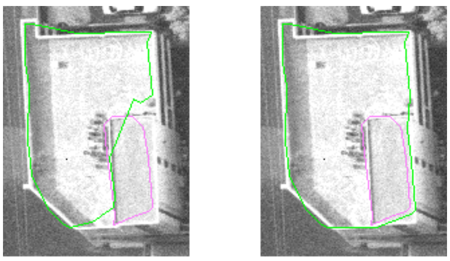


**Fig. 3. Polygon merging.**

**3) Parameter space level process**

1. Find edge candidates

To find edge equivalent to building boundary among a lot of edges, we project all the polygons left at the polygon level process to image space through collinearity condition equation and then, apply morphology dilation to find edge candidates.


**Fig. 4. Edge candidates.**

2. Extraction of building boundary

To extract building boundary we apply hough transformation and then, find accumulator cell of maximum value. Straight line relevant to this cell is longest side of the building boundary. Also, applying angle and distance condition on the accumulator cell we could extract the other side of building boundaries. Figure 5 shows the result.

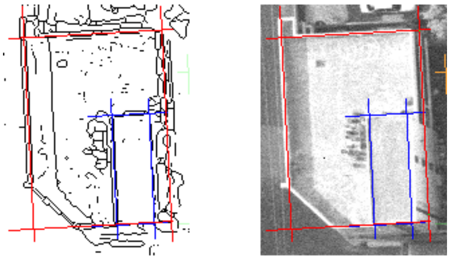


**Fig. 5. Building boundary.**

## 3. Experiment Results

**1) Data**

Test area is Chungjoo city in republic of Korea. Point density of LIDAR data is 1.22point/m$^2$ and scale of aerial photo is 1/5000.

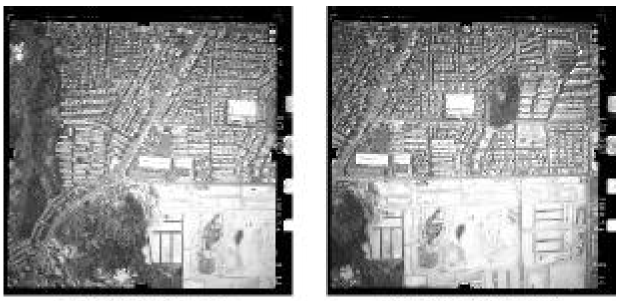


**Fig. 5. Aerial imagery of test area.**

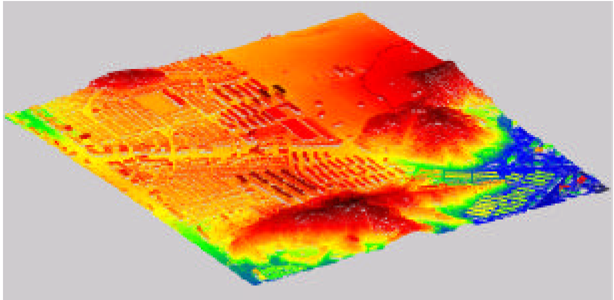

**Fig. 5. LIDAR data of test area.**

### 2) Results

To verify accuracy of extracted building corner points, we calculate ground coordinate of corner points through space intersection and then, compare that with the result from digital photogrammetry system. Table 1. shows the result.

**Table 1. Accuracy of building corner points extracted by proposed algorithm.**

| ID | Reference | | | Calculated | | | Difference | | |
|---|---|---|---|---|---|---|---|---|---|
| | X(m) | Y(m) | Z(m) | X(m) | Y(m) | Z(m) | X(m) | Y(m) | Z(m) |
| a1 | 241126.787 | 349869.228 | 87.856 | 241126.692 | 349869.250 | 87.697 | 0.095 | -0.023 | 0.159 |
| a2 | 241126.918 | 349858.467 | 87.729 | 241126.912 | 349858.099 | 87.710 | 0.005 | 0.367 | 0.019 |
| a3 | 241215.240 | 349859.607 | 87.824 | 241215.434 | 349859.311 | 88.485 | -0.194 | 0.296 | -0.661 |
| a4 | 241215.046 | 349870.639 | 87.824 | 241215.239 | 349870.436 | 88.504 | -0.193 | 0.203 | -0.680 |
| b1 | 241139.709 | 349841.715 | 87.051 | 241139.707 | 349841.609 | 87.052 | 0.002 | 0.106 | -0.001 |
| b2 | 241139.929 | 349830.831 | 87.085 | 241139.924 | 349830.516 | 87.066 | 0.004 | 0.315 | 0.019 |
| b3 | 241215.671 | 349832.156 | 86.932 | 241215.756 | 349831.622 | 87.588 | -0.084 | 0.535 | -0.656 |
| b4 | 241215.518 | 349842.942 | 87.277 | 241215.562 | 349842.749 | 87.602 | -0.044 | 0.193 | -0.325 |
| c1 | 241133.873 | 349813.833 | 86.480 | 241133.965 | 349813.717 | 86.646 | -0.092 | 0.117 | -0.166 |
| c2 | 241134.004 | 349803.174 | 86.349 | 241134.099 | 349803.269 | 86.535 | -0.095 | -0.095 | -0.185 |
| c3 | 241222.434 | 349804.583 | 86.463 | 241222.518 | 349804.650 | 87.153 | -0.084 | -0.068 | -0.690 |
| c4 | 241222.311 | 349815.282 | 86.624 | 241222.320 | 349815.089 | 87.122 | -0.009 | 0.192 | -0.498 |
| d1 | 241121.487 | 349777.551 | 91.736 | 241121.485 | 349777.446 | 91.737 | 0.001 | 0.105 | -0.001 |
| d2 | 241121.602 | 349766.501 | 91.750 | 241121.706 | 349766.449 | 91.755 | -0.104 | 0.053 | -0.005 |
| d3 | 241222.408 | 349767.972 | 91.535 | 241222.450 | 349768.075 | 91.875 | -0.043 | -0.103 | -0.340 |
| d4 | 241222.250 | 349779.069 | 91.382 | 241222.332 | 349779.055 | 92.062 | -0.082 | 0.014 | -0.680 |
| e1 | 241247.240 | 349874.302 | 113.367 | 241247.437 | 349874.229 | 113.841 | -0.197 | 0.073 | -0.474 |
| e2 | 241247.493 | 349863.190 | 112.973 | 241247.550 | 349862.900 | 113.597 | -0.057 | 0.290 | -0.624 |
| e3 | 241298.555 | 349863.347 | 113.101 | 241298.762 | 349863.250 | 113.425 | -0.207 | 0.096 | -0.324 |
| e4 | 241298.494 | 349874.701 | 113.518 | 241298.645 | 349874.573 | 113.688 | -0.151 | 0.129 | -0.170 |
| f1 | 241242.325 | 349828.310 | 107.593 | 241242.357 | 349828.282 | 107.913 | -0.032 | 0.028 | -0.320 |
| f2 | 241242.358 | 349816.048 | 107.636 | 241242.465 | 349816.305 | 107.635 | -0.107 | -0.257 | 0.001 |
| f3 | 241297.587 | 349816.459 | 107.480 | 241297.607 | 349816.642 | 108.476 | -0.020 | -0.183 | -0.996 |
| f4 | 241297.520 | 349827.731 | 107.558 | 241297.492 | 349828.596 | 108.775 | 0.028 | -0.865 | -1.217 |
| g1 | 241261.287 | 349791.991 | 96.664 | 241261.302 | 349791.802 | 96.153 | -0.015 | 0.189 | 0.511 |
| g2 | 241261.203 | 349779.691 | 95.883 | 241261.436 | 349779.787 | 96.216 | -0.233 | -0.096 | -0.333 |
| g3 | 241299.235 | 349779.836 | 93.574 | 241299.401 | 349780.032 | 94.092 | -0.166 | -0.197 | -0.518 |
| g4 | 241299.220 | 349792.045 | 93.524 | 241299.329 | 349791.823 | 93.847 | -0.109 | 0.221 | -0.323 |
| | | | | | | RMSE | ±0.081 | ±0.247 | ±0.359 |

## 4. Conclusions

This paper describes the algorithm for extraction of building boundary from LIDAR data with panchromatic aerial imagery. We showed how the aerial image can be fused with LIDAR data in the building boundary extraction process. The experimental results showed that the RMSEs of building corner points in X, Y and Z were ±8.1㎝, ±24.7㎝, ±35.9㎝, respectively.

## References


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