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Review Article

PERSPECTIVES OF USE OF MODERN INFORMATION TECHNOLOGIES FOR FORESTRY

DMITRIY VLADIMIR ALEKSANDROVICH USTYUGOV* AND DMITRIY OLEGOVICH KVOCHKIN

Syktyvkar State University, 167001, Komi Republic, Syktyvkar, Oktyabrsky prospect, 55, Russia

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ABSTRACT

The article contains the review of the modern information technologies that can be used in the informational support of the forest-based sector. The tools developed using the actual software-based methods allow to decrease significantly the cost and complexity of the forestry due to the efficiency of calculations, adequacy of the applied mathematical models and automation. The described methods were studied and applied when developing the low-cost forestry technology at the Syktyvkar State University named after Pitirim Sorokin.

INTRODUCTION

Nowadays, the problem of weak informational support of the forestry of the Russian Federation is acute. The ideas of the complete informational support of all fields of economy appeared in the Soviet Union (the project of the National Automatized System (NAS) was developed by Glushkov (Revich and Malinovskii, 2014); however, due to the inertia of the party and administrative apparatus, the system was not realized) and the satisfactory results were not achieved. Now we can observe the absence of the deployed universal information systems (Malikova 2010); there is no possibility to perform the complete inventory of forests, adequate estimation of economic potential, to develop the plan of branch development, forest restoration, to provide the interaction with other economy branches.

One of the directions of the international project "Taiga 5D" implemented in 2015-2016 at the Syktyvkar State University named after Pitirim Sorokin was the development of software for work with a ground LIDAR-device allowing to obtain the map of tree location of the sampling unit, software for work with the photographs obtained from the unmanned aerial vehicles including the satellite maps. One of the objectives was the study of the potentially applicable modern computer technologies in the forestry.

ARTIFICIAL NEURAL NETWORKS

An artificial neural network (ANN) is a software or hardware implementation of the mathematical model of the system of biological nerve cells. In the model, the role of the nerve cells is played by the artificial neurons (software or hardware). When processing the various data, the neural networks provide the efficient solution of problems of pattern recognition and adaptive control, and allow to organize the parallel processing of information.

The main advantage of the neural networks in comparison with the traditional algorithms is the possibility of study. Technically it means the identification of coefficients of connection between the neurons (synapses). During the process of study, the neural network can reveal the complicated dependency between the input and output data and also perform the generalization. This means that after a successful training the neural network can return the correct result even on the base and also incomplete or partially damaged (for example, noisy) data.

The first variant of the application of neural networks in the forestry is the processing of the photographs of area obtained from the aerial vehicles (including the unmanned vehicles) (Skidmore, *et al*., 1997).

***Corresponding authors email: ustyugovva@gmail.com**

Now the knowledge base of forests in the Russian Federation is not satisfactory. At the same time now there is a possibility to obtain the images of forests and other objects at the high accuracy of detalization. The processing of such big volumes of information requires the availability of the powerful machines and application of the processing methods one of which is the processing by means of ANN.

When using ANN for the computing of the number and size of trees, it is necessary to form the base of reference images, by means of which the network will be trained (Gong, *et al.*, 2013). To build a universal system, these references are to be of different types: they should include the images of softwood and hardwood trees, the recognition of the tree species is also possible according to its crown form, there should also be the images of trees in the different seasons (information of trees, collected in autumn and winter can be useful for estimation of the forest condition). After training, the system can work with the photo images from various sources, of various quality and detalization determining the qualitative and quantitative composition of forest. The obtained information can be recorded in the regional and federal data bases and used for the centralized planning of the forestry.

Besides the trees the neural network can be trained to recognize the other objects: burnt or cut areas of forest, elements of landscape (hills, cavities), rivers and other water bodies and also the roads and other objects of economic infrastructure.

Analyzing the photos of the area after the forest fire, we can determine the damage incurred and also to determine the factors connected to the flash and spread of fire. The latter allows to reveal the areas where the probability of fire will be high due to the anthropogenic or natural factors (thunder storms), to determine the probable direction of motion of fire along the relief structure and wind map. For the latter, the additional information is required that can be obtained by integration into the system of photos analysis of climatological data bases.

As the efficient economy presupposes the storage and transportation of products (in case of forestry it is a processed wood), work of neural networks when recognizing these objects gives the raw data for algorithms solving the transport problems. The determination and analysis of the possible channels of transportation of products (roads, rivers) will allow to plan the production process qualitatively (Hickey, 2015). These problems can also be solved by specially trained neural networks and this confirms the diversity of ANN. Having rather powerful computing resources the use of ANN helps to solve the whole set of problems from the analysis of the photos of forests to the economic planning.

TECHNOLOGY OF PARALLEL COMPUTATIONS CUDA

Due to the architecture, the calculation of neurons interaction of ANN can efficiently be performed using the multiprocessor systems. As the computer clusters have a higher cost the realization of ANN algorithms on the compute kernel of video card can become a low-cost solution.

In 2007, the company Nvidia published the first version technology CUDA (Compute Unified Device Architecture) that is a software-hardware platform for calculations on graphic processors. A set of programs CUDA SDK allows to organize the work of the graphic accelerator and to control its memory using the wide-spread language C and in its own discretion (CUDA, 2016).

From the point of view of the architecture, the graphic processor is a scalable set of streaming multiprocessors (Streaming Multiprocessor, SM). Every SM maintains the simultaneous fulfillment of hundreds of flows and because the graphic processor contains some of such SM, thousands of independent program flows can be executed simultaneously on the video card. At the same time, every flow has its own counter of instructions, a set of registers and a variant of fulfilment in case of availability of branches in the code. The flows are combined into the decision blocks that are executed on the multiprocessors; decision blocks are combined into the structures grid. The parallel execution of the code allows to accelerate the process of calculation saving time tens or hundred times in comparison with the calculation on the ordinary multicore processor of the general application.

The work with CUDA is available in many popular programming languages (C, C++, Python, Fortran) and in the popular operation systems (Windows, systems on the base of core Linux). Cross platform gives the possibility to make a flexible choice of the hardware and software platform to build the system of information processing.

The program using CUDA is divided into two parts: a part that is performed on the central processor and responsible for the interaction with the user, work with the subsystem input-output and a part performed on the graphic processor (so-called

core). The part performed on the central processor can be written in any language among the above-mentioned languages and this allows to use their peculiarities, ready libraries for the fast development and consequently, makes the process of the branch information support less expensive. So, for example, the language Python has libraries for scientific calculations, for creation of ANN and also some frameworks are written in Python for creation of Web-applications (for example, Django) and tool kits for creation of applications with the graphic interface that is one tool covers all possible fields of software development.

There are several directions of application of CUDA technologies for information support of the forestry. We have already mentioned the possibility of ANN algorithm execution. Another important direction of application of multiprocessor system CUDA is a static processing of data array of trees obtained by means of the analysis of photographs. As a set of indicators can be achieved for every tree, such as coordinates, thickness, height, crown diameter, the total volume of data of all timber complex is estimated by the dozens of terabytes. The processing of such volume of data in personal computers, calculation of the statistic parameters would take a lot of time. Multithread processing on video cards with a large volume of fast video memory allows to speed up the process significantly. The composition of the generalizing statistics will allow to obtain many raw data to build the new mathematical models of growth, development, aging of the forest taking into account the set of climatic, topographic and anthropogenic factors.

Finally, the flows CUDA can be applied for program implementation of mathematical models. As even the non-expensive domestic video cards are equipped with the multi-core processors, even small forestry divisions will get the possibility to automatize the calculation process of forest indicators and planning of cutting activity, forest restoration including the activity after acts of God.

LIDAR DEVICES

LIDAR is a class of the optical measuring devices designed for the aerial or ground laser scanning of the objects of observations. In contrast to the mechanical or ultrasound sounding methods (Chufyrev and Ustyugov, 2015), it allows to perform the non-contact measurements with the higher scanning frequency and a narrow diagram of direction of the laser beams at the higher allowable distance of scanning.

For forestry, the scanning of single trees, circular scanning of the sampling unit of the set radius and aerial scanning of the forest canopy are of a particular interest. The purpose of such scanning is to get the point cloud corresponding to one tree or the large forest for the further building of a digital model of the area. So, called technology of the aerial laser scanning (ALS) is of a great interest. This is explained by the fact that ALS allows to increase significantly the area of the processed forests in calculations for one working day of a forest engineer, and to decrease the specific cost of the research of a forest hectare and also to organize the data collection in the remote places of the planet.

The technology is widely used when performing the forest inventory. The work of Hyyppä et al. (Hyyppä, *et al*., 2004) describes the algorithms and methods of information extraction from the pixel array. The author mentions the method of aerial optical sounding combined with the hyperspectral photo survey of high resolution. It is emphasized that the laser scanning allows to obtain the high-resolution altitude values of measurement points and at the same time the photographs allow to obtain the additional information (color, geometry of crown), necessary for the determination of the species of planted forest and the condition of trees. Danilin and Medvedev (Danilin and Medvedev, 2004; Danilin and Medvedev, 2011) determined the LIDAR technology for inventory of the forest in the Central Siberia (Russian Federation). The authors mentioned the high accuracy of the obtained results at the significant decrease of time of works and material costs. (Holmgren, *et al*., 2004) represents the results of the large-scale laser scanning of 29 forest stands in the central Sweden of the total square 5000 hectares. The author mentions that at 1.2 laser measurements per one square meter the mean-square deviations from the average value for: height up to 0.8 m, diameter up to 1.9 cm, bole area up to 3 m^2 ha^{-1} and the volume of wood products up to 28 m^3 ha^{-1}. The mentioned error values taking into account the area covered by the research allow to reveal that using the means of the aerial laser scanning the accuracy can be achieved not worse than while using the traditional ground methods of forest inventory.

The perspective of using of ground lidar-devices in the forestry engineering branch should be mentioned. This class of devices is portable small laser scanners with high accuracy optical range finder, a computing module of data collection and additional modules of global positioning, wireless connection and photo survey. The ground scanning is necessary for the information detalization of forest stand obtained by

the ALS method. It is possible due to the fact that the speed of measurements of the ground laser scanners (GLS) can reach up to 1 mln points per second in the scanning area of 500 m^2 at the radius of the sampling unit 9 m. The density of the measurement points is much higher than while using the ALS technology and images obtained by means of GLS usually bear an extremely large volume of information (Seredovich, *et al*., 2009). The specialized neural network or the free system of tools for the data processing 3D Forest (3D Forest – Terrestrial Lidar Data Processing Tool, 2016), developed especially for the processing and analysis of data obtained by the ground laser scanning, can be used as a processor for data collected.

The device of the ground laser scanning was developed in 2015-2016 at the Syktyvkar State University named after Pitirim Sorokin (Komi Republic) using the financial support of the Ministry of Education and Science of the Russian Federation within the framework of the project of the low-cost technology of the forestry. For the data collection of the ground laser scanning, the platform Raspberry Pi 2B with the additional modules were used: optical range finder, HD-camera, digital three-axis magnetometer (compass) and a mechanical module of automated panoraming. The hardware part is controlled by the modification of information system (IS) offered by (Kvochkin, 2016). IS is written in Python using the framework Django and is a multilevel system of lidar control providing also the remote access to the installation.

Beside the ground survey, the large forests were surveyed from the unmanned aerial vehicle using a hyperspectral high-resolution camera. The results of measurements were processed by the software application Photoscan on the productive computer on the base of Intel Xeon 3.3 GHz, volume of RAM 24 Gb, and three computers nVidia® Tesla® C2050 PCI-Express × 16 3072 Mb. CUDA technology was applied for processing.

CONCLUSION

The current state of the branch of the information technologies allows to solve the problems of automation of calculations, planning, analysis in any sector of the economy, including the forestry sector. It is impossible to obtain the high results without the specialists possessing the knowledge in the field of information technologies and also in the field within the framework of which the updating of the approaches to the problem solving is necessary. It is known that the process of such integration is rather low. However, now there are all the prerequisites to combine the efforts of specialists from various fields for solving the acute problems of informational support of the branches of economy.

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