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Research

MOBILE DEVICE OF THE AUTOMATED FOREST INVENTORY

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ABSTRACT

This article represents the review of the hardware part of the developed solution of the measurement automation of the number of trees and their diameters when performing the forestry inventory. The forest quality and the growth rates influence significantly the economy of the forestry enterprises; the timely inventory helps to make prognosis concerning the future cost of the areas and to plan the improvement measures of the growth quality. The modern instrumental methods of measurements allow to perform the much time-consuming forest inventory. The offered device allows to automatize the working process of the technical forester on the sampling unit and to decrease the time of the surface measurements. The mobile device of the surface measurements is an integral part of the complex of forest inventory including the photogrammetric researches of the surface observation: aerial photographic survey, using the unmanned aerial vehicle (UAV) and the photographs from the satellite.

INTRODUCTION

According to the working document accepted by the Food and Agriculture Organization of the United Nations (FAO UN) concerning the global estimation of the forestry resources, the forests possess the multiple environment-oriented and social and economic functions that have an important value at the global and regional levels (Global Estimation of Forest Resources, 2010, 2008). The importance of the accurate and updated information of the state of forest resources is especially emphasized.

The state and private forests in the territory of the Russian Federation are subjected to the inventory and this is stated at the legislation level. The inventory is determined as a course of actions to check the state of the forests and obtain their quantitative and qualitative characteristics (Federal Law No. 200-FZ, July 3, 2016). The qualitative estimation of the forest can be obtained when performing the inventory of the sampling units. The objects of inventory can be single trees and the large forests. Among the main inventory indicators of the forest objects, the following are distinguished: diameter, age, height, and growth (Martynov, *et al*., 2008). According to these parameters, one can estimate the stand of timber, basal area and the volume of the wood-base material. Accumulatively, all qualitative characteristics form the economy of the forest plot.

It is a typical fact that for a more qualitative prognosis of the volumes of timber obtained from one or another forest plot and that means for the prognosis of the economy, the permanent control of the whole forest area is required and the inventory of the above described parameters shall be performed timely.

The automation of the forest inventory is a critical problem of the forestry branch not only for the increase in the economic efficiency of the forestry but also for the rationalization of the use of forest area. The use of digital technologies allows to decrease the time of description of the stratum and to obtain the qualitative parameters of the forest with high accuracy. The convenient technology for this task is a surface and aerial optical scanning of the forest area with the further software processing of the pixel array. The works (Alekseev, *et al*., 2016) offer the automation methods with the use of geographical information systems (GIS) and the methods of remote sensing of the Earth, including the use of a UAV and

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lidar-technologies (light identification, detection and ranging) that can be a qualitative replacement of the ultrasound scanning devices offered in the work (Chufyrev, *et al.*, 2015). Lidar-technologies are now one of the most significant instruments of the forest inventory (Technology of Aerial Laser Scanning (LIDAR) for Forest Inventory, 2014) and geodesy (LIDAR (Light Detection And Ranging)-Technology of Laser Scanning, N. D.). In particular, the combination of the lidar-technology and the high resolution panoramic photography allows to check the results of scanning qualitatively and to collect the additional information about the process of inventory to determine the species and quality of trees of the stratum (Haala, *et al.*, 2004).

The objective of the present work was the development of the surface mobile device for the panoramic laser scanning of a forest plot.

METHODS

Laser scanning device (lidar) is a mobile hardware and software system for data collection (HSS DC) built on the platform of the microcomputer Raspberry Pi 2B. The flow chart of the device is shown in Fig. 1.

The developed HSS DC includes five functional components.

1. Laser range-finder module LDK-2M-30-RS-B is connected by means of the interface UART. It is made on the microcontroller STM32. The component allows to perform the point measurement of the range to the object by means of a laser. The maximal range is 30 meters; the accuracy is ± 3 mm.

2. The module of the digital camera Raspberry Pi Cam Module v2. It is connected by means of the interface CSI. It is used to make photographs of the forest plots for the further building of the panorama of the sampling unit.

3. The adapter module of microcomputer and rotating platform are made on the four optocouplers K1010 (two optocouplers per axis: panorama and inclination). It is connected to the digital interface with its own communication protocol. The platform position is controlled by means of this module.

4. The module of three-axis digital compass HMC5883L. It is connected to the serial interface I2C. It is used to determine the azimuth for every determined point in the forest area.

5. The wireless module Wi-Fi, connected by means of the interface USB. It is necessary for connection to the device and its control.

The independence of the HSS DC in the forest conditions is provided by the small size power supply source on lithium-ion batteries of high capacity 20,000 mAh. The offered solution is convenient from the point of view of the compactness of the unit: the power supply source is assembled in the casing with the microcomputer and does not make the transportation process to the new sampling unit more complicated.

The microcomputer of the HSS DC is controlled by the operation system Raspbian Jessie and the web-oriented information system for data collection developed on the framework Django 1.10.

The interconnection of the program sub-levels of the HSS DC is shown in Fig. 2. The measurements

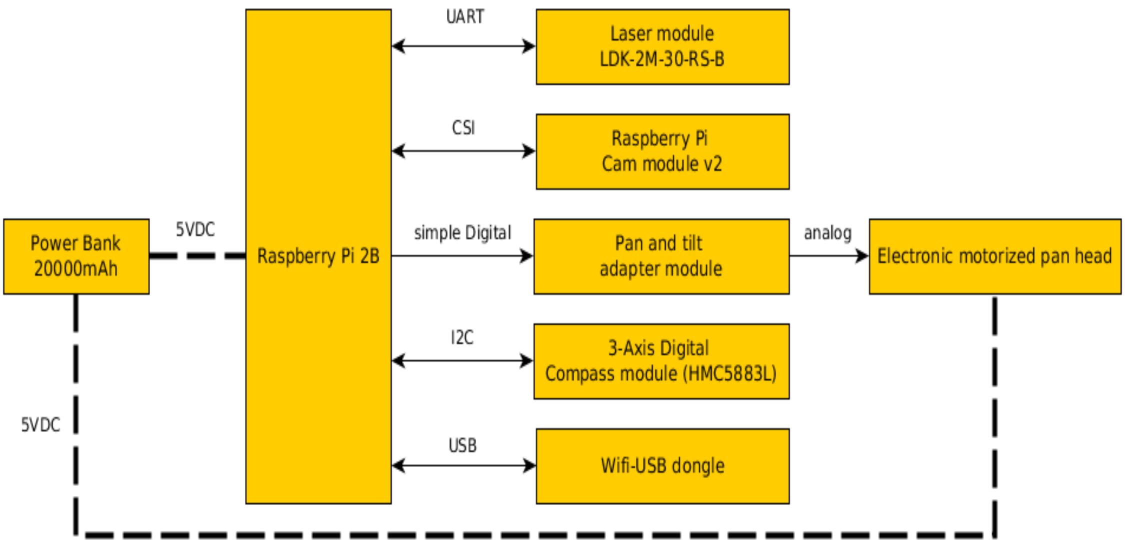

Fig. 1 Flow chart of the laser scanning device.

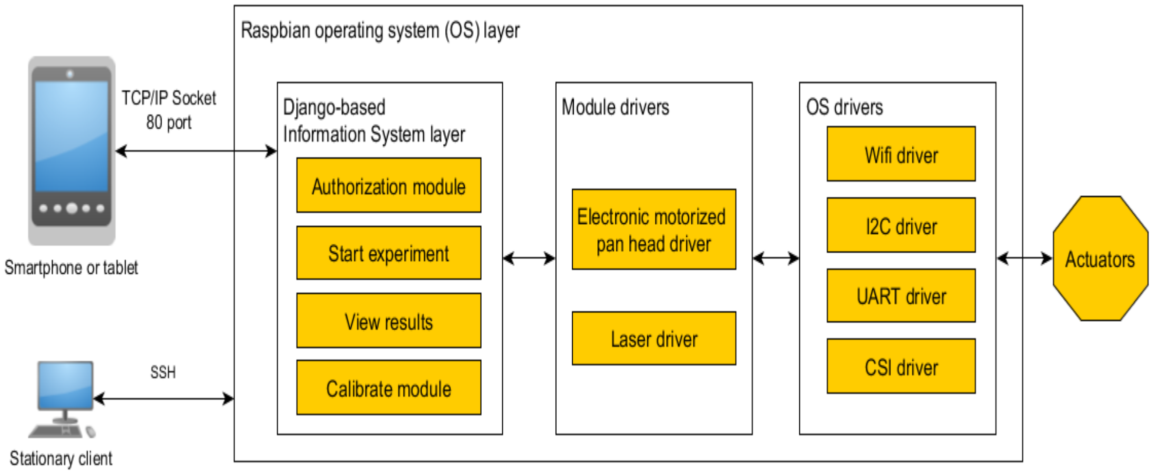

Fig. 2 Flow chart of the program level of the HSS DC.

on the sampling unit are performed using the mobile device (smartphone, tablet); the control of state and management are performed via web-interface. The information system has several functions: authorization to separate the access rights, preliminary calibration of the device, review of the results of measurements performed and start of new experiments.

The methods of the interaction of the information system and drivers of the devices are similar to the methods offered in the work (Haala, *et al*., 2004). The interaction with the actuators is done via the module drivers and drivers of the operation system of the interface buses (USB, I2C, UART, CSI). The module drivers are independent program developments of the offered hardware solution. The mobile module HSS DC works as a server of the information system.

The method of scanning of a sampling unit consists of three stages. At the first stage, the operator assembles the mobile platform in the observation point (the recommended height of measurements is 1 m to 1.5 m) and sets the initial point of scanning in the north according to GPS-navigator. This requirement is not compulsory but it facilitates the post-processing of the collected data.

The second stage is preparation: using the smartphone or tablet the operator switches on the data transfer via Wi-Fi and the mode of access point with parameters by which the scanning module is configured (on default the operator knows the name of the access point and password). Then it is started and the scanning device is heated, the power cable is connected to the calculation module and the module of the turning platform. The time of transfer to the working mode is 1 to 2 minutes. At the last step of the preparation stage, the operator connects to the device via web-interface using the smartphone or tablet and passes authorization.

The third stage is an experiment. Following the command of the operator via the web-interface, the HSS DC prepares the form of record of date and time of the experiment in the local data base of the experiments, absolute coordinates obtained by the external GPS-navigator and identifier of the sampling unit. After checking the accuracy of the data inserted the device is transferred into the mode of the consecutive measurements and photographing of the area.

A pitch of the platform turn is set as a constant value; the azimuth for the measuring point of space is calculated according to the measurements of the digital compass HMC5883L. All measurements are recorded in the file of register according to the format "[Angle] [Range]". Measurement control of every point is performed using the sound signaling of the mobile platform.

The measurements are completed automatically after crossing of point of 360° by the scanning ray. The transfer to a new sampling unit can be made without switching off of the HSS DC that allows the operator to omit the preparation stage. If the flash memory of the microcomputer Raspberry Pi 2B is not enough the additional memory storages can be connected.

The extraction of the information and post-processing of the collected data of the laser scanning is performed at the stationary client via connection by SSH to the device.

RESULTS AND DISCUSSION

The developed HSS DC of the laser scanning of the sampling units was tested using the pine forest with the coordinates 61°39'39.6"N 50°46'29.4"E (the data were obtained using GPS-navigator Garmin GPSMAP 60CS to a tolerance of ± 10 meters). Fig. 3 shows a part of the sampling unit with the device assembly.

As a result of the measurements, from one sampling unit the pixel array of two-dimension space was obtained consisting of 2560 elements. This corresponds to the scanning pitch of 0.14°. The average time of one measurement is 1.1 sec; at the same time, the total time of measurements for one sampling unit is from 40 to 60 minutes. The length of the experiment depends greatly from the condition of atmosphere and the availability of precipitation. The device has a built-in program correction of the laser scanning in the conditions of rain or fog.

The collected pixel array of the panoramic measurement was processed and visualized at the stationary client. According to the photographs the panorama of the area was made. Fig. 4 shows the south part of the panorama of the sampling unit with a viewing angle 103° ± 1°. The trees were marked to compare with the visualized pixel array. Fig. 5 shows the map of the forest (along the axes the area coordinates are shown regarding the measuring point in mm, obtained as a result of the laser scanning with the filtration of data in the radius of 9 meters from the measuring point (black circle). For every tree, the designed radius of stem in mm to a tolerance ± 3 mm was marked. In total, 22 trees were on the sampling unit. The north tree was a calibration point of the device and the graph is made with overlapping. For the trees with markings A, B, C, D, E, F the radius measurements of the stems were made manually. The data comparison is shown in the Table 1.

Fig. 3 The device is in a working mode.

Fig. 4 South part of panorama of the sampling unit.

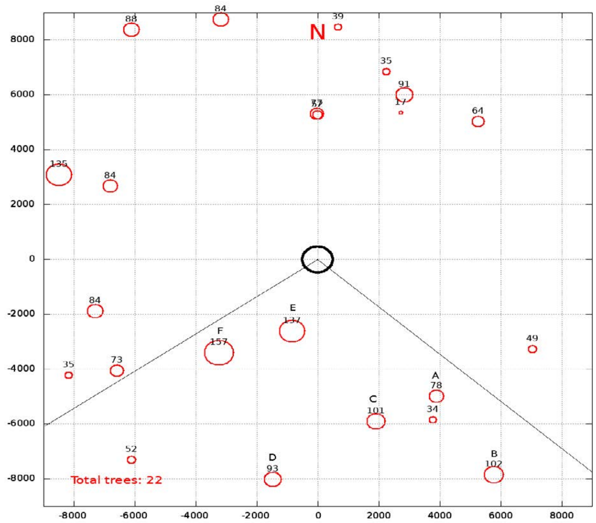

Fig. 5 The processed scanning pixel array of the sampling unit.

We can observe the correspondence of the experimental and theoretical data within the range of tolerances for the trees A, B, C, D. The trees E and F have significant discrepancies with the real values and require the recalculation. The conformity of the data obtained on the panorama forest area of the sampling unit with the view angle 103° ± 1° was 66.7%.

Despite the high noise level in the scanning plane (availability of branches and bushes), we can achieve the accurate distinguishing of the trees with stem diameters from 34 mm ± 3 mm. It became possible

due to the use of a laser range finder on the hardware platform with a narrow diagram of direction and also due to the software of the post-processing of the data collected.

CONCLUSION

The device was developed that is designed for the automation of the surface forest inventory using the technology of the panoramic area scanning. Mobile surface scanner allows to decrease the time

Table 1. The data comparison

Tree	Real radius, mm	Design radius, mm	Discrepancy, mm
A	70 ± 10	78 ± 3	8
B	106 ± 10	102 ± 3	4
C	90 ± 10	101 ± 3	11
D	89 ± 10	93 ± 3	4
E	99 ± 10	137 ± 3	38
F	100 ± 10	157 ± 3	57

of inventory of the sampling unit, to exclude the errors stipulated by the human factor, to provide the visualized information (panoramic photographs and calculation maps of the forestry) to the forest experts during the office analysis of the forestry materials.

The field tests were performed in the forestry of the average density for the hardware and software system of the data collection. The mobile device showed the fail-safe work at the temperature of the environment -8.0°C at the air relative humidity 80% and atmospheric pressure 748.9 mm of mercury (data were obtained from the weather forecast archive of the weather station in Syktyvkar, Komi Republic on November 6, 2016 (Weather in Syktyvkar, N. D)). According to the results of the test, we can conclude that the developed device has perspectives of application when performing the forest inventory with the sampling units in the radius of 9 m at the average and high density and radius 15 m to 30 m at the low density of forestry.

The main tasks that this developed device can solve are the obtaining of data about the species growing at the sampling unit, number of trees, their diameters and quality of timber. The additional parameters required for the detailed description of forest (height, undergrowth) can be achieved when using the means of aerial scanning and aerial photographic surveying together with the developed HSS DC.

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REFERENCES

Alekseev, A.S., Nikiforov, A.A., Mikhailova, A.A. and Vagizov, M.R. 2016. A new method of determination of inventory characteristics of the forest crops according to the high-resolution photographs from the unmanned aerial vehicle (UAV). *Proceedings of the St. Petersburg Forestry Academy*. 215 : 6-18.

Bocharova, A.A. 2010. Application of remote methods of sensing for rational use of forest resource. Interekspo Geo-Sibir', 3 (2).

Blokhin, D.Yu. (N. D.). GIS-Technologies in the forestry and forest industry. Krasnoyarsk: Krasnoyarsk State Agrarian University.

Chufyrev, A.E. and Ustyugov, B.A. 2015. Development of the ultrasound range finder on microcontroller. *Int. J. Sci. Res.* 7 : 133-135.

Global Forest Resources Assessment. 2010. Global estimation of forest resources 2010. Guidelines of the national reporting within the frameworks of global forest resources assessment-2010.

Haala, N., Reulke, R., Thies, M. and Aschoff, T. 2004. Combination of terrestrial laser scanning with high resolution panoramic images for investigation in forest applications and tree species recognition.

Kvochkin, D.O. 2016. Information system “remote laboratory”. Information Technologies in Management and Economics, 1 (04).

Forest Code of the Russian Federation: Federal Law No. 200-FZ (rev. July 3, 2016).

LIDAR (Light Detection and Ranging)-LIDAR-Technology of Laser Scanning. (N.D).

Martynov, A.N., Melnikov, E.S., Kovyazin, V.F., Anikin, A.S., Minaev, V.N. and Belyaeva, N.V. 2008. Principles of forestry and forest inventory: Textbook for students of the specialty 250300: Technology and equipment of the logging and woodworking industries and the specialty 120303: City Cadastre. Saint Petersburg: Lan.

rp5.ru reliable prognosis. Weather for 243 countries of the world (N. D.). 20 June, 2016.

Technology of Aerial Laser Scanning (LIDAR) for Forest Inventory. (2014).