ALGORITHMS FOR ESTIMATING FOREST INVENTORY PARAMETERS FROM DATA ACQUIRED BY REMOTE SENSING METHODS

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Abstract: Two technologies- LiDAR (Light Detection and Ranging) and aero photography- have a huge potential in forest taxation, which is a process of gathering different parameters of specific region. Both technologies can be used for finding different parameters of interest, such as number of trees, tree height and other. This paper presents the results of usage analysis for LiDAR and aero photography, and describes their possibilities. Also it contains an analysis of tree identifying algorithms and describes ways of their usage in different processes.

1 INTRODUCTION

Taxation process is very important for performing forest management planning activities, especially because its performance frequency and prerequisites are defined by law. Unfortunately, methods that are available today require a lot of time and funds.
To reduce the usage of resources, new methods must be developed or some existing ones must be adopted from different fields. Two appropriate candidates, which already have application for data collection in other fields, are described in this article. Those technologies are aero photography and Light Detection and Ranging (LiDAR) (Lim et al. 2003). Using them to acquire taxation parameters is not a simple task which options must be analyzed.
In both cases the main task is not to deal with the problems of technical type (technology is already being used in other fields and is also adaptable for this one). The main problem is to interpret the result data appropriately – to find out taxation parameters of different regions using information which is gathered by aero photography or LiDAR technologies. In this article use cases and potentials of both methods are analyzed and algorithms for tree identification are described.

2 PROCESS OF TAXATION

The aim of forest taxation and accounting corresponding data is to gather geodetic materials and overall information about woods that is under jurisdiction of some managers or owners. Data about territories is collected using geodetic methods and aero photography materials (Sile 2006). There are two types of taxation: precise (every tree is measured using special tools – a very expensive and time consuming process) and group evaluation (in defined region average parameters are measured for each kind of tree) (Dagis 2006). In practice precise taxation is used only to calculate value of property before performing the main timber cutting process. Different situation is with group evaluation which must be performed once in every ten years as it is defined by law. This taxation type is used mostly for informative reasons - to find out exact situation on given property and to decide what economical activities must be performed there (Dagis, 2007). Precise evolution of forest region from group data is almost impossible. Methods that allow to execute this task exist (Ozolins, 2004; Ozolins, 2006; Dagis et al. 2006), but they only give approximate results (Smits, Dagis, 2007). One of the biggest needs for forest owners and some republic services is to improve taxation process in the way that it becomes faster and cheaper so the management planning and all economical activities would consume less resources (Oss, 2006).

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3 PROCESS OF MANAGEMENT

Planning is the most complicated task that is performed in enterprise and it requires very precise data.
Information that is used for planning must describe not only existing situation, but also be with high accuracy and degree of detailed elaboration to serve as a basis for forecasting evolution possibilities in defined terms. Every company must have this kind of data to solve everyday tasks and all their decisions need to be data based. This statement applies to all kind of enterprises and especially in the field of forestry where data acquisition is called taxation. Of course company can have a lot of different information sources which must be taken into account, but taxation data that describes real time quantitative parameters of forest is the most important one.

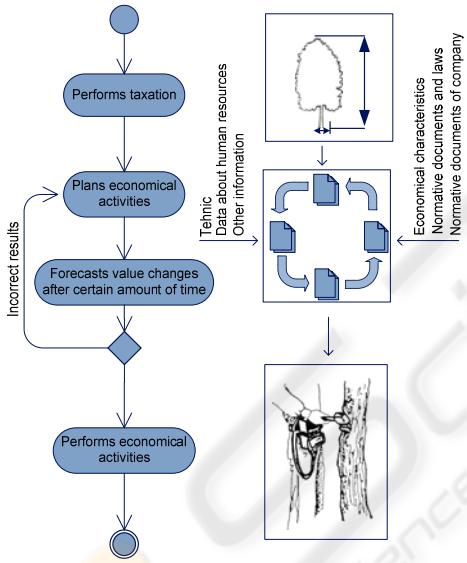

Figure 1: Data acquisition in management process.

Figure 1 shows the process of planning economical activities that must be performed in forest. The main part of the diagram is a loop in which potential result is evaluated by considering how it will change after certain economical tasks are performed. These activities are executed as many times as needed to find some politically correct result. Before the beginning of searching process real taxation are preformed and data that describes the existing situation are gathered. Planning tasks are being done by using this information and some peripheral data - normative documents, laws, and descriptions about availability of resources.

4 REMOTE SENSING METHODS

Data gathering is the main task of taxation process and to complete it specially educated people must go to forest and find out information that describes some regions. Performance procedure and time schedules of this process are described by law. Unfortunately, traditional way of doing it is expensive and time consuming – a specialist with adequate knowledge to create sampling plot and measure its characteristics must visit every territory of interest. Costs of this work scenario can be found as sum of: specialist education, time and travel price and expenses of measuring process. Traditional taxation is not only ineffective in terms of time, but it also gives only very local information that must be generalized by specific mathematical methods. These calculations are related with certain growth of data error which can be statistically evaluated. Methods that are not so local and describe much larger territories consuming less time (and also reducing the main source of mistakes – human factor) must be created. In the next chapters of this article two technologies (aero photography and LiDAR) for data acquisition that can describe very large regions will be overlooked. Both methods have big potential and are being examined by specialists in different countries and science fields. The task that should be solved in nearest times to enable full scale usage of these methods is data processing to convert them into form which is understandable to information systems. Transforming information that is gathered either by aero photography or LiDAR is not a trivial task, because complicated algorithms that help to find informative relationships in data are needed. Also to use both of mentioned technologies and to find out specific characteristics of different regions precise GIS coordinates of each point must be available.

4.1 Use Cases of Aero Photography

Aero photography is an image that is taken from airplane flying at certain height. It allows acquiring data that describes earth surface and all objects that is located on it. The quality of pictures and possible use cases are closely related to the height and stability of a flight. An image acquiring by using pilotless technologies has become very popular in the most recent periods of time, because of its small expense and simplicity of usage.
An aero photograph that describes different territories has been used for many years and the

main field of interest for it was cartography. Many well known geographic information systems are equipped with algorithms that allow creating a photo layer to display them on a map.

The most important feature of such photography is that the objects shown on it are attached to their location by coordinates of the real world. With the improvement of technologies and rise of calculation powers of computer systems new usage possibilities for these images have appeared, for example evaluation of specific objects.

Using algorithms for object recognition in images can be performed in three modes – automatic, half automatics and manual. Each of the mentioned modes has well known precondition – photo quality which can be described by many components such as color, contrast, graininess, the amount of objects and others. The relationship between quality and automation level can be stated – for higher quality higher automation level can be used.

Acquiring useful image is not a trivial task, because many factors such as weather, time of the year, quality of equipment must be taken into account. Also height of flight is very important and can be altered depending on the goals of photography. For example, if the main task is to get the density of trees in some region then the height can be comparatively big, but if it is necessary to find the size of leafage or even a kind of a tree, the height must be small. In the first situation the main benefit can be found in the fact that for describing some region a smaller number of photos can be taken then in the second situation. A specific task can be solved only when all needed data is acquired for the territory of interest.

Aero photography has many use cases, but for taxation the most important ones are:

1. Finding the number and coordinates of a tree;
2. Finding the size of a leafage ;
3. Finding the kind of a tree;
4. Finding the borderlines of a territory;
5. Finding forest vistas and roads;
6. Evaluating territories gutted by fire;
7. Evaluating windfalls.

Image processing algorithms are needed for solving all of the mentioned tasks. The first, the fourth, and the fifth tasks need photos with the smallest resolution. All other tasks need qualitative pictures which contain plenty of data to use methods that can separate tree leafage and measure its parameters. For all of the pictures widely known algorithms or simple each pixel overlooking loops can be used. In this situation a very popular group of segmentation an algorithm that needs to know a number of clusters cannot be utilized because it is the parameter that the system is looking for.

If the system finds specific segments by using these methods, then by knowing the height of a flight and the angle of a camera, the size of leafage can be calculated.

For tree kind determination it is necessary to recognize the structure of an object, were at a certain scale contours of a leaf which is taken from the image and searched in the previously defined collection. Another way of solving this task is by using colored recognition (each tree kind has its specific color). The main drawback of this method is that the color depends on weather and photo filters used in the picture making. It means that automatic use of this method is almost impossible.

4.2 Tree Identification using Aero Photography

Crating automatic methods is a very difficult task and the first step in it is to understand half automatic or even manual solutions. We will describe an algorithm for identifying a tree that works in a half automatic mode. For this method images attached to GIS coordinates are needed and also a full photo cannot be used, but only a part of it where the angle of photography and surface is close to 90^{o}, because in other case it is a side-view. So the images must overlap and cover some part of the same territory. Tops of a tree on the images usually can be well separated from the background and their color depends on the time of the year and weather. Therefore to realize half automatic way of recognition it is necessary to select a few pixels from tree tops (2 to 5). Every shown point gives us information of the possible color and by adding some dispersion to it (recommended 5-15%) we define a pattern to look for in the rest of a picture. Dispersion and location of points are parameters that user can change depending on results. Minimal ($\mathbf{R_{min}}$) and maximal ($\mathbf{R_{max}}$) radius is given in numbers and by using them in combination with tree top color dispersion, searching for a particular tree can be preformed.

Algorithm for finding tree center works with one correction (Fig. 2) – searching is performed on **X** and **Y** scales by using colors. First of all, tree top start point $\mathbf{x_1}$ and end point $\mathbf{x_2}$ have to be found, then an average value $\mathbf{x_0}$ is calculated $\mathbf{x_0 = (x_2+x_1)/2}$. From the point $\mathbf{x_0}$ on **Y** scale minimal $\mathbf{y_1}$ and maximal $\mathbf{y_2}$ values are found. In the same way as $\mathbf{x_0}$ the value of $\mathbf{y_0}$ is calculated $\mathbf{y_0 = (y_2+y_1)/2}$.

The center of a tree top is found by correcting **x** values corresponding to the newly found $\mathbf{y_0}$ value. Using center coordinates every point that is located at a distance of radius $\mathbf{R_{tree}=min(R_{max},R_{lefage})}$ is considered to belong to a single tree. After writing necessary data into result collection newly found tree top is removed from the searching region. After that new searching iterations are being performed while group of points where $\mathbf{R_{lefage}>R_{min}}$ can be found.

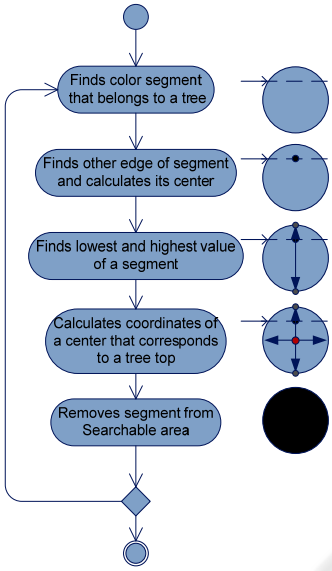

Figure 2: Activities of finding tree top center in aero photography.

By utilizing described method every tree center in a photo is found. Using GIS coordinates' a real location of a tree on 2D plane can be calculated and later utilized for taxation data concretization with different methods. From discovered points the number of trees per hectare can be found. And also by using leafage diameter and tree height the relationships between an approximate diameter and the density of a tree trunk can be calculated. For the precise taxation these results must be improved with a data from different methods.

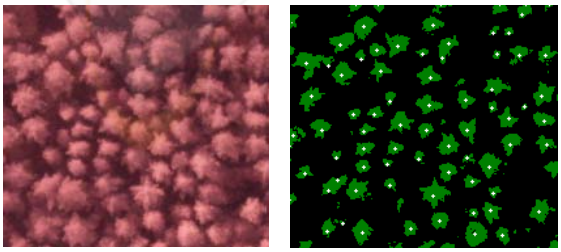

Figure 3: Photo before and after using tree recognition algorithm.

Identifying a tree on a photography using automatic mode is a very complicated task. It has a lot of preconditions for data gathering technologies and processing algorithms. Two tasks that must be solved to realize fully automatic tree recognition are:

1. Acquisition of qualitative picture where all necessary attributive data is saved together with the image (for example previously mentioned tree top point colors);
2. Use of universal algorithms that regardless on different picture parameters can find number of segments and filter needless data.

5 USAGE OF LiDAR IN TAXATION

LiDAR is a new theology that is being used to acquire information about earth relief and objects located on it in three dimensional plans (Lim et al. 2003). It is done by using special laser and light registering device. The main principle of this method is the same as in the case of radar – the time in which emitted signal returns to the source is being measured. The only difference from simple radar is that instead of radio signal laser light is used. LiDAR technology is used in many fields and some of them are: archeology, geography, geology and remote sensing.

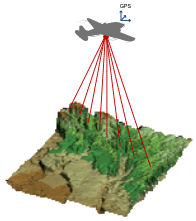

Figure 4: LiDAR data acquisition.

LiDAR measurements are performed by using airplane that is equipped with a device of global positioning and laser scanner device that during a flight perpendicularly to its direction (Fig. 4) measure light reflection points. Mistakes of data that rise depending on scanner angle and flight stability are eliminated in the process of measurement.

By visualization of gathered points three dimensional model of a tree (or any other object), that describes its characteristics can be created. These models can be analyzed with aim of finding some special parameters of an individual tree or even of all sampling plot. Usage of this method in taxation process still is an object of research and it is necessary to clarify its qualitative and quantitative parameters – costs, preciseness of measurements and how it works in different kinds of forests.

Tree counting using LiDAR data can be done similarly to aero photo. the difference is that in photography the color was analyzed for each pixel, but in LiDAR data 3D coordinates of each point must be examined.

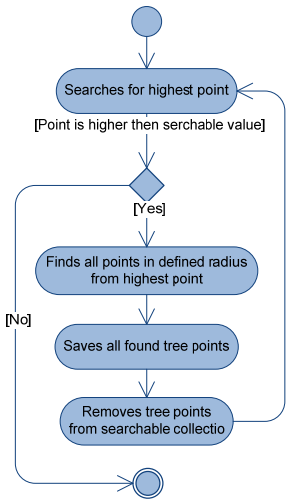

Figure 5: Tree identification by using LiDAR data.

For identifying a single tree or finding an overall number simple algorithm that analyze picture by dividing it into small regions can be used. The highest point in each field is calculated and it is assumed to be the top point of the highest tree (Fig. 5). Around this point using defined radius segmentation can be performed to define all points that belong only to a single tree. Afterwards all located segments are removed from data collection and new search for the highest point started. Tests show that this simple algorithm works well in a forest with not very high density and only one floor of trees.

6 CONCLUSIONS

Aero photography and LiDAR data can be used for finding a number of trees and its coordinates. Identifying a kind of a tree is a task that doesn't have one universal solution and research of its possibilities must be continued.

The main benefit from using LiDAR technology is that from its data tree height can easy be found, because every point is described in three dimensions.

The biggest drawback for both methods is that there is no direct way of finding the most important taxation parameter – diameter of a tree.

Using both of described technologies together in the same region can raise their efficiency.

Data processing can be performed in three modes – automatic, half automatic or manual. For realization of automatic mode it is necessary to create not only adequate data processing algorithms, but also it requires certain methodology of data gathering.

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