SOFTWARE SYSTEM FOR AUTOMATEDFOREST INVENTORY

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ABSTRACT

The article considers the problem of application of the laser devices for forest inventory. The article contains mainly the description of the software system for automated forest inventory using a laser range finder. The system includes the low-level programs of interaction of sensors with microcomputer controlling the developed device, the information system for the information accumulation and interaction with the user and also the software for the analysis of the raw data. The novelty of this approach is in the application of the multi-level structure for the control of the measurement process, and the possibility of the system scaling. The developed equipment is a part of the low-cost technology of forestry created in the Syktyvkar State University named after Pitirim Sorokin.

Keywords: taxation, laser range finder, magnetometer, information system, pattern recognition.

1. INTRODUCTION

Now the inventory technologies on the base of LIDAR-devices (Light Detection and Ranging) are actively developed and implemented in the forestry branch. The laser scanning devices installed on the flying vehicles allow to determine with a high accuracy such characteristics of the forests as the height of trees, number and coordinates of trees, crown density, volume of biomass (Andersen *et al.*, 2005). The range finders of high accuracy (up to 15 cm) are installed on the aircrafts flying around the sampling units. According to the obtained data (usually time is measured during which a laser impulse issued by the transmitter returns to the receiving device), the three-dimension model of the forest plot is built by means of the digital processing methods and then using the specialized software the above mentioned parameters are determined.

The low-cost technology of the forestry developed in the Syktyvkar State University named after Pitirim Sorokin is based upon the use of the unmanned aerial vehicles (UAVs) of a small size and the load bearing capacity up to 2 kg that does not allow to use the standard LIDAR-equipment for this purpose and therefore the flying vehicles are equipped with the high resolution cameras only. To increase the accuracy of the technology the ground LIDAR-device was created that can replace the applied traditional measurement devices such as ultrasound scanners, altimeters and calipers (Chufyrev, & Ustyugov, 2015). The device consists of a laser range finder, a GPS module to determine the absolute coordinates, a digital compass, a photo camera and a microcomputer to coordinate the device actions.

2. BRIEF SUMMARY OF HARDWARE PLATFORM

The popular single-board microcomputer Raspberry Pi 2 was chosen for control. This device is a reliable solution due to the high quality assembly (in comparison with many copies and analogues manufactured in China), stable software and actively developing community. The computer is working under control of the operation system Raspbian that is a distribution of the free system Linux. The use of the free software allows to reduce the cost of the development process, and as a result, to decrease the price of the finished devices. The availability of a core module and the libraries for the low-level work with sensors in the operation system also plays an important role for creation of the automated measuring systems.

The device can be controlled by means of a wireless method via web-interface due to the availability of the functional web-site in the control system. At this in the field conditions the Wi-Fi access point is required. Usually, the function of the modern smartphones or tablet computers to work as an access point is used. Thus, the mobile device becomes a functional element of the system working as a connecting element and a remote control as well. The absence of the communication cable with the remote control allows to decrease the range of the working temperatures and also to improve the possibilities of the waterproofing of the device casing because it does not require installing a port outside the casing.

The main measuring element of the device is a laser range finder LDK-2M-30-RS manufactured by Egismos (Laser Distance Measure Kit,2010), allowing to measure the distances to the objects from 0.2 to 30 m with 3 mm tolerance. The measurement frequency is 2-10 Hz; the range of working temperatures is 0-40 °C. The range finder consists of a microcontroller controlling its work, receiving the commands from the microcomputer and transmitting the results of the measurements via interface RS-232.

A digital compass is necessary to determine the turning angle of the movable platform and the calculations of the absolute coordinates of trees. The magnetometer HMC5883L was used; it was manufactured by Honeywell developing the low cost and reliable solutions. The sensor provides the accuracy up to 2° due to 12-bit AD converter; the frequency of the measurement result is 160 Hz. These parameters satisfy the specified requirements.

A complete camera Raspberry Pi 2 was used to make photographs because it provides the acceptable quality of photographs. It should be mentioned that the

quality of the photographs from the ground device is not a critical factor in the project because they are used for adjustment, calibration and also for clarification of the results of the automated analysis by the operator of the information system. A photo survey is performed several times at several stages of the panoramic survey of the range finder. It allows to reach the required overlapping coefficient of photos 60%. Moreover, the high frequency of survey is not acceptable because according to the documentation the time necessary for the camera to restore the characteristics reaches 1 second and the holding time for such interval between the constrain angles of the device can significantly increase the working time.

All equipment is packed into the waterproof casing and is installed on the turning platform designed for the automated panoramic photo survey. To control the platform the special program module was created. The minimal angle of the platform turn allows to achieve the resolution 1-2 cm at the distance up to 20 m. In some cases such accuracy is not required (for example, if only big trees of almost the same size are located on the selected plot), the software contains the control elements of speed and constrain angle of the turning platform.

3. SOFTWARE FOR WORK WITH SENSORS

The libraries were created in the language Python 2 to work with the sensors. The choice of language is stipulated by the fact that there are a lot of cross-platform libraries for the low level work with the devices transmitting the data by buses I2C, SPI, USART, and this facilitates the work of the writers. Also the reason was that the information system of the developed hardware-software system was written in Python and this explains the simplicity of connection of programs.

The laser range finder supports the following commands: reading of the firmware version of device, reading of the address of device, reading of the error code of device, switching on/off of the laser pointer, switching on/off of the audible indication, single measurements, start and stop of the continuous series of measurements. The following format of the data exchange is used for work with a range finder: first the initialization byte (0xAA) is transmitted, then the bytes of address and commands, and the set of bytes of the useful load, control sum and the final byte (0xA8). When performing the measurements, the useful load contains the distance in millimeters to the object in the text format: 6 digit orders.

A program code for the improvement of structure and simplicity of the further integration into the general software system was developed within the frameworks of the object-oriented approach. The core of the library is the class Egismos_laser( ) the methods of which realize the functions specified above. As the connection with the module is performed using the interface UART (the virtual serial port is used) the class instance serial.Serial( ) is declared and initialized in the class constructor accepting

the connection characteristics as parameters (speed, availability of the parity bit, etc.). As the library serial is a cross platform, the developed library for the laser range finder can be used for the development in the environment of any operation system for which the language Python is supported.

The used digital compass is an I2C device with the address 0x1E (3-Axis Digital Compass IC HMC5883L, 2013). It consists of 3 magneto-resistant sensors made of permalloy connected to a 12-byte AD converter by means of a multiplexor. The device supports the modes of singe measurements, series of measurements and no activity mode providing the minimal energy consumption. The control and adjustment of the device is performed by record of the necessary values into the built-in registers. Reading of the state and results of measurements is also made from the registers. The built-in module I2C of the processor of microcomputer is used for the work with a compass.

As for the earlier described sensor, the library is written using the object-oriented approach. The class HMC_Compass( ) contains a set of methods allowing to adjust the parameters of the measuring devices such as a magnification factor (it is selected accordingly to the maximal value of the measured magnetic field and influences the errors of the measurements), the number of AD samplings according to which the averaging is performed to form the total result, and the frequency of measurements.

4. INFORMATION SYSTEM OF DEVICE

The described hardware-software system works under control of the information system (IS) developed by Kvochkin on the base of the Syktyvkar State University named after Pitirim Sorokin. This IS is written in the language Python and is a multilevel control system of the experimental and production objects providing the remote access (Designing of Information Systems: Main Notions of the Designing Technology of Information Systems (IS), n.d.).

The internal structure of the IS is shown in Figure-1. The requests of automatization, access to the task solving and receiving of the results of already completed experiments are made using the functional web-site built on the framework Django (Django Documentation, n.d.). The graphic user interface based upon the web-technologies allows to solve the problem of cross platforms providing the access of the users to the IS in the environment of any operation system.

The processing of the user requests to the remote experiment is performed via application-service "Manager of the laboratory" that is the core of the IS. For every low-level task of control of the experiment, a separate managing Python-script and Django-application are created with the following registration in the general structure of IS (Kvochkin, 2016).
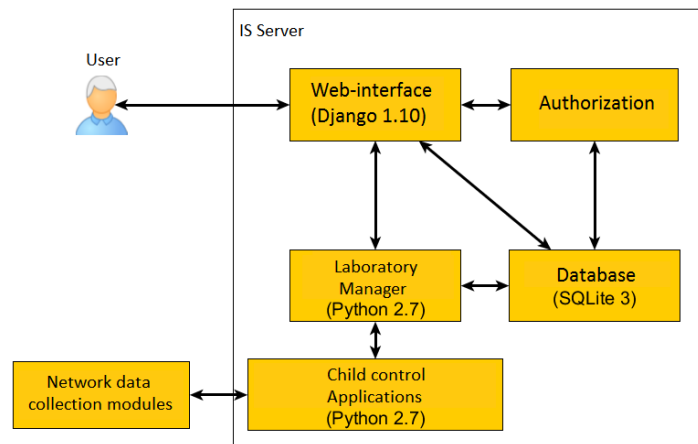
Figure-1. The structure of the device software infrastructure.

The accumulation of information of the performed experiments, registered users, and current experiments is made in the data base SQLite 3. Besides, the results of the experiments are stored in the form of files with the output data from every unit and can be visualized or processed by other software on the side of the server without the modification of the IS core (Dmitriev, & Korotina, 2007).

The interaction between the web-site and the core of the IS and also between the "Manager of the laboratory" and the subsidiary managing applications is made by means of the mechanism of local sockets. The basis of the protocol of interaction consists of the text commands with a set of arguments encapsulated in a TCP-packet.

When receiving the request for the implementation of a new experiment, the "Manager of the laboratory" initiates the checking of the availability of the remote installation and the further start of the corresponding managing Phyton-script with binding to the local socket for control. Thus, the communication interfaces do not cross and work independently in the started experiments.

During the work of the device, the results of measurements of a range and azimuth are stored in a separated directory in the format CSV. A simple text format allows exporting the stored data for processing by the external means regarding the system. At the same time, a record of the current experiment is made in the data base of the experiments. The review of the intermediate results is possible from the graphic user interface and also the program control panel with the possibility to cancel suspends and restarts the measurements. The photographs obtained from the photo camera are also stored in the directory of the experiment.

The graphic user interface contains the controls of the device allowing setting the parameters of scanning, elements containing the current values of sensors. The main principle of work with the device is that the user sets the required values, starts the process of measurements and goes to the shadow zone (at the distance of more than 25 m from the telescopic support with the device or behind the big tree) or follows the device to be away from the field of vision of the camera and range finder.

If the user moves away from the device he has the ability to control it continuously by means of the interface of the information system. The special area of the window of browser shows the current view of the camera and the values of sensors; however, to save the energy of the mobile device and accumulator of the main unit the continuous control can be switched off by the information system. In this case at every step of measurements the device makes a sound signal and that allows controlling its work even when the mobile device is switched off.

Besides the automated mode of measurements, there is a manual mode using which the user can set the device on the extreme points of a tree and perform the measurements by means of the special control buttons orientating on the view from the camera and also the light indicator of the range finder. When the factors of noise are absent such as bushes (for example, a pine wood: the stems of high pines are usually smooth and all the other garbles can be absent), such mode can provide good results (Kapralov, 2010).

After the completion of the experiment, the program-processors can be called from the graphic interface, for example, the software for graph building (in the project, the free instrument gnuplot is used), an external program for building of a panoramic view, or a program for the data analysis of measurements of the range finder.
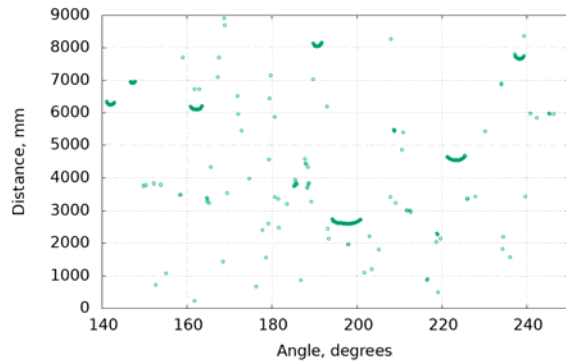
4. DISCUSSION OF RESULTS

A special program module in the language Python was written to recognize the trees in the obtained pixel array of the panoramic laser survey. As in the previous cases, the object-oriented approach was applied.
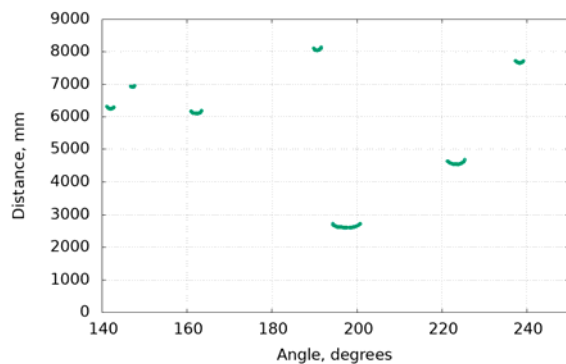
Before the attempts of recognition of trees in the set of unprocessed data, it is necessary to clear this set from noises, random pixels (Figure-2). The criterion of randomness of the particular chosen pixel is the absence of the neighboring pixels located at the distance less than the

set distance. These pixels can correspond to the hit of the laser ray into the branches of trees or bushes or in the light gap between the trees. In the last case, the control diagram of the range finder cannot determine the distance to the object because the waiting time of the reflected ray exceeds the critical time.

a)

b)

Figure-2. The results of measurements with noises
(a) and cleared ones from noises (b).

The class instances Tree( ) united into a tuple are used to store the information of the found trees. The class contains the following information about a tree: pixel array, associated with it from the initial set of pixels, diameter, distance from the tree to the azimuth. The recognition algorithm of trees makes a passage on the pixel array finding such fragments of array the pixels of which stand from each other at the distance not more than the set value delta in the adjustments of the algorithm. After detection of all fragments of the close standing pixels, the selection according to size is performed. If the fragment consists of less than 5 pixels it is rejected. It is explained by the fact that the trees to measure the size of which at least five steps of the range finder were required do not have any value from the point of view of the timber and need not to be taken into account in the total statistics (Avery, & Harold, 2002).
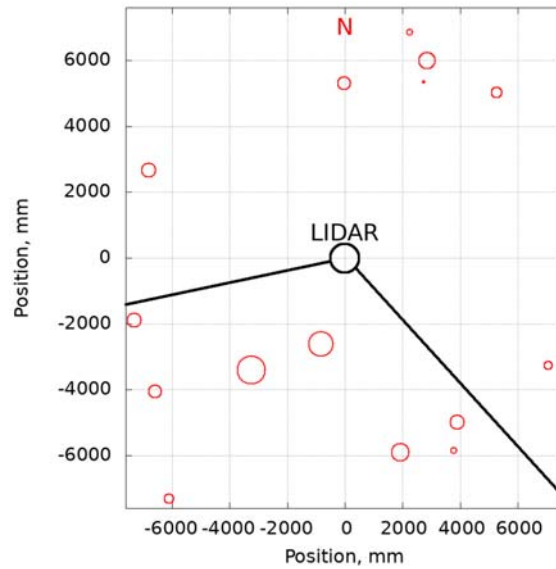

Figure-3. Tree map of the sampling unit obtained bymeans of a LIDAR-device. The field of vision of the device with the graphs in the Figure-2 is marked by lines.

Pixels making the large fragments of the initial pixel array are placed into the set of pixels of the class instances Tree( ) and then the calculation methods of diameters and coordinates are called consequently for all instances. The obtained data are sent into a file and then the map of a plot is made in the center of which there is a telescopic support with a range finder and the centers of circumferences marked on the map match the calculated coordinates of the centers of trees regarding the range finder, the diameters of circumferences are proportional to the calculated diameters of trees (Figure-3). Later, this map can be overlapped with the photographs obtained from the unmanned aerial vehicles Design of Forest Inventory Methodology Using LIDAR application, 2014) for the adjustment of the work of system, for calibration or clarification of data (depending upon the situation or obtained from the unmanned aerial vehicle, or obtained from the ground equipment).

5. CONCLUSIONS
The described software system allows to simplify significantly the forest inventory at many levels. At the level of measurements of the quantity and parameters of trees of the particular sampling units, the developed LIDAR-device allows to speed up the process of measurement several times in comparison with the existing methods. The availability of the information system allows to perform the information system development of the branch at the level of the particular forest division and due to the possibility of scaling – at the level of a region or a country.

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REFERENCES

3-Axis Digital Compass IC HMC5883L. 2013. Retrieved December 1, 2016, from https://cdn-shop.adafruit.com/datasheets/HMC5883L_3-Axis_Digital_Compass_IC.pdf.

Andersen H.-E., McGaughey R.J. and Reutebuch S.E. 2005. Estimating Forest Canopy Fuel Parameters Using LIDAR Data. Remote Sensing of the Environment.94, 441-449.

Avery T.E. and Burkhart H.E. 2002. Forest Measurements (5th ed.) New York: McGraw-Hill.

Chufyrev A.E. and Ustyugov B.A. 2015. Razrabotka ul'trazvukovogo dal'nomera na mikrokontrollere [Development of the Ultrasound Range Finder on Microcontroller]. International Research Journal. 7-1(38): 133-135.

Design of Forest Inventory Methodology Using LIDAR Application. 2014. Retrieved December 1, 2016, fromhttp://proforbiomed.eu/sites/default/files/LIDAR-inventory_en_1.pdf.

Django Documentation. (n.d.). Retrieved December 1, 2016, from https://docs.djangoproject.com/en/1.10/.

Dmitriev V.M. and Korotina T.Y. 2007. Principles for the Implementation of Automated Laboratory Facilities with Local and Remote Access. Reports of the Tomsk State University of control systems and Radioelectronics. 2(16): 121-128.

Kapralov E.G. 2010. Geoinformatika [Geoinformatics]. Moscow: Academy.

Kvochkin D.O. 2016. Informatsionnaya sistema Distantsionnaya laboratoriya. [Information System Distance laboratory]. Information Technologies in Management and Economics, 1(04).Retrieved December 1, 2016, from http://itue.ru/?p=879.

Laser Distance Measure Kit. 2010. Retrieved December 1, 2016, from http://www.egismos.com/intergrated-photonics-modules/Laser-distance-measurer-module-M2.pdf.

Proektirovanie informatsionnykh sistem: Osnovnye ponyatiya tekhnologii proektirovaniya informatsionnykh sistem (IS) [Designing of Information Systems: Main Notions of the Designing Technology of Information Systems (IS)]. (n.d.). Retrieved December 1, 2016, from http://www.intuit.ru/studies/courses/2195/55/lecture/1618?page=3.