Analysis of algorithms for terrestrial recognition of woody vegetation using 3D-laser scanning technology

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Abstract. This article analyzes the main algorithms for automated recognition of woody vegetation. Their accuracy and feasibility of their use are analyzed in comparison with the traditional method of terrestrial scanning and manual processing of the results. After a detailed analysis of the existing algorithms, it was concluded that the multiclass graph cut method is the most efficient for segmenting trees. But at the same time, it was found that each of the algorithms has a number of disadvantages. Thus, it is justified that further research is needed on this issue.

1. Introduction

Currently, one of the most innovative technologies that allows finding out complete information about a specific object is laser scanning. Due to its versatility, this technology has already found its application in many areas of human activity. Laser scanning is subdivided into:

- Air;
- Terrestrial;
- Mobile.

In this case, laser scanning is used when carrying out geodetic works of various levels of complexity. The result of field measurements is an array of point clouds, with the help of which certain objects are subsequently drawn. At the same time, in our time, scientific research is being carried out related to object recognition using laser scanning in an automatic mode. Since laser scanning in geodesy is mostly used when scanning a territory, this scientific work will consider algorithms and programs for recognizing territories. It should be noted that, in many cases, various objects are located in a particular area which also need to be recognized. Most often these are either static objects (trees, roads), or some movable objects, for example, cars. This article will analyze algorithms specifically for recognizing objects of woody vegetation.

2. Materials and methods

To identify the most optimal algorithm, it is necessary to compare them with each other and with the classical method of object recognition using laser scanning. The general scheme of the classical algorithm for laser scanning and processing is shown in Figure 1.
It should be noted that the total duration of work when carried out by the algorithm presented in Figure 1 depends, firstly, on the total area of the area, and secondly, on the software used, as well as the skill of the cameraman who processes the measurement results. Carrying out work using this algorithm takes a long time. It should be noted that the integration of various algorithms and software products of automated object recognition into the traditional method of terrain scanning will greatly simplify the process of drawing a point cloud. As practice shows, a surveyor, when processing the results of laser scanning, if there is a task to draw trees, spends significant labor resources on this. Automation of this type of work will significantly improve the production process, eliminate operator errors, and increase the efficiency of work. Automatic tree segmentation can be used in forestry and agriculture: for accounting and inventory of woody vegetation, for monitoring the condition of trees, predicting the condition of territories occupied by vegetation. Therefore, this scientific work will consider the methods of automated recognition of trees. Of course, the automatic identification of trees in a certain point cloud can reduce its processing, but in order to implement such methods in the scanning algorithm shown in Figure 1, it is necessary to make sure that this integration is appropriate, which will be described below. [1-4]

3. Analysis of algorithms for automated tree recognition
The first tree recognition method was developed by the research team of the Natural Resources Institute of Finland. With the help of this algorithm, such tree species as spruce, pine and birch were recognized.
This method of tree segmentation is based on primitive geometric shapes that simulate the crown of a particular tree, its branches, trunk, etc. In addition, the search for a particular type of tree occurs according to such signs as:

- Trunk diameter;
- Number of branches;
- Nature of vegetation, etc.;

The terrain was scanned in 5 different forests using a ground-based laser scanner. After loading the point cloud into specialized software for processing the results of laser scanning, the tree was automatically segmented. This happens in the following way: the operator manually gets rid of unnecessary sections of point clouds, then the trees are divided into primitives, and with the help of simple geometric shapes the branches of the tree, its trunk, crown, etc. are segmented, and after that the type of tree is recognized [5]. The classification of trees by species was carried out according to three methods, namely:

- Method of the nearest k-neighbors;
- Method of support vectors;
- Polynomial regression method.

These methods differ from each other, firstly, by the software used. Secondly, by the formulas, with the help of which a particular type of tree is identified. But, as applied research has shown, regardless of the used tree classification method, the result is equally correct. The end result is complete identification and visualization of the tree. A general visualization of the tree using this method is shown in Figure 2. The image was taken from www.24gadget.ru [5].

![Figure 2. Visualization of the scanned tree on a mobile device](image)

After field studies, the dependence of the accuracy of finding the type of tree on the type of forest was found. For example, when scanning a birch grove and pine forest, the accuracy of the results was 90%, and when working in a mixed forest, the accuracy was 65-70%. It cannot be denied that the direct dependence of the quality of determining the type of tree on the type of forest negatively affects the overall result of laser scanning using this algorithm. Despite this, the accuracy of tree classification is quite high. It should be noted that further improvement of this algorithm is necessary, first of all, by increasing the types of tree species that can be identified using this algorithm [5].

The second algorithm was developed by scientists at the British University of Cambridge. This method is based on a flexible multiclass graph dissection. If the application of the previous algorithm is more aimed at forests of a temperate climate, then this method is more aimed at forests with high humidity, for example, the South American jungle, where field work was carried out with further segmentation of trees using the algorithm presented below [6].

Unlike the previous method, scanning was carried out not by a ground laser scanner, but by an unmanned aerial vehicle with an active rangefinder in the optical range (hereinafter referred to as lidar).
Also, as in the previous time, point clouds were loaded into specialized software. The next step was automatic filtering of the 3D laser scanning result using the LASTools software. After getting rid of the noise, the remaining point clouds were loaded into MATLAB. In this program, the construction and segmentation of trees took place. The sequence was as follows: first, the weight of the common features in trees was calculated. Then the clusters were calculated using k-selection. After that, the graphs were cut, the result of which was used to draw the trees [6].

While the first presented method is more aimed at the classification of trees, the tree segmentation method, created by the research team of the University of Cambridge, was developed, first of all, for monitoring the state of tree species. When periodically scanning the territory, at least once every six months, and processing point arrays, using this algorithm, it is possible to track the growth and crown diameter of a particular tree. This, in turn, makes it possible to track the total carbon content in the plant, help to learn about the general condition of the tree and identify dead and diseased areas of woody vegetation [6].

After conducting a study on the quality of tree identification using this algorithm, it was found that the accuracy of tree detection using the multiclass graph cut method for tree vegetation with a height of more than 10 meters was about 80%, which is a fairly good result. As for the accuracy of identifying trees less than 10 meters in height, it turned out to be an order of magnitude lower (40%). This fact indicates that the considered algorithm is best used to identify tall tree vegetation rather than low one. But at the same time, it should be noted that the scanning, according to the result of which the trees were segmented using a multiclass graph cut, was carried out using drones with a lidar, which contributes to a decreased accuracy of scanning low vegetation. But since the field work was carried out in tropical forests with high humidity, ground-based laser scanning in such conditions is quite problematic. This necessitates the use of precisely airborne laser scanning in such conditions [6].

The third and final method that will be considered in this research paper was developed by a research team from Finland in collaboration with British colleagues. As with all previous algorithms, the first step in this tree segmentation method is 3D laser scanning. In this case, the scanning is carried out on the ground. After that, as in all the previously mentioned algorithms, the point array is loaded into the specialized software MATLAB for processing the results of ground laser scanning. Next, the operator needs to remove unnecessary points so that they do not participate in tree segmentation. After that, the operator starts the automatic segmentation of a particular tree. It happens as follows: with the help of volumetric geometric shapes, namely cylinders, the automated drawing of the point cloud begins. The trunk of the tree is a tall and long cylinder, while the branches are made up of small cylinders. This is how the tree is segmented in this algorithm [7].

After checking this algorithm, it was found that using this method, the tree is recognized quite accurately (80%). But at the same time, in some cases, the segmentation did not capture the entire tree, or 2 trees were segmented into one, especially when the trees are too close [7-10].

4. Results and discussion

Summarizing all three methods and algorithms considered in this article for segmentation of point clouds of areas with woody vegetation, the following block diagrams can be drawn up, presented in Figure 3.

After analyzing the block diagrams of these algorithms for segmentation of woody vegetation, the following conclusions can be drawn: firstly, the first action for these algorithms is identical—it is a three-dimensional laser scanning. However, it should be noted that in some cases the scanning was terrestrial, and in others it was airborne.

Secondly, all point clouds are loaded into special software for further processing. It should be noted that in the segmentation method by cutting graphs, unnecessary points are automatically deleted, and in the rest it is manual. After analyzing the algorithms for automatic tree segmentation, it can be concluded that all the previously mentioned methods recognize trees with a sufficiently high accuracy. In addition, it cannot be denied that each of these algorithms has their drawbacks:

1. The first method is only suitable for spruce, pine and birch;
2. Using the second algorithm, it is quite problematic to recognize low trees;
3. When applying the last recognition method, extra points can be captured, or 2 trees can be segmented into one.

Figure 3. Block diagram of the algorithms considered in this work

But at the same time, after analyzing the algorithms for automatic tree segmentation, we can conclude that all the previously mentioned methods recognize trees with a sufficiently high accuracy. Since the graph cutting algorithm allows automatically removing unnecessary points and due to the fact that this method quite accurately identifies tall trees, it is most advisable to choose such a tree segmentation algorithm among all the methods presented. Regarding the comparison with the traditional scanning
method (Figure 1), this method can be used for tall trees, but for scanning woody vegetation less than 10 meters in height, it is best to choose the classic scanning method [11-13].

5. Conclusion
Despite the fact that each of the presented algorithms is not devoid of shortcomings, each of the presented algorithms is accurate, to one degree or another. And it cannot be denied that the presence of a significant number of studies in this area is quite positive, since automatic recognition of objects, including trees, will facilitate laser scanning of the terrain and subsequent processing of point arrays. Consequently, works devoted to pattern recognition and classification of laser reflection points are quite relevant today, and have a number of promising directions for research. Therefore, it is necessary to conduct scientific research in this area for the subsequent application of algorithms for recognizing scanned objects in practice [14].

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