STREET TREE EXTRACTION BASED ON VEHICLE LIDAR POINT CLOUD

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ABSTRACT: Vehicle LiDAR provides an efficient means to acquire 3D point clouds of urban roads. For engineering practical application, we have developed a technical method to obtain street trees from vehicle-borne LiDAR quickly. Ground filtering algorithm was used to extract non-ground point clouds. A canopy height model (CHM) was created by using ground point clouds and non-terrestrial point clouds. Based on CHM, the local maximum window with variable window sizes was used to search the treetops of the crown, and to identify the treetops of individual tree crown and the extraction of individual tree. Using the crown treetops mark, marker-controlled watershed method was applied to segmentation algorithm into isolating individual trees. This method can quickly and effectively extract street trees information.

1. INTRODUCTION

As an important part of urban road scene, the rapid and automatic extraction and classification of street trees is of great significance to the construction of digital and smart city. Traditional surveying and mapping methods not only need to spend a lot of manpower and financial resources, but also have very low efficiency. As a high-efficiency 3D geospatial information acquisition technology, the vehicle-borne light detection and ranging system (vehicle-borne LiDAR) can quickly obtain detailed 3D spatial information of road and ground objects on both sides, and the spatial characteristics of street trees can be accurately expressed in the three-dimensional point cloud, providing a new technical support for obtaining the street trees. Individual tree extraction from urban MLS point clouds has many urban applications, such as tree inventories, green view rate estimation, 3D street tree modeling, and urban planning (Lu et al. 2014; Lin and Hyyppa 2012). However, urban MLS point clouds are usually characterized by complex scenes, large data volume, and uneven spatial distribution. These issues pose significant challenges to extract individual trees from urban MLS point clouds. The extraction of street trees in vehicle- borne LiDAR point cloud data has been a research hotspot for scholars. A block-based elevation filtering approach was used to remove ground points from urban MLS point clouds (Yua et al. 2014). By using Euclidean distance clustering, the non-ground points were grouped into a set of clusters. After that, a voxel-based normalized cut segmentation method was used to separate the clusters containing multiple instances. Finally, a template matching-based strategy was used to extract the individual trees. Zhong Ruofei (Zhong et al. 2013)used the RGB information of high-resolution panoramic images to divide the vehicle LiDAR point cloud into ground point cloud and non-ground point cloud, segmented the tree information based on the non-ground point cloud data, and extracted the attribute information of a single tree. However, the assistance of image data is required, which limits the universality of this method. Monnier (Monnier, Vallet, and Soheilian 2012) detected the center position of the tree and the crown of the tree by projecting the point cloud to a two-dimensional horizontal plane, based on the center point of the canopy, using the principle of the closest distance, to achieve the basic segmentation of the point cloud of connected street trees. (Li, Cheng, and Xiao 2022) propose a branch-trunk-constrained hierarchical clustering method to individually extract street trees from mobile laser scanning (MLS) point clouds. A semantic segmentation deep network is applied to segment tree points from raw urban MLS point clouds, and then the segmented tree points are further grouped into a set of tree clusters using Euclidean distance clustering. Next, a pointwise direction embedding deep network is proposed to predict the direction vectors pointing to tree centers for each tree cluster to enhance the boundaries of instance-level trees. After that, a direction aggregation-based strategy is developed to detect the tree centers for each tree cluster, and the clusters are classified into single-tree clusters and multi-tree clusters based on the number of detected tree centers. Finally, the single-tree clusters are directly extracted as individual trees(Luo et al. 2021) .

However, there were still some error extractions, the process is complicated. For engineering practical application, we have developed a technical method to obtain street trees from vehicle-borne LiDAR quickly.

2. METHODOLOGY

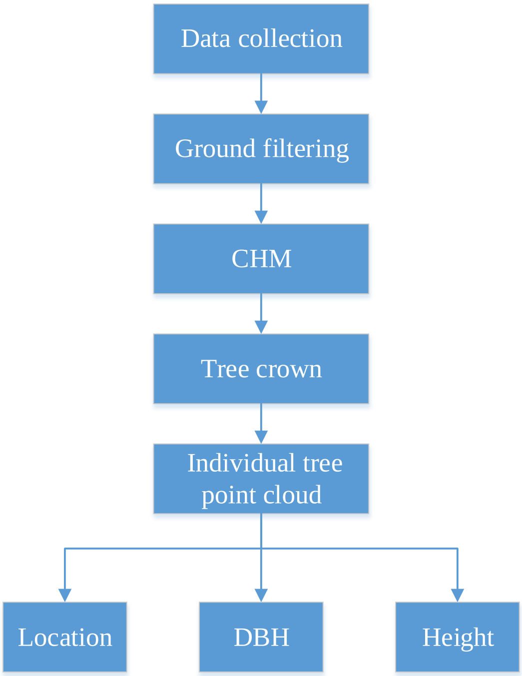


Figure 1 Flow chart

2.1 Mobile Laser Scanning System

In 2021, GZPI integrate high-standard core sensors such as AP60 inertial navigation system, Regal VUX-1 laser scanner, Ladybug5+ panoramic camera, etc., and develop a new generation of high-precision vehicle-mounted mobile measurement system (Figure 2), which can efficiently collect high-precision and high-density 3D true-color point clouds (Figure 3) and high-resolution 360° panoramic images along the road.

Figure 2 High-precision vehicle-mounted mobile measurement system

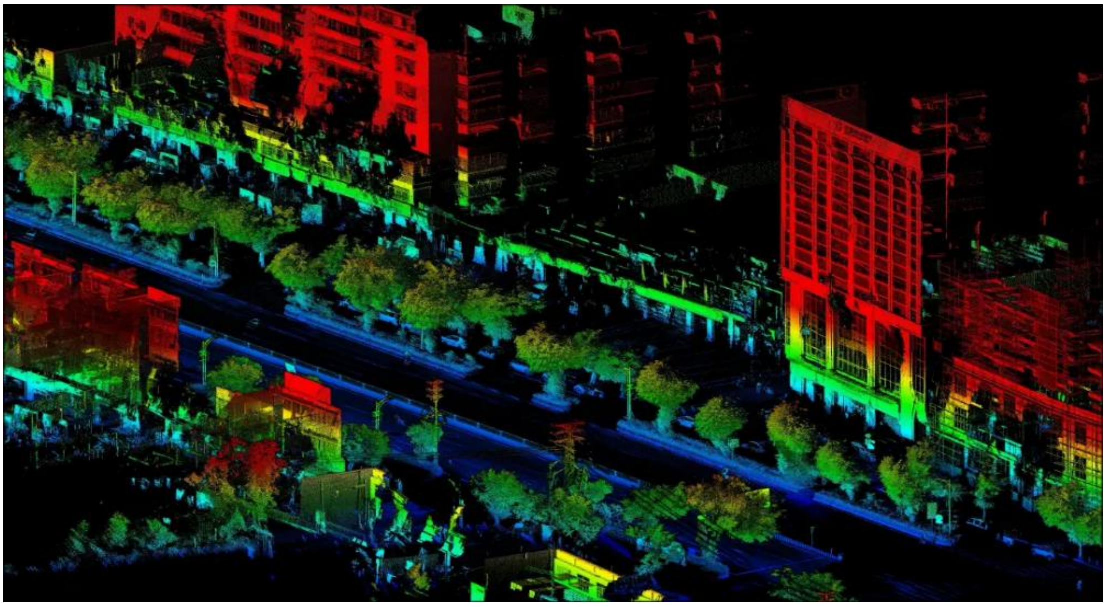


Figure 3 Point cloud

2.2 Ground Filtering

Ground point cloud was separated by using progressive morphological filtering algorithm(Zhang,   Keqi et al. 2003).

1) Creates a regular grid at intervals of point cloud spacing. The ID number of the grid is the index number of each point in the grid.

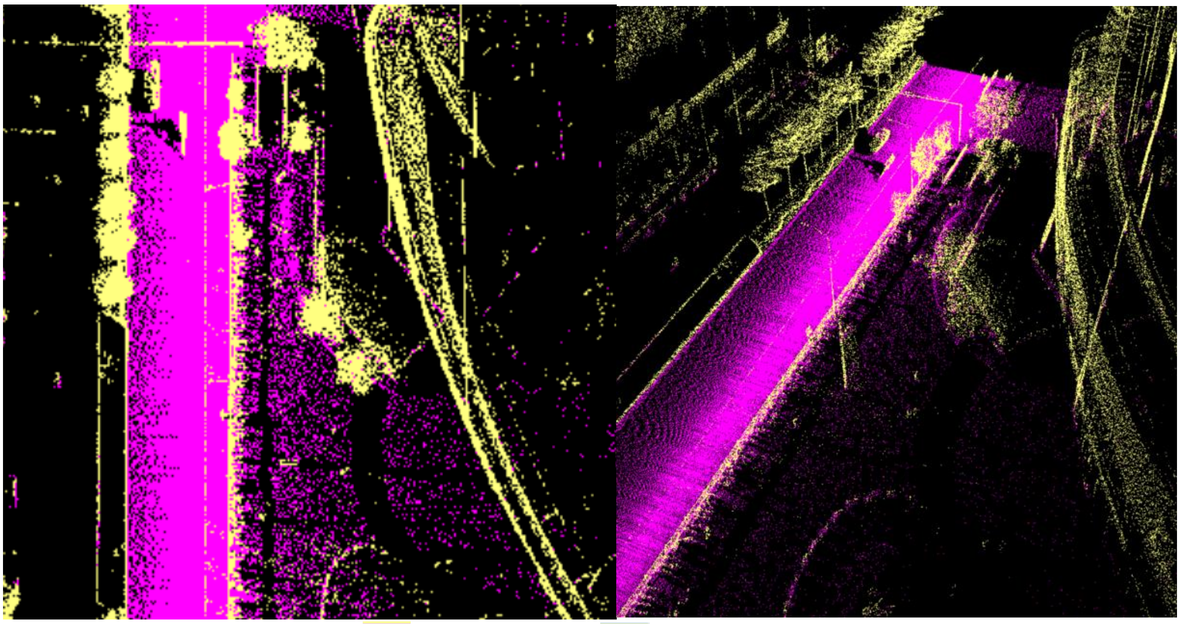
2) Erosion operation Start from the grid in the lower left corner, move from left to right, bottom to top, translate with the window size w* w, calculate the minimum value of the elevation z of all points in the window, and assign it to the point contained in the grid elevation Z_e after pitting.

3) Dilation operation Start from the grid in the lower left corner, move from left to right, bottom to top, translate with the window size w* w, calculate the maximum value of the Z_e elevation after erosion of all points in the window, and assign the dilated elevation to all points in the grid dilate.

4) Set the height difference threshold H_t according to the height difference threshold calculation function

5) The attribute category of the point. Calculate the difference between the elevation value Z_d after the point expansion and the elevation z of the point before step (4), if the difference is less than or equal to the height difference threshold, mark the classified attribute category of the data point as a ground point, otherwise the attribute category of the point is marked as a non-ground point, and the elevation value Z_d after the point is expanded is used as the elevation value z of the point;

6) Repeat steps (2) to (5) until the loop is terminated



Ground point non-ground point

Figure 4 Ground filtering

2.3 Canopy Height Model (CHM)

Use the ground points to normalize the non-ground points, and keep the points with a height greater than 3 meters to make CHM (nDSM) (Figure 5)

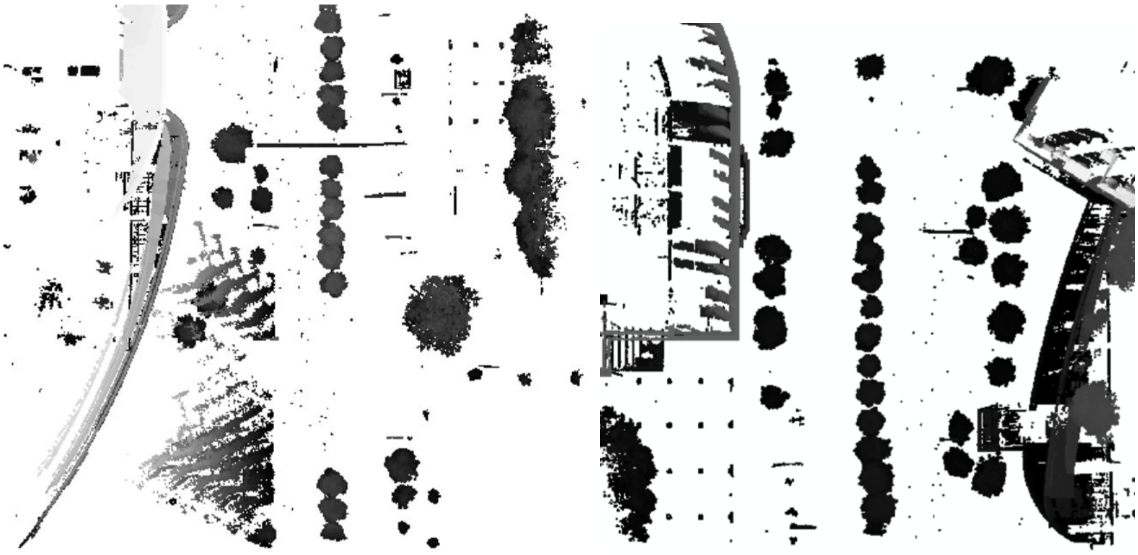
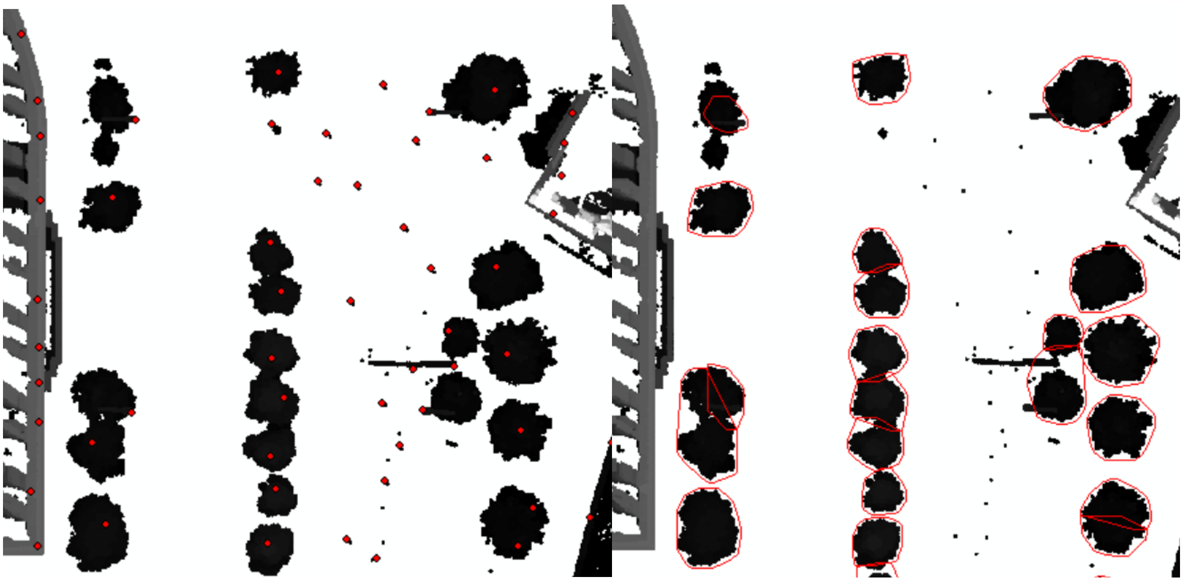


Figure 5 Canopy height model

2.4 Individual Tree Segmentation

Based on CHM, the local maximum window with variable window sizes was used to search the treetops of the crown (Figure 6(a)), and to identify the treetops of individual tree crown and the extraction of individual tree (Figure 6(b)). Using the crown treetops mark, marker-controlled watershed method was applied to segmentation algorithm into isolating individual trees(Guo et al. 2016).

Use local maximum window to extract treetops, many small objects are extracted, remove the small objects and use watershed algorithm to extract tree crowns



(a) Tree tops (b) Tree crowns

Figure 6 Individual tree segmentation

3. CONCLUSION

Point clouds on both sides of the road can be obtained quickly and efficiently using our vehicle-borne LiDAR system. This method can quickly and effectively extract street tree information, However, due to the interference of buildings, street lights, and traffic facilities near the road, more non-tree vertices are extracted. These non-tree tops need to be removed to extract accurate street trees information, which spending a lot of work. In the future, using semantic segmentation method to segment tree points from raw urban MLS point clouds would be a good choice.

Acknowledgment

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