A Hybrid Approach for Building candidate Extraction from High-Resolution Satellite Imagery

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ABSTRACT:

The purpose of this study is to extract information about building candidate over inaccessible areas using high resolution satellite images. A 3D point cloud obtained by multiple images matching using existing satellite images contains a large number of noise and holes. These noise and holes have the effect of distorting shapes and reducing location accuracy in building modeling. In this paper, we use SGM(Semi-Global Matching), which is a dense point matching method, and pen-sharpened image information to overcome these limitations. The 3D point cloud data obtained by using the SGM is separated into the ground and non-ground data by using the SMRF(Simple Morphological Filter) algorithm, Non-ground point data is grouped by each building, taking into account the spatiality of each point to create an initial building hypothesis. The pen sharpened image acquires a plurality of segments by using color based mean-shift segmentation.

Initial building hypothesis is projected on to the color segments using the RPC(Rational Polynomial Coefficient) information. Refined building hypothesis is extracted considering the redundancy and space of the projected initial building hypothesis and the image segments. Line detection and space splitting techniques were used for boundary extraction in refined building hypothesis Building candidates are determined by combining the boundaries obtained with line detection and spatial segmentation techniques with refined building hypotheses.

The results were evaluated qualitatively by contrasting with the satellite image, and the positional information of the building edge was acquired from the image data to quantitatively evaluate the relative positional accuracy.

1. Introduction

As the spread of high resolution satellite imagery grows, we can acquire high-quality image information about the entire earth regularly. The advantage of high-resolution satellite image data is that it is not affected by accessibility to the area of interest. Therefore, the use of high-resolution satellite imagery can efficiently acquire terrain and building information for inaccessible areas where data acquisition is not possible from field surveying, aerial photographing, and LiDAR scanning.

The purpose of this study is to extract information about building candidate over inaccessible areas using high resolution satellite images. This study proceeds as follows.

1. Generation of 3D point cloud data through stereo image matching.
2. Generation of initial building hypothesis using Ground & Non-Ground Separator and 3D points grouping
3. Color-based segmentation using pan-sharpened images.
4. Generation of refined building hypothesis using both of initial building hypothesis and Color-segments.
5. Extraction of building candidate using refined building hypothesis, line detection and space splitting

Stereo image matching can be performed through global matching technique. Local matching or window-based matching has a high occurrence of mismatching in regions where the repeated structure or feature is not large, and generates a lot of noise and holes. Global matching can accurately extract the shape of buildings through cost optimization.(Seung Hae Baek, 2010) Therefore, in this study, we applied the SGM (Semi-Global Matching) technique, a high density image matching technique proposed by Hirschmuller (2008). SGM(Semi-Global Matching) is used as a way to match the pixel unit and to increase the search area. After each pixel traversal, cost optimization can extract more dense point cloud data. Next, the dense point cloud data is separated into Ground & Non-Ground data using SMRF(Simple Morphological Filter). SMRF is a Ground & Non-Ground point cloud data separation method. (Thomas J. Pingel et al, 2013) SMRF is relatively superior to the adaptive TIN model. (Axelsson, P., 2000)

An initial building hypothesis was generated by grouping the points below a certain distance by calculating the distances between the points in the separated Non-Ground data. However, the extracted initial hypothesis contains a lot of noise and holes resulting from the limitations of image matching technology. Therefore, refine process is necessary to overcome this limitation.

We overcome this by using color information of images, not just 3d point clouds. Pan-sharpened images and color segmentation methods were used. The pan-sharpened image is generated by combining multi-spectral image and panchromatic image, and partitions buildings and terrain by using color information of the pan-sharpened image. This improves the split result compared to the gray scale based approach.

Project the initial building hypothesis onto the color segment, calculate the redundancy, and remove the noise to obtain the refined building hypothesis. refined building hypothesis can achieve final building candidate through line detection and spatial partitioning. A buffer is created on the left and right image of Building hypothesis, and the outline of the building is specified through LSD(Line Segment Detector). (Rafael Grompone von Gioi et al, 2010) When applying a Kenny edge detector and performing a half transform when extracting lines, a high edge density texture area can cause many false detections when applying a canny edge detector. Ignoring the direction of the edge point, this algorithm takes the line segment in an unusual direction. Also, setting thresholds is a fundamental problem for all detection methods. LSD uses the same parameters to solve this problem and provides better performance in line extraction. The lines generated by LSD intersect the lines from merging and left and right images to extract the final line. The final lines are space split using the TIN method. Next, calculate the redundancy calculation of the partitioned space and refined hypotheses and combine them to extract the final building candidate.

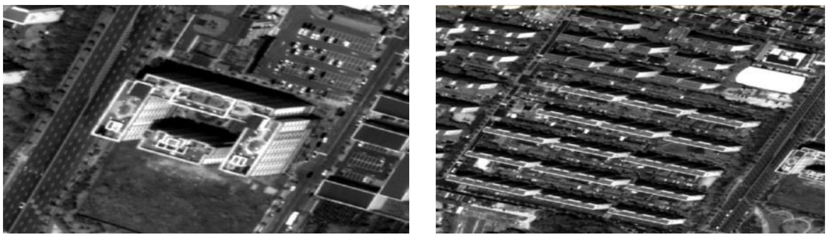
This paper proceeds as follows. Chapter 2 discusses stereo matching, ground plane separation, initial hypothesis generation, color segmentation, and outline and building candidate extraction. Chapter 3 shows the final experimental results of the extracted building candidate and analysis of the accuracy on the image. Chapter 4 discusses the conclusions and future work of this study.

2. Hybrid approach for building extraction

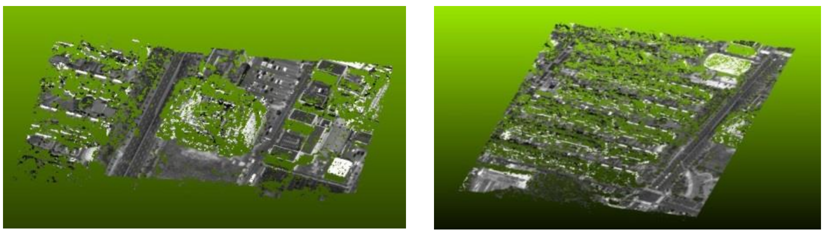
2.1 SGM-based dense point cloud data generation

The SGM searches disparity cost between pixels corresponding to each other in multiple directions, accumulates the disparity cost in the search area, and performs image matching using the cost. To calculate disparity cost, Census is adopted (Humenberger, M., 2010). Afterwards, the coordinates of matching points are calculated using the final disparity map and the RPCs (Rational Polynomial Coefficients) of the satellite images. WorldView-2 taken over Daejeon, Korea, is utilized for this experiment.

Fig 1. (a), (b) show the tall buildings in the area, and (c), (d) are the results of the SGM of (a), (b). Buildings with higher phases generate more noise and occlusion in matching Fig 2. (a), (b) and (c) show satellite images of the selected area. Also, Fig 2. (d), (e), and (f) shows the respective SGM results. Many point clouds can be obtained in relatively low buildings, but noise and holes can be fatal to objects and model extraction. For the progress of the experiment, three buildings of Fig 2. were used as the experiment area.

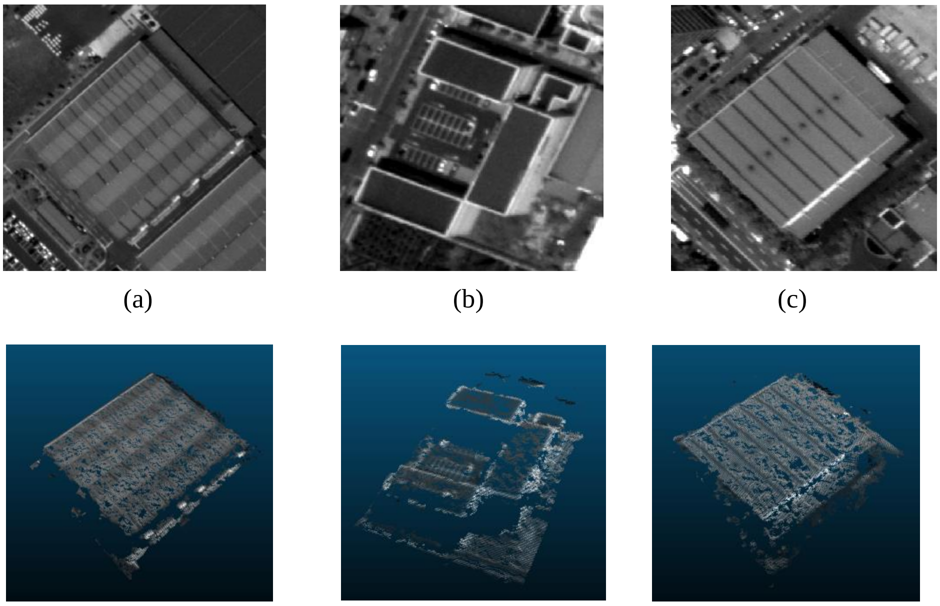


(a) (b)



(c) (d)

Figure 1. Satellite images and SGM Results for Tall Buildings



(a) (b) (c)

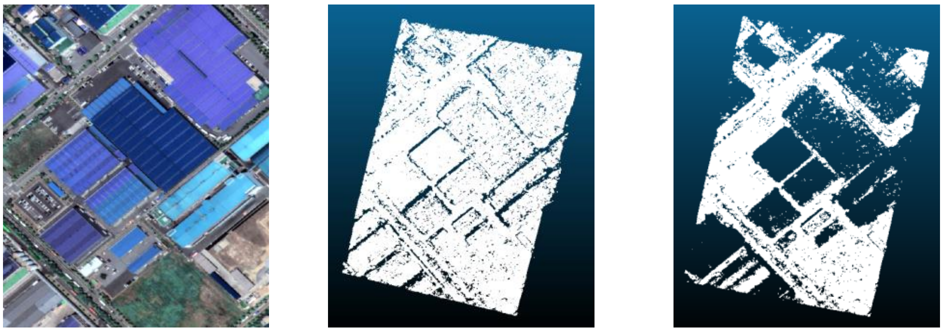
(d) (e) (f)

Figure 2. Satellite images and 3D point cloud data over the areas of interest

2.2 Non-ground and ground point data separation using SMRF

The SMRF(Simple Morphological Filter) technique is based on simple morphological image processing steps. This method is proposed by Thomas J. Pingel et al. (2013), and its superiority to other approaches is proved. Fig. 3 shows the ground and non-ground separation results after SMRF. Spatial connectivity analysis and group size checking are applied afterwards to determine the initial building candidates.

Fig. 3 (a) is a pan-sharpened satellite image, and (b) is a point cloud of the region. (c) is ground point data separated by SMRF, and (d) is non-ground point data separated by SMRF. They then grouped together to remove noise from the non-ground data and create initial building hypothesis using the non-ground data. Data groups are grouped by calculating the three-dimensional distance of each point, a point located below a certain distance. Fig. 3 (e) removes points that are difficult to judge as buildings below a certain size from non-ground data. Fig. 3 (f) expresses the result of point grouping in color considering three-dimensional spatiality. Fig. 3 (g), (h), and (i) are the results of the separation of ground level data from the test area, green points are ground data, and other colors are non-ground data.



(a) (b) (c)

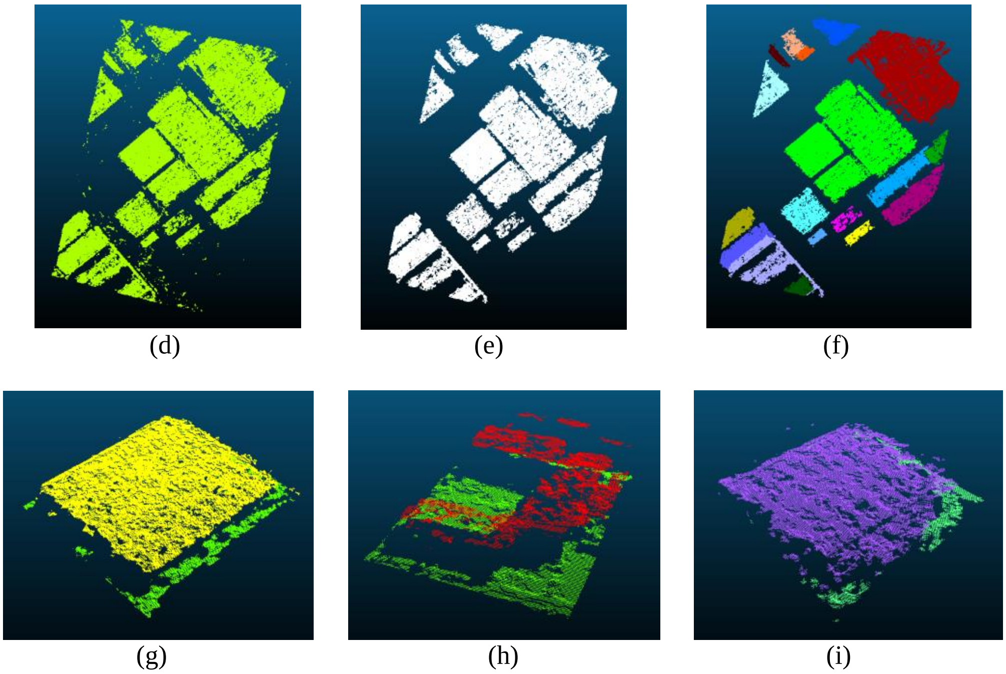


Figure 3. Ground and non-ground separation results and Initial hypothesis

2.3 Refined hypothesis extraction using color-based segmentation

At this stage, mean-shift technique and pan-sharpened image are utilized to acquire color-based segments. This technique exhibits relatively stable segmentation performance in various image data including natural environments. (D. Comaniciu et al., 2002) The color-based segments used the image of the grouped point cloud. Fig. 4 shows the derived color-based segmentation results. In this figure, different colors indicate different segments. Next, refined hypothesis considers spatial overlap between the initial building candidates (projected onto the satellite image) and the color segments (extracted by mean-shift) to improve the quality of building candidates. As the first step, the 3D points belonging to the initial building candidates are projected onto the satellite imagery (Fig 5. a, b, c).

Afterwards, the degree of overlap between the projected initial building candidates and color segments is checked. All the color segments satisfying a certain level of overlap are consolidated as one segment. Spatial connectivity in 2D space is also considered by applying connected component analysis. Fig 5. (d), (e), (f) are the results of refined building hypothesis in the experimental area.

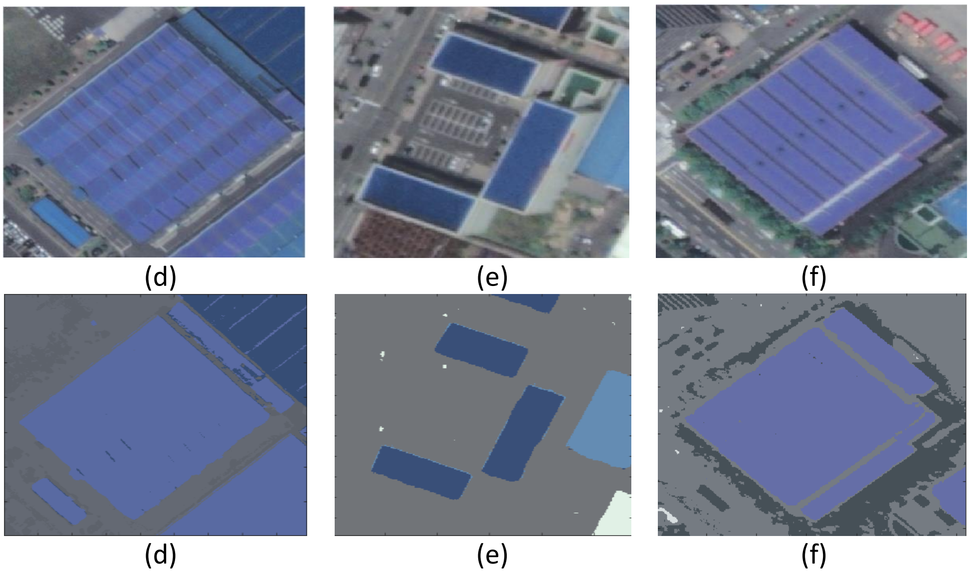
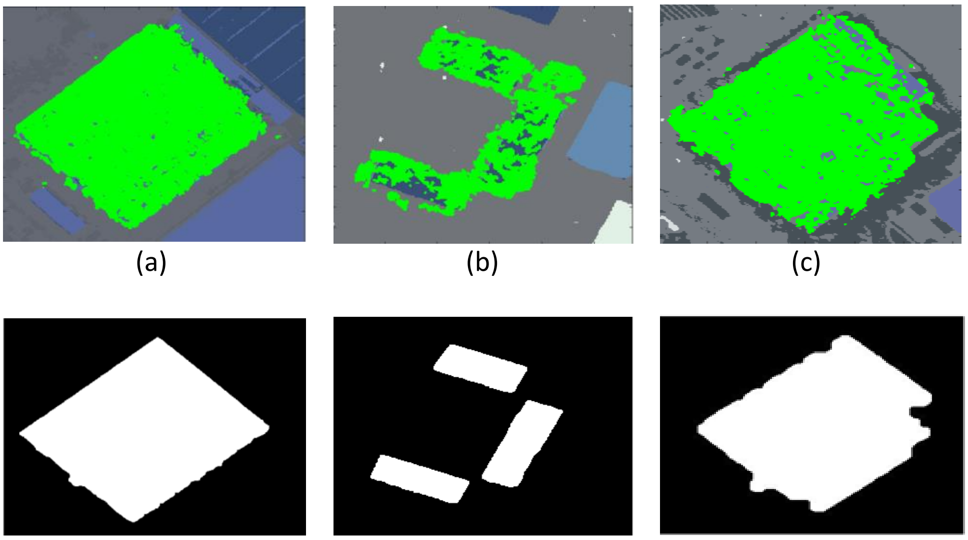


Figure 4. Color-based segmentation results using pan-sharpened images



(a) (b) (c)

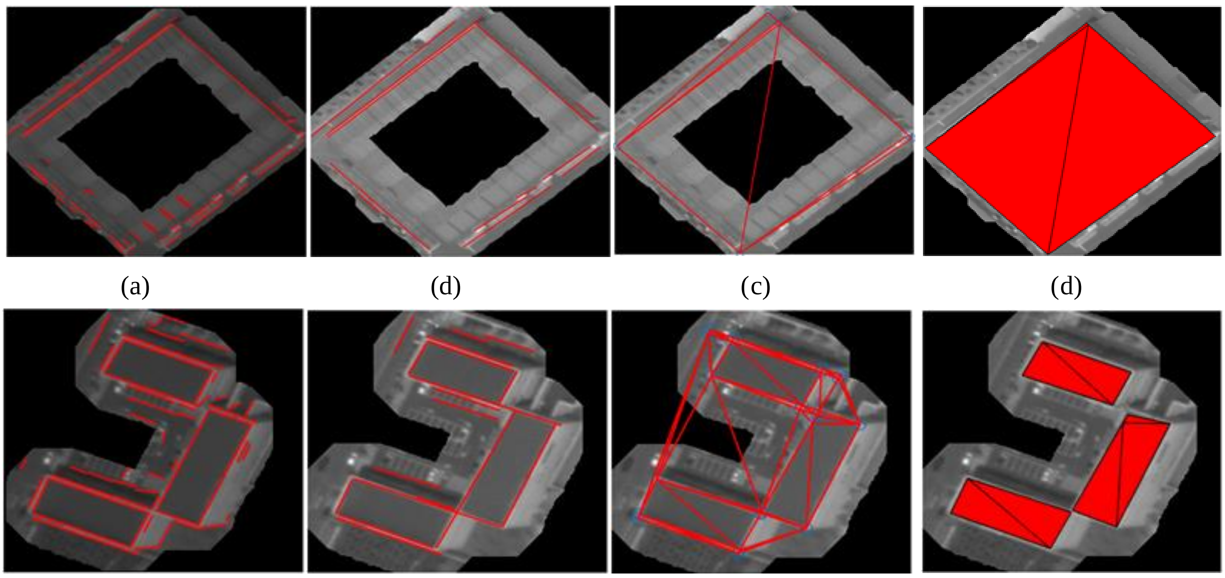
(d) (e) (f)

Figure 5. Point cloud projection on segment images and refined building hypothesis

2.4 Building candidate extraction using refined building hypothesis

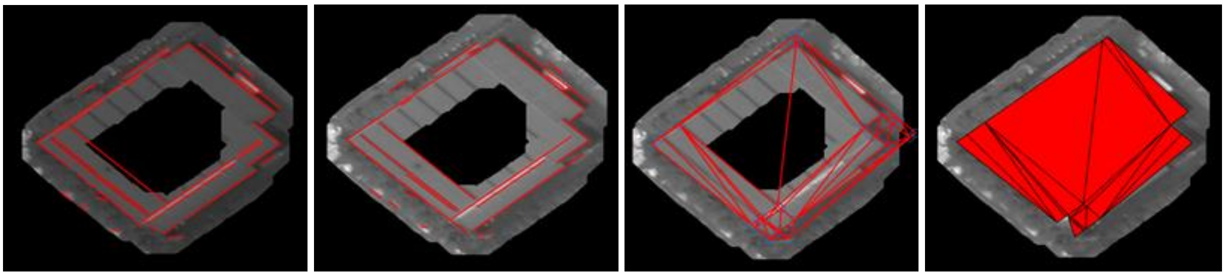
Load the image into the Refined Building Hypothesis. Create a buffer around the loaded image and proceed with line extraction. Line extraction used line segment detection (LSD) and applied to left and right stereo images. Line merging then merges adjacent lines and removes lines below a certain length. Intersect the lines of merging left and right images. Spatial partitioning is performed using the lines created by the intersection. Triangulated irregular network (TIN) was used for the spatial partitioning method, and the final building candidate was extracted by calculating refined hypothesis and redundancy.

Fig. 6 (a), (e) and (i) are the line results extracted by using the LSD of each experimental area. (d), (f) and (j) are the line merging results of each experimental area.(c), (g) and (k) are spatial splitting results after line intersection of left and right images, and (d), (h) and (l) are final building candidate extraction results.



(a) (d) (c) (d)

(e) (f) (g) (h)



(i) (j) (k) (l)

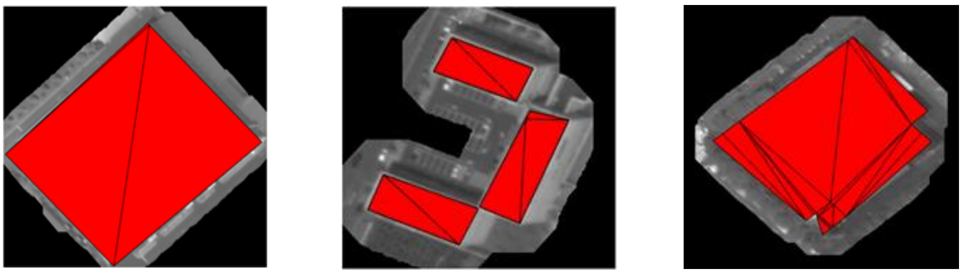
Figure 6. Step-by-Step Extraction of Boundary and Plane using Refined B.H

3. Results and analysis

Fig. 7 (a), (b) and (c) show the satellite images of the test area. (d), (e) and (f) are the extraction results of the building candidate of the test area. As a qualitative evaluation, Fig. 7 (d) shows the inaccuracy of building boundary line extraction, which causes distortion of the building candidate because the line of the road was extracted instead of the gable roof cross section. Fig. 7 (e), the area extracted from the inner wall of the fence, not the outermost line, was extracted with the outermost line. Fig. 7 (f) has a complex building shape and an incorrect building candidate was extracted due to the errors of the refined hypothesis and the line extraction error.

Table 1. is the average data for each building, comparing the edge location information of each experimental building candidate with the edge location information measured manually. The error was calculated to be 11.839pixels maximum and 2.541pixels minimum, and the average error in the ground coordinate system was converted by multiplying the World View-2 image resolution by 0.5m.

(a) (b) (c)



(d) (e) (f)

Figure 7. Satellite images of the test area and building candidate extraction results

Table 1. Average result of each building

Test building	Image average (pixel)	Distance average (m)
Fig 7. (d)	11.839	5.920
Fig 7. (e)	2.541	1.270
Fig 7. (f)	4.069	2.035

4. Conclusion and future work

In this paper, we proposed a hybrid approach for extracting building candidates from high-resolution satellite imagery while considering object and image space. This approach is proposed to overcome the limitations of building candidate extraction when using only either 2D image or 3D point cloud data. The complexity of image segmentation (from 2D image) is reduced by limiting the searching areas into the initial building candidates. Moreover, the use of line detection and spatial partitioning techniques has reduced the effects of noise and holes from 3D point clouds. The possibility of applying the proposed approach to acquire high-quality building candidate is verified through the experimental results. Future work will improve line extraction and spatial separation performance to reshape and reshape 3D building shapes for various complex building roofs.

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