Building edge extraction based on DSM digital surface model and LIDAR point cloud data

Hui Kong¹,²,³, a

¹Shaanxi Provincial Land Engineering Construction Group Co., Ltd., China
²Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China
³Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Land and Resources, Xi'an 710075, China

a283125485@qq.com

Abstract. LIDAR (Light Detect And Ranging) is a new measurement system that USES laser beam scanning to Detect targets And measure distances, And can directly And quickly obtain high-precision digital surface models (DSM) of different areas, such as urban areas. This can make up for the defect of image data in the third dimension. The emergence of this technology provides a new way for the rapid extraction of surface models, especially for buildings in urban areas. In this paper, based on the airborne LIDAR point cloud data, the irregular discrete LIDAR point cloud data grid resampling rules, get digital surface model (DSM), and then carried out in accordance with the elevation gray quantitative generated DSM depth image, using edge detection operator to extract buildings, using orthogonal constraint to the adjacent segment Angle adjustment, to obtain the edge information in line with the actual situation of buildings. Finally, the accuracy and precision of segmentation results are analysed.

1. Introduction
Currently, airborne LIDAR data, as a precise and rapid acquisition of three-dimensional data, is gradually used as a modeling data source involving three-dimensional information. It is an advanced active sensing system for airborne laser detection and ranging installed on aircraft. It is an integrated application system of GPS, INS and laser ranging. The measured data is the discrete point set of Digital Surface Model (DSM), which contains spatial high-precision three-dimensional information and laser intensity information. By means of high-speed laser scanning measurement, the 3d coordinate data of the surface of the measured object can be obtained quickly with large area and high resolution. It has the advantages of rapid production of DTM/DSM, high quality terrain data, free from restrictions of sunshine and weather conditions, all-weather ground observation, low cost and great application potential, etc., making this technology also has broad development prospects and application requirements in many fields such as three-dimensional urban modeling and terrain mapping.

2. Building edge detection algorithm
The edge of the image is of great significance to human vision, and human visual system is largely dependent on the edge to recognize objects. Edge contains rich internal information (such as direction,
step property, shape, etc.), which is an important attribute to extract image features in image recognition. There is an edge between two adjacent regions with different gray values. The edge is the result of the gray discontinuity, which can be easily detected by the derivative. Edge feature can not only be used for image segmentation and texture analysis, but also be an important information source for 3d object extraction.

Edge detection is one of the classical research subjects of image analysis. Edge detection first detects the discontinuity of the image's local characteristics, and then connects the discontinuous edge pixels into a complete boundary. The characteristic of edge is that the pixels along the edge change gently, while the pixels along the vertical edge change sharply. This paper focuses on building segmentation based on mean shift depth images generated by LIDAR data.

2.1. Principle of Mean Shift algorithm
Mean shift algorithm (Comaneci et al., 2002) is a fast parameter less pattern matching algorithm based on kernel density gradient estimation. Kernel density estimation (also known as Parzen window estimation) is a very effective probability density estimation method. Suppose the finite set in d-dimensional Euclidean space Rd \( S = \{ x_i \}_{i=1}^N \). Its unknown probability density function is \( f(x) \). Select the centrosymmetric kernel function \( K(x) \) and the bandwidth matrix \( H \) of \( d \times d \), then the multivariate kernel function is estimated as follows:

\[
\hat{f}(x) = \frac{1}{n} \sum_{i=1}^{n} K_{H}(x - x_i)
\]

Type in the \( K_H(x) = |H|^{-1/2}K(H^{-1/2}x) \)

In order to simplify the processing, radial symmetric kernel functions satisfying \( K(x) = c_k,d \cdot k(\|x\|^2) \) are usually used, and \( K(x) \) (a convex function with decreasing monotonic value in the mean shift algorithm) is called the profile function of \( K(x) \). \( K(x) \) define the integral \([0, \infty)\), \( c_k \), \( d \) for the constant coefficient, and the coefficient of the effect of \( k \) (x) is the integral of 1. To simplify the calculation, usually take \( H \) for diagonal matrix \( H = \text{diag}[h_1^2, ..., h_d^2] \) or \( H = h^2I \). I, \( d \times d \) unit matrix. Generally use the second \( H \) density estimation can be simplified, so you need to define a parameter \( H \) can be greater than zero bandwidth for kernel density estimation, kernel density estimation can be written as:

\[
\hat{f}_{h,h}(x) = \frac{c_{k,d}}{nh^d} \sum_{i=1}^{n} K\left(\frac{\|x - x_i\|^2}{h}\right) x \in \mathbb{R}^d
\]

Where, \( c_k \) and \( d \) are defined as follows: \( n \) is the number of reference samples, \( h \) is the bandwidth, and \( x_i \) is the ith sample point in the window. \( x \) is the center point of the kernel function, that is, the data point to be processed. Then the meaning of kernel density estimation is that the average value of the local kernel function centered on each data point is taken as the estimated value of the probability density function of the data point, or the weighted local average of the estimated point is calculated in the window centered on the estimated point. The bandwidth parameter \( h \) determines the size of the window, that is, the size of the local neighborhood.

2.2. Edge optimization
In reality, buildings are carefully designed and conform to certain regular shapes, so the ideal result of detection should be a polygon with smooth edges and right angles (generally approximate rectangle). The operation in the previous part only gave the main direction when merging the line segments. For the line segments that have not been re-merged, although the general direction is correct, there is still a certain Angle between the line segments and the edge of the actual building. Therefore, the direction of the line segments needs to be slightly adjusted to make it more consistent with the actual situation. Implementation idea: traverse each line segment and compare the Angle between the line segment and the main direction line. When it is greater than 45°, adjust the Angle to make it perpendicular to the
main direction; when it is less than 45°, make it parallel to the main direction. As shown in the FIG.1, the included Angle between line segment ab and the main direction line is less than 45°. After passing the midpoint o of ab, a straight line parallel to the main direction line is determined. Then, line segment pl with line segment o as the midpoint and the length of line segment ab is intercepted, which is the adjusted edge.

![Image](image.png)

**Figure 1.** Right-angle constraint process

Implementation process:

```matlab
[L1 Index1]=max (Len(:))
xy2 = [lines (Index1).point1; lines (Index1).point2];
x2=[lines(Index1).point1(1) lines(Index1).point2(1)];
y2=[lines (Index1).point1(2) lines (Index1).point2(2)];
k2=(lines(Index1).point1(2) - lines(Index1).point2(2))/(lines(Index1).point1(1) - lines(Index1).point2(1));
for i = 1:length(lines)
    xy1 = [lines(i).point1; lines(i).point2];
x1=[lines(i).point1(1) lines(i).point2(1)];
y1=[lines(i).point1(2) lines(i).point2(2)];
k1=(lines(i).point1(2) - lines(i).point2(2))/(lines(i).point1(1) - lines(i).point2(1));
zhenqie=abs(k1 - k2)/(1+k1*k2);
jiaodu=atan(zhenqie)*180/3.14;
n=length(x1);
m=length(x2);
juli=zeros(n, m);
for ii=1:n
    for jj=1:n
        juli(ii, jj)=sqrt((x1(ii) - x2(jj)).^2+(y1(ii) - y2(jj)).^2);
    end
[min_juli, min_point]=min(juli(:));
j0=fix(min_point/n)+1;
```
i0=mod(min_point, n);
if jiaodu>80
    lines(i).point1(1)=lines(Index1).point1(1)
    lines(i).point1(2)=lines(Index1).point1(2)
    k1=-1.0/k2
    b=lines(Index1).point2(1)-k1*lines(Index1).point1(1)
    b0=lines(i).point2(1)-k2*lines(i).point2(1)
    lines(i).point2(1)=(b0-b)/(k1-k2)
    lines(i).point2(2)=k2*lines(i).point2(1)+b0
else
    biaoji=0;
end
end

3. Analysis of experimental data and results

3.1. The experimental data
The original experimental data adopted in this paper is the 3d discrete point cloud coordinate data obtained after preprocessing of LIDAR original data. Its format is an ASCII text file stored in the form of geodetic coordinate system. Each record includes X, Y, Z coordinate values and reflection intensity values, and their arrangement is irregular, as shown in FIG.2.

![Figure 2. LIDAR data](image)

3.2. Point cloud data processing
After removing the maximum and minimum values of the data, data points are encrypted, as shown in FIG.3. DSM was generated by IDW difference operation of 3D ANALYST module in ARCGIS, and the pixel size was set at 0.5 to generate DSM image, as shown in FIG.4. Due to the large amount of data, a small area will be reduced as the experimental area for the consideration of the following experiments. FIG.5 is the DSM image after the reduction.
Figure 3. Data points before and after encryption

Figure 4. DSM image

Figure 5. DSM data after clipping

Generate the depth image of FIG.6, DSM according to the histogram of FIG.7.0

Figure 6. Histogram
Median filtering (FIG.8), histogram threshold segmentation (FIG.9), and removal of small patches (FIG.10) were preprocessed.

3.3. The experimental results

Figure 8. Median filtered image

Figure 9. Histogram threshold segmentation

Figure 10. Removal of small area image spots

Figure 11. Canny detection result

Figure 12. Right-angle constraint
3.4. The experimental conclusion

As can be seen from the experimental results, the late from canny test results to optimize processing, building has the edge information from the curve of the image pixels in the space to make a straight run of transformation in the parameter space, although the effect is not ideal, but there has been a great breakthrough, the edge is no longer a jagged, in addition, our experiment to join right Angle constraint condition, etc. Results are basically in agreement with that on the edge of the building. But there are some problems:

1) The right-angle constraint in this experiment did not consider the connection of adjacent line segments, but simply carried out the rotation of the midpoint of a winding segment, so the discontinuous line segment of the result was not a closed surface. In addition, the boundary will be offset.

2) At the time of removing the information such as trees, utility poles, USES is to divide, small area of the city road there will be a long time on both sides of the great trees, and the distance is very close to each other, branches and leaves has crossed together, form a considerable area, then choose to small area division is no way to filter out the information, will influence the test results.

3) Most of the buildings in the city are rectangular or polygons composed of right angles, but some special buildings, such as the stadium, are oval. The method in this experiment is not applicable to those buildings with curved edges.

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