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Determination of the forest inventory indicators according to the photographs of the unmanned aerial vehicles

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ABSTRACT

The article considers a problem of application of the special software to determine the forest inventory characteristics according to the photographs obtained from the unmanned aerial vehicles. The software system includes the low-level programs for analysis of the raw data (recognition of trees in the photos) and an information system for the accumulation and analysis of the information and interaction with a user. The novelty of the approach is the software application of the multileveled structure to determine the required characteristics and interaction with the user via the Internet network. The described software was developed within the framework of the creation of the low-cost technology of forestry on the base of the Syktyvkar State University named after Pitirim Sorokin.

Key words *: Inventory, Information system, Forest maps, Samples recognition.*

Introduction

Currently, the knowledge database of state of the forest complex of the Russian Federation is non-satisfactory. Since January 2007 till 2010, the planned forest inventory measures were not performed, but later the Order of the State Forest Inventory was developed according to the Forest Code. However, due to the insufficient financing and deterioration of the social conditions of the employees during last 20 years the forest branch lost significantly its production and human resources (Malikova, 2010). An additional factor is a weak information system development of the branch. The specified peculiarities of the present provision set the problem of development and implementation of the state-of-art equipment and information systems for the scientific institutions that will allow to build the system of a rational use of the forest resources (Kapralov, 2010).

Within the framework of the project "Development of the low-cost high planning technology of the forestry based upon the cloud processing of the multi-angle hyperspectral survey from the unmanned aerial vehicles and long-term prognosis of the forest-based sector" implemented at the Syktyvkar State University named after Pitirim Sorokin in 2015-2016, Vagizov developed the information system for the complex processing of the photographs obtained from the unmanned aerial vehicles (Vagizov, 2016). This system allows to determine the inventory parameters of the large forests and this helps to determine the number and coordinates of trees, volume of commercial timber and also to control the scale of the forest cuts and estimate the consequences of the forest fires, etc.

Development of low cost technology of forestry

The complex project "Taiga 5D" was implemented

at the Syktyvkar State University named after Pitirim Sorokin during 2015-2016 to satisfy the demands of the forestry of the Russian Federation for the information system development and a rational approach to the inventory. An important rationalization proposal made within the frameworks of the project development was a proposal to use a hardware complex for inventory consisting of a ground LIDAR-device and an unmanned aerial vehicle equipped with the photo camera producing the survey in various spectral ranges (visible and infrared light).

It was shown that the operation of the unmanned aerial vehicles allows to obtain the qualitative photographs applicable for the further analysis and at the same time the expenditures will reduce significantly in comparison with the traditional photo survey from the airplanes. The applied unmanned aerial vehicle can stay in the air up to 60 minutes and move at a speed of up to 50 km/h; during one flight it can make a survey of the area up to 0.5 km^2. Payload weight does not exceed 2 kg and this allows to use the high resolution complex photo cameras Sony. The airborne geodesic receiver can work with the systems GLONASS and GPS providing the accuracy of positioning 5-10 cm.

The ground LIDAR-device was developed to increase the accuracy of the obtained data (Andersen *et al.*, 2005), which represents the software controlled laser range finder working together with the unmanned aerial vehicle (Chufyrev and Ustyugov, 2016). When performing the air survey there is a particular tolerance when calculating the number or determination of the tree diameters because the crowns of trees are of a different form. The form and size are subjected to the statistics laws typical for this area and this age of the forest (West, 2015). The joined use of data obtained by the ground and aerial devices allows to obtain the true picture of state of the large forest. The special software Photoscan allows to build the three dimension models having the available high resolution photographs.

Thus, the complex of two non-expensive devices allows to collect the qualitative set of data to build the mathematical models and analysis (Kvochkin, 2016). In turn, the mathematical models, and statistical data obtained during the systematic monitoring of the forest condition provide the possibility to build the scientific and statistically grounded prognosis system of the forest condition (Avery and Harold, 2002).

Software for Photograph Analysis

Within the framework of the project, Vagizov developed the complex program for analysis of the images obtained by the aerial photography method, including the unmanned aerial vehicles.

As the photographs are raster images the following characteristics should be taken into account to get the material applicable for the analysis: space resolution of an image, brightness, contrast ratio, sharpness, pixilation, etc. To improve the image characteristics the special program filters increasing the readability of the digital material for the recognition algorithms can be used. For this purpose in the project the filter "Brilliance" of the free graphic package Inkscape was used. Also the filters Inkscape were applied for the fragmentation and pixilation of images.

For program recognition of trees, the algorithms should be taught by means of setting of sample images. The recognition mechanism uses the pixel-by-pixel comparison of the area of the processed image of a considered tree with the sample image and the hit ratio $0 < k < 1$ is calculated. The preliminary transformation of the change of size and rotation are made above the working area of the image. If as a result of the analysis it is revealed that the hit ratio exceeds 0.7 the object on the photograph is marked in the information system as a tree, it gets the identifier and its data are recorded into the data base.

Tree Recognition Algorithm According to Photographs from Unmanned Aerial Vehicles

Using the image review window the user chooses the land lot on which the number of trees should be calculated. To increase the accuracy of the image the enhancing filters are imposed. Then the image segmentation is made, that is, the areas are distinguished that are similar according to the characteristic. After this, the user shall create the reference database for every segment. For this, the sampling of 24 reference images is made with a size of 32 × 32 pixels from the image under analysis. The recognition algorithm is written in the JavaScript language; for storage of references and recognition of objects, the database MySQL is used. For the operation of algorithm, the operator sets the critical value of the hit ratio. The following parameters influence the efficiency of the algorithm operation: size of image, size of reference matrix, detalization and resolution of an image, and consequently, basing upon these

parameters it is necessary to choose the critical value rationally.

Recognition is made in two stages: first, the boundaries of the element are determined, and then the colour characteristics of all pixels inside the contour of the element in the system RGB are compared with the characteristics of the reference pixels. After the completion of the recognition procedure, the result is shown to the operator in the form of a reporting table, the fields of which contain the data of the quantity of the areas of the image compared with references (i.e. trees), theirs coordinates and indentifiers. The trees are marked by points on the image (Fig. 1).

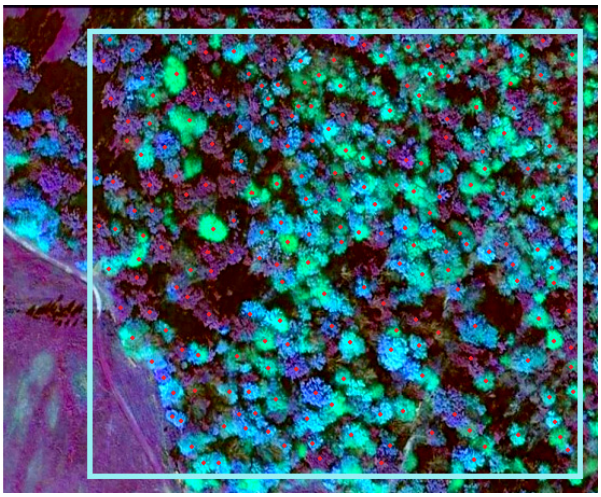

Fig. 1. The image with the recognized trees, marked by points.

To increase the accuracy of recognition we can use the segmentation of the image when imposing the additional filters and increasing the scale. At this, the time of algorithm execution will depend upon the memory volume, taken by the image and system characteristics of the computing unit which performs the processing. Therefore, when selecting the parameters of the recognition system it is necessary to take into account the use of memory by the algorithm and the processing time because the information system containing the tree recognition system as a module and working into the interactive mode shall provide the acceptable reactivity (Designing of Information Systems: Main Notions of the Designing Technology of Information Systems (IS), n.d.).

So, the described algorithm is a part of the complex information system designed for the accumulation and analysis of the photographic data.

Results of Discussion

The author of the system of determination of forest inventory characteristics according to photographs Vagizov distinguishes the following reasons for development of the information system as a service on the Internet network: most of the local forest divisions in the Russian Federation do not possess powerful computational nodes and qualified personnel that can install and support the operation of the system; placement of the system in the Internet network allows to perform the analysis when controlling the various devices (including the mobile devices); this also gives the possibility to analyze the obtained data in the field conditions with the available wireless connection to the Internet network; there is a possibility to compare the data obtained from the unmanned aerial vehicles with the data of public cartographic services such as Google Maps and many others.

In the beginning of work, the interactive service offers to the user to choose a region of the country and a particular forest division. Then in a special window of the system the images of maps appear, obtained from the public sources. Also the user has the possibility to download the images obtained from the unmanned aerial vehicles from the external source. After the completion of this procedure, the user determines visually the variant of the image that is the most suitable for the further analysis and presses the button “Select” as a result of which the dialog window of image selection appears. At this stage, the means of interface of the applied programming in the fixed image require to choose a square within the range of which the analysis procedure will be performed.

At the second stage, the user shall fill the table of references; for the efficient operation of the algorithm, at least 16 reference fragments shall be set. To increase the accuracy of recognition the matrix of reference samples can be enlarged; thus, the variety of the samples will be higher and the percent of the recognized elements will be bigger. After selecting the menu option “Fill the matrix of reference samples”, the fragments are stored in the server of the information system. After the completion of the recognition procedure, the user can store the report in the server or to download it to the local or external media.

Due to the module structure, the information system can be enlarged by the new modules, including those realizing various algorithms of object recognition including the recognition of the damaged trees according to the photographs in the infrared optical range, land lots with absent forest cover due to the cutting or fire, etc.

Directions of Development of Information System

Besides the direct measurements, one of the objectives of the development of software within the frameworks of the project "Taiga 5D" is the inventory and prognosis of the forest condition for the period up to several decades. This was the reason why one of the directions of development of the information system is the development and implementation of the automated determination of parameters necessary for the functioning of the mathematical models of condition and economic potential of the forest plots.

Beside the problem of calculations of the forest economic efficiency, the economist of the forest branch faces the problems of determination of the efficiency of logistics and storage. Consequently, the developed information system can be enlarged by the modules of recognition according to the aerial photographs of the objects of road infrastructure and also the objects that can obstruct the access to the large forest (mountain groups, rivers, lakes, etc.).

To accelerate the calculations performed with the large sets of the initial data the compute core of the system can be rewritten in the language C with the support of the technology NVidia CUDA (CUDA, n.d.). This technology allows to perform the parallel calculations on video cards including the fast RAM GDDR5 and many processors. In the literature it is mentioned that the productivity of calculations in comparison with the modern multi-core processors of the working stations can be increased hundred times when applying the parallel algorithms and making calculations on video cards. When using the current client-server architecture the final user is released from the necessity to purchase the expensive video cards.

The neural networks technologies are implemented to intensify the algorithm work. The neural network is a software system acting not only according to the algorithm but also on the base of the experience accumulated by it. During the process of learning the neural network can reveal the complicated dependencies between the input data and output data and also their integration. This means that in case of the successful learning the network can get back the correct result on the base of data that were missing in the learning selection and also of incomplete and/or noisy partially corrupted data (Artificial Neural Network, n.d.). The neural network shall be taught to react correctly to the basic situations to work with recognition of the images. Later, working with many users and large sets of data the neural network capable for self-learning will improve its computational capabilities and the recognition quality. Beside the software optimization, there is a possibility of the hardware optimization by means of application for the calculations of the specialized neural processors and microprocessors of ASIC type oriented to the implementation of the particular mathematical problems.

Conclusion

The described software system allows to facilitate significantly the forest inventory at many levels due to the use of the Internet network resources. Interactive service allows to release the user from the necessity to possess the powerful computing means for image analysis and also for storage of the volumetric data bases containing the data of the forest lots up to the information of every individual tree. The availability of the information system allows to implement the information system development of the branch at the level of the particular forestry divisions and due to the possibility of scaling – at the level of the region or the country.

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