New Method and Software for the Round Timber Automatic Measurement

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Abstract—This paper is devoted to the description and validation of the round timber volume measurement method on the basis of the photogrammetry analysis of the log pile end images. The method is based on the specialized software which allows user to perform automatic analysis of the images involved abuts detection and determination geometry and orientation of each log in the pile. It is followed by manual edit of the obtained results and final calculation of the log pile cubic capacity according to the piece-by-piece measurement method. The software output was compared against manual piece-by-piece measurement method. Results of two measurement techniques were thoroughly analyzed and visual estimation of their output data showed that algorithm gives a misleading result in cases of abuts with strong elliptical form, however, in other cases its result is more reasonable than manual measurement. According to the testing results the average error of the algorithm for the log pile photogrammetry measurement is less than 9.2% with an average error of 5.14%. Thus, the method of the log piles measurement using the developed algorithm can be successfully applied in the activity of forest enterprises as far as industry standards establish the maximum volume measurement error for the round timber accounting in the range ±12%.

Keywords—Automatic detection, experiment, image processing, log pile measurement, piece-by-piece measurement.

I. INTRODUCTION

The problem of the accurate accounting of raw materials and products is one of the most significant in respect to a constant struggle to minimize production costs. There are many different methods of measuring the timber volume. They differ from each other both in terms of physical principles and methods of volume management. The peculiarity of round timber is a high level of measurement error, which leads to a shortage or surplus in the revision of timber residues in warehouses and fluctuations in the consumption of timber during processing. Most methods for measuring the volume of round timber were developed more than 20 years ago [1]:

− piece-by-piece measurement by the upper abut diameter and tabular calculation of the volume;

− piece-by-piece volume measurement by the median diameter;

− geometric group method of measurement;

− weight group method.

The idea of the given method is to obtain the images of the pile ends with further processing of the photography by specialized software. During the image processing, the software produces:

− automatic detection of all visible abuts in each image;

− reconstruction of the 3D spatial structure of the pile;

− calculation of the quantitative characteristics of each log and a pile as a whole. These quantitative characteristics are: the upper and lower diameters and volume of each log along with the volume of the pile.

The software for round timber cubic capacity measurement is designed and suitable for calculating a volume and geometry of the logs stacked in a pile. The purpose of the software is computing of the quantity and volume of the stacked logs via image analysis, i.e. photogrammetry. The software is developed for tablets and other mobile devices under Android OS and adapted for manipulating with images. The execution sequence of the user is the following:

− Loading of images. The number of images depends on the availability of the sidewalls of the deck for photograph. The measurement could be carried out via one or two projections of the log deck.

− Calibration of each image. Calibration means the determination of the inner and outer parameters of the camera. There are manual and automatic calibration modes in the software.

− Automatic search of the log cuts in the image.

− Manual editing. It is necessary to correct the results of the automatic isolating, i.e. to eliminate the 1 and 2 type errors and adjust log cut edges.

− Achievement and analysis of the results. Software output is saved as a detail report in the local database for further editing or data export into delivery note in PDF format.

The paper is devoted to the thorough description of the software for round timber volume measurement including the detail description of its structure and testing against piece-by-piece manual measurement method.

II. STRUCTURE OF THE SOFTWARE

The software for the mobile measurement of the round

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timber is designed on the basis of the described algorithm and suitable for calculating a volume and geometry of the logs stacked in a pile. Actually the task of the measurement method validation resolves itself to the task of the software for the mobile account of the round timber validation against existed measurement techniques.

The software is designed to conduct operations with maximum possible automatic performance, however, the tools for manual editing of the processing result are also provided.
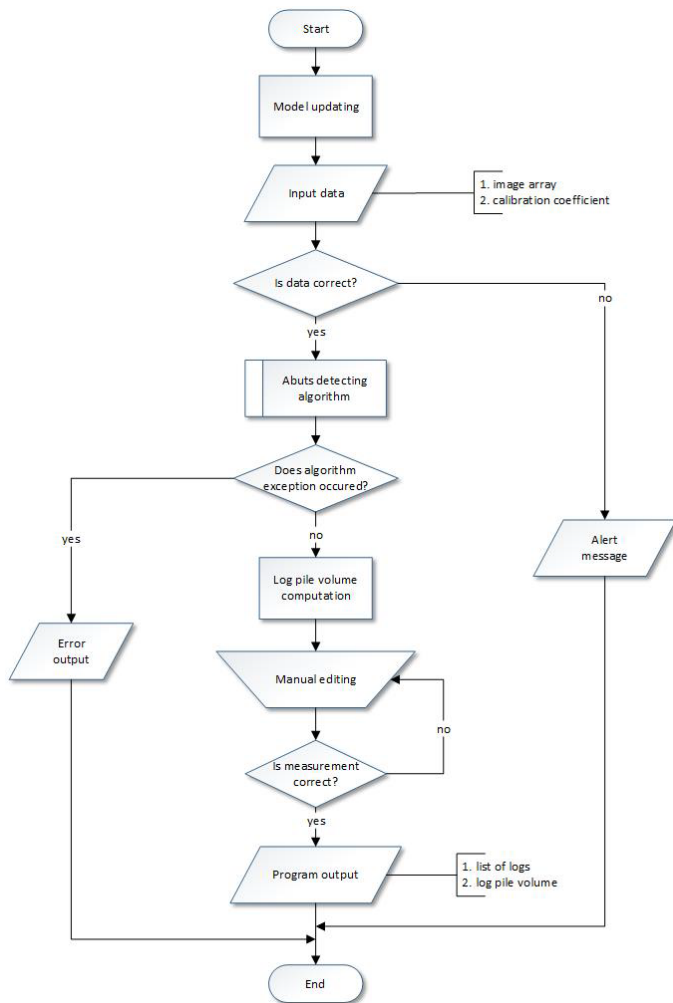

Fig. 1 software processing flow chart

The sequence of operations for obtaining the log pile measurement results is following:
1) Uploading one or two images into the program. Number of images is selected according to the available viewpoints of the log pile ends and assigned in the global settings of the program
2) Calibration of each image. Calibration consists in determination of the inner and outer parameters of the camera. It can be implemented in automatic mode with particular standard object detection or manually by the user.
3) Automatic detection of abuts [2, 3]. This stage is performed independently from the user.
4) Manual editing. It is implemented in cases of algorithm

detection error, for example for the overlapped abuts.
5) Result generation and analysis. Program output is presented in the form of a detailed report which can be edited afterwards or exported in doc, xls, pdf format.

The control-flow chart of the software processing is shown in Fig. 1.

A. Calibration

The purpose of the calibration is to assign the correspondence between pixel size of the abuts in the image with their real size [4]. The software provides calibration by the standard object or selected abut. The principal of the automatic calibration is described in the [5,6]. If automatic detection of the standard object is failed the calibration object is selected manually. It is recommended to choose the one abut which is located in the center of the image and has regular circle form.

The calibration is launched by clicking the calibration icon (see Fig. 2) in the workspace. In case of two-image mode the
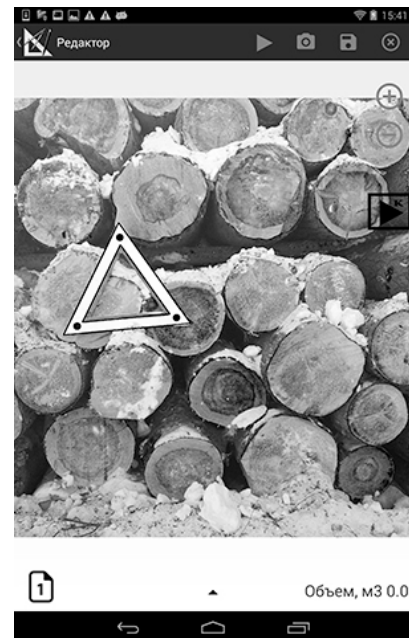

Fig. 2 standard object detection

calibration should be implemented to each image.

B. Automatic analysis

Automatic analysis and editing module is the main authority of the software. There are a few methods for the automatic round timber volume measurement [7-10]. The methods for the abuts detection which are described in this papers can be divided into two categories. First category includes methods based on the machine learning. In [9] Herbon et al. describe the iterative algorithm for detection and segmentation which uses the descriptors of interest points based on histogram of oriented gradients (HOG) [12] in combination with Haar features and local binary patterns (LBP) at the stage of the log abut detection. Gutzeit and Voskamp in [8] applied Viola-Jones algorithm means for implementation of the cascade of the classifiers where each of them is the assembly of weak

classifiers; the features for the detection algorithm are the rectangular Haar ones. Second category consists of the unsupervised training methods which are used the assumptions of the form and size of logs [7, 10]. In general, these methods are based on the Hough transform [15, 16] or its modifications and used to detect log abuts in the image in the form of circles or ellipses.

The idea of the author's algorithm is in the abuts detection and pile modeling on the basis of the detected contours in the one or two images. 3D model of the pile provides insight into
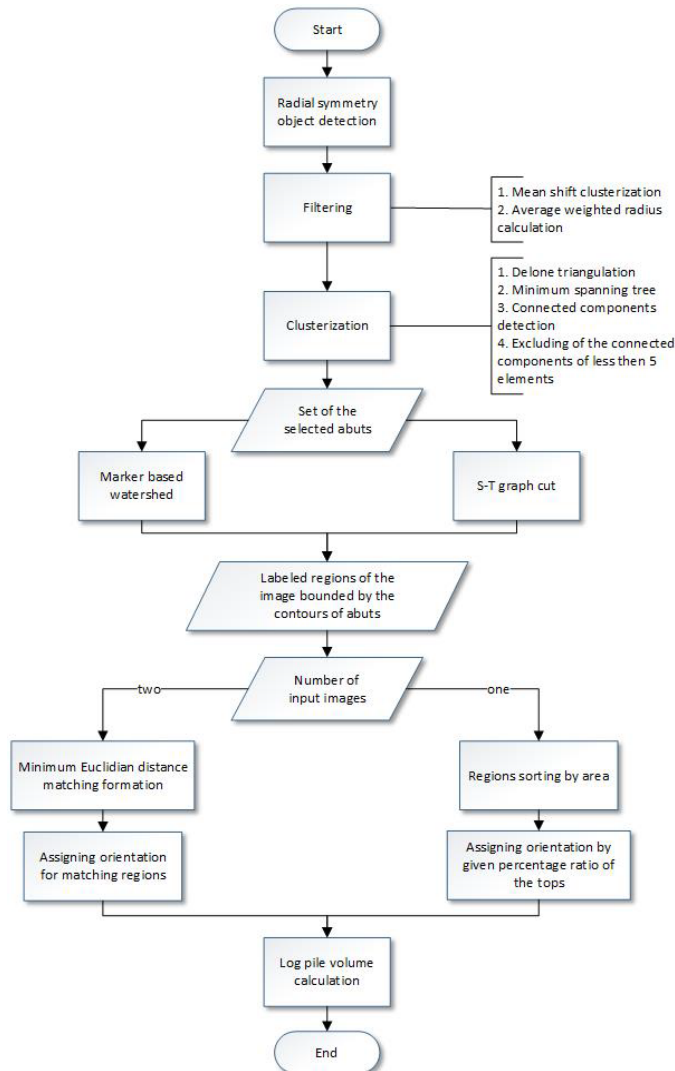

Fig. 3 algorithm control-flow chart

the orientation of the logs in a pile and, with a priori information about length, each log volume and therefore the volume of the pile can be measured. The control-flow chart is shown in Fig. 3.

Automatic detection is performed independently; result of the operation is displayed to the user immediately after algorithm execution. Detected abuts are highlighted with color marker. Also the diameter and orientation of each abut can be displayed in the image (if specified in global settings). When the calibration is performed the analysis results – quantity and

volume of logs – are displayed in info panel (see Fig. 4).

The volume measurement is performed according to the

Fig. 4 result of the automatic measurement

requirements document (GOST 32594-2013 and GOST 2708-75).

C. Editing

After the automatic algorithm execution some abuts may be undetected while other objects in the image may be detected incorrectly, so the manual editing should be implemented. In order to add new object in the image the tool "+" (see Fig. 5a) should be selected. Then the new object will be added after clicking in the image area. Deleting of the objects is implemented by selecting "–" tool (see Fig. 5b) and clicking objects in the image. In order to exit adding/deleting abuts mode user should click the active tool again.

Addition of the objects is implemented on the basis of the Lee algorithm [17]. The listing of the procedure is given below.

```
mask.put(p, (byte) 2);
next.add(p);
while (!next.isEmpty()){
replaceQueuees();
for( i=0;i<current.size();i++ ){
checkNeighbors ( current.poll() );
```

current, next – pixel queues of the current and next level respectively.

Four neighbor pixels are checked for similarity with given pixel:

```
void checkNeighbors (Point p){
checkForSimilarity( p, new Point(p.x, p.y-
1) );
checkForSimilarity(  p,  new  Point(p.x,
p.y+1) );
checkForSimilarity(  p,  new  Point(p.x-1,
p.y) );
checkForSimilarity(  p,  new  Point(p.x+1,
p.y) );
```

```
}
   The pixel similarity test function is following:
void checkForSimilarity( Point startPoint,
Point checkPoint ){
if ( isPixelExists(checkPoint) ){
if(areColorsSimilar(
img.getPixel(startPoint.x,
startPoint.y),
img.getPixel(checkPoint.x, checkPoint.y) )
){
mask.put( checkPoint, SIMILAR );
next.add( checkPoint );
}
else mask.put( checkPoint, NOT_SIMILAR );
}}
```

method isPixelExists(checkPoint) checks for image array overrun,

mask – structure which stores the checked pixels labeled as included to or excluded from resulted image area.

Pixel color similarity test function is flowing:

```
boolean areColorsSimilar(int c1, int c2){
int differenceR = Abs( c1.red -c2.red );
int differenceG = Abs( c1.green -c2.green
);
int differenceB = Abs( c1.blue -c2.blue );
int maxDifference = Max( differenceR,
differenceG, differenceB );
return  maxDifference < step ? true :
false;
}
```

step – algorithm sensitivity.

The software is approximate abut by equivalent ellipse and its diameter is calculated as average of major and minor axes (according to GOST). Manual editing allows user to resize objects by clicking them when "+" and "–" tools are inactive. In this case the anchor points of the ellipse become available (see Fig. 5) so user can stretch, rotate or relocate it.

Fig. 5 manual edit; tools: a) add object b) delete object c) top label
d) butt label

Orientation (top or butt) is assigned for each abut according to the following rules:

In case of two images processing the orientation is determined by comparison of two abuts for each log and bigger one is labeled as butt whereas smaller – as top.

In case of one image processing orientation is assigned selectively on the basis of the area of the image regions related to abuts and specified percentage ration of the top abuts. In this mode the manual editing of the orientation is provided: after the particular abut selecting the tools "Top" and "Butt" (displayed as letters "K" and "B" respectively, see Fig. 5c,d) are appeared in the workspace and user can assign the orientation for the abut by selecting one of them.

III. LOG PILE VOLUME MEASUREMENT

The main feature of the round timber is the high rate of their metering error. The measurement without tolerance is impossible. Industry standards establish the maximum volume measurement error for the round timber at the rate comprised between $\pm$ 3% and $\pm$12% which is much higher than the measurement error for any other product. Significant error for the round timber measurement is driven by the following reasons:

− Irregular shape of the logs and piles, density and moisture content fluctuations, barked or debarked logs;

− Errors of the features (defects, species) expert estimation and parameters visual measuring by a tollyman

− Eventually variation of the parameters and estimated features, their dependence on wood growing conditions, processing and storage of round timber [18].

The log pile volume measurement is carried out according to the GOST 32594-2013 on the basis of the introduced mathematical model. Measuring object is defined as sum of the cone frustums where accessible for measurement bases described through equivalent ellipses.

The top and butt diameter of each log is calculated as arithmetic mean of major and minor axis of an ellipse

$$d = \frac{d_1 + d_2}{2} \tag{1}$$

The volume of the pile is calculated as a sum of its log volumes:

$$V = \sum_{i=0}^{n} V_i \tag{2}$$

The volume of the each log is measured by the one of the following methods.

The cone frustum method assumes measurement of the top diameter d, butt diameter D and log length L. The volume is calculated as following:

$$V = \frac{3,1416 \cdot L(d^2 + D^2 + d \cdot D)}{12 \cdot 10000} \tag{3}$$

The frustum cone and average taper method assumes volume measurement as a product of cross section at the middle of the log and log length. As far as technological

process of the top diameter measurement is much easier then mid diameter the conversion of the top diameter d to the mid one d_m according to the formula (4) is applied.

$$d_m = d + s \cdot \frac{L}{2} \qquad (4)$$

where d – top diameter, cm, s – rise, cm/m, L – log length, m.

The volume measurement is implemented as following:

$$V = \frac{3,1416 \cdot L \cdot \left(d + s \cdot \frac{L}{2} \right)^2}{4 \cdot 10000} \qquad (5)$$

IV. TESTING AND RESULTS

The developed algorithm is implemented in the software for mobile measurement of the round timber. Testing of this software in order to validate author's measurement method against the piece-by-piece measurement method by GOST 2708 was carried out on the tablet Samsung Galaxy Tab 3 GT0P5210 16 Gb 10,1". Requirements to the picture taking are the following: camera is parallel to the abuts plane, pile is located at the center of the frame with space between the frame edge and the nearest abut.

The comparative analysis of the automatic algorithm output and manual piece-by-piece measurement for two log piles is given below in order to evaluate the fidelity of the data obtained by the software. The first log pile with enumerated abuts is shown in Fig. 6. The diagram in Fig. 7 demonstrates the comparison of the manual and automatic methods results.

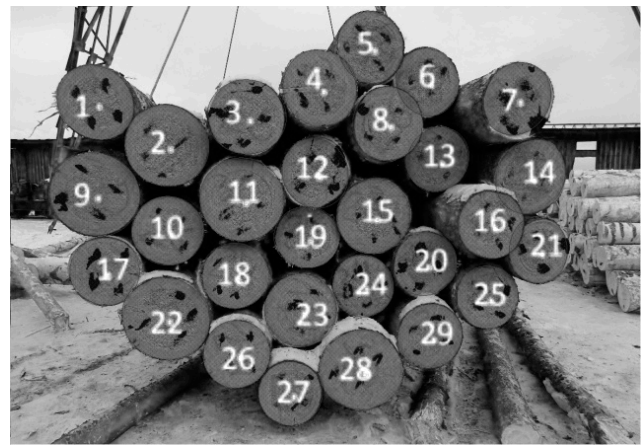The analysis of the data fidelity is carried out by the

Fig. 6 sample № 1

matching the contours of the abuts equivalent ellipses (Fig. 8). According to the diagram the abuts №№ 4 and 29 have equivalent diameter of 26 cm according to the manual measurement. The algorithm gives 30 cm and 24 cm respectively. Contour matching shows that the diameter of the abut № 4 is much bigger.

Another pair is №№ 13 and 27. According to the manual measurement their diameters differ by the 4 cm (26 cm and 22 cm respectively). Algorithm output shows their equivalence – 24 cm. Contour matching shows that the diameters are equal.

Pair of logs №№ 2 and 28. According to the manual measurement their diameters differ by the 4 cm (28 cm and 32 cm respectively). Algorithm output shows their equivalence – 32 cm. Contour matching shows that the diameters are equal.
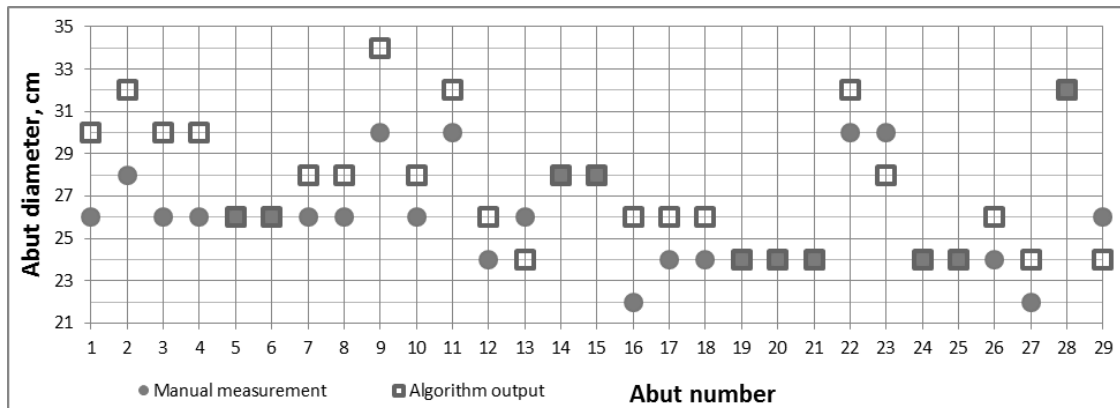

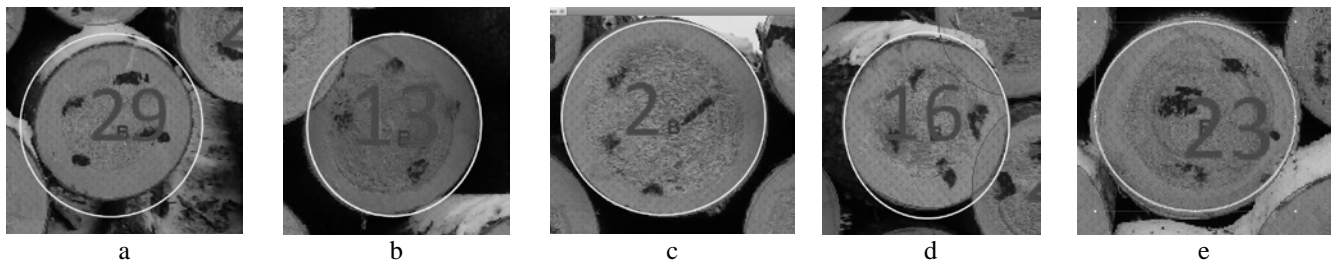
Fig. 7 measurement methods comparison for sample № 1

Fig. 8 visual comparison of the abuts contours from sapmle № 1: a) 4 and 29 b) 13 and 27 c) 2 and 28 d) 5 and 16 e) 10 and 23
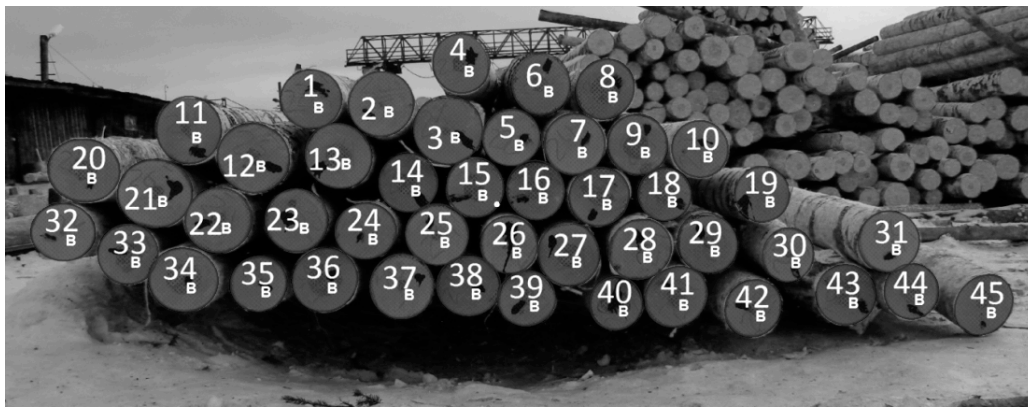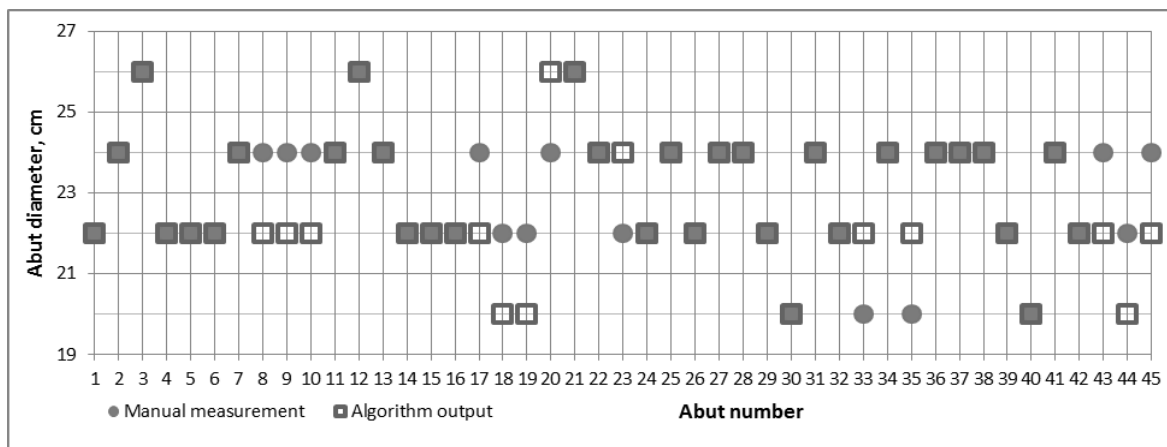
Fig. 9 sample № 2

Fig. 10 measurement methods comparison for sample № 2

Pair of logs №№ 5 and 16. According to the manual measurement their diameters differ by the 4 cm (26 cm and 22 cm respectively). Algorithm output shows their equivalence – 26 cm. Contour matching shows that the diameter of the abut № 5 is actually bigger than one of the abut № 16, so the algorithm gives the misleading result in this case.

Pair of logs №№ 10 and 23. According to the manual measurement their diameters differ by the 4 cm (26 cm and 30 cm respectively). Algorithm output shows their equivalence at 28 cm. Contour matching shows that in fact the diameters are unequal but the difference is about +/-2 cm.

The result of the contours matching shows that the mismatch of the algorithm output is true only for the pair №№ 5 and 16. In other cases for the selected logs with the highest mismatching (more than 4 cm) the automatic algorithm output seems to be more valid against manual piece-by-piece measurement.

Fig. 9 shows the second log pile sample with enumerated abuts. The diagram in Fig. 10 demonstrates the comparison of the manual and automatic methods results.

The analysis of the second sample shows that the manual measurement and algorithm output are almost match and the discrepancy in 2 cm is a result of the abut diameter determination by one axis (typical of manual measurement) or two orthogonal axes (algorithm).

The thorough analysis of the round timber volume measurement method and its validation against the manual measurement was carried out. Visual estimation for the cases of significant mismatching (4 cm and above) shows the inaccuracy of both methods in different situations. Algorithm analysis is much more sensitive to the abuts with strong elliptical form (Fig. 8d, contour of the log № 5), however, in other cases its result is more reasonable than manual measurement.

The influence of the optical distortions over the algorithm output is not detected as far as there was no situation when diameters values match in the center of the image and differ in the edges. The discrepancy of the methods in 2 cm is a result of the abut diameter determination by one axis (typical of manual measurement) or two orthogonal axes (algorithm).

The 940 measurements (see Fig. 11) of the log piles were carried out during the algorithm testing under the different conditions:

− In stack and in the log truck,

− Stacked oriented (by tops or butts) to the camera or randomized,

− Different weather conditions (snow, solar etc.).

According to the testing results the maximum error of the algorithm for the log pile photogrammetry measurement is less than 9.2% with an average error of 5.14% (see Fig. 12). The tolerance of the measurement of the same log pile from the different viewpoints is less than 1%.
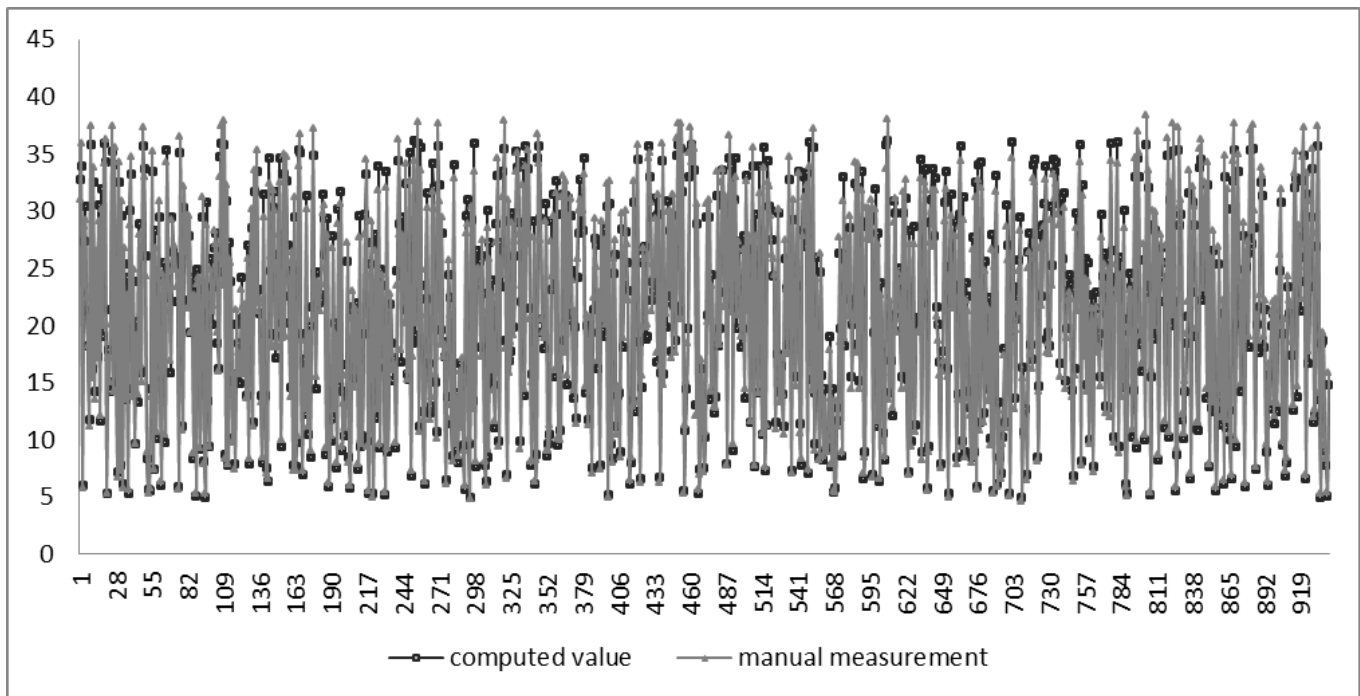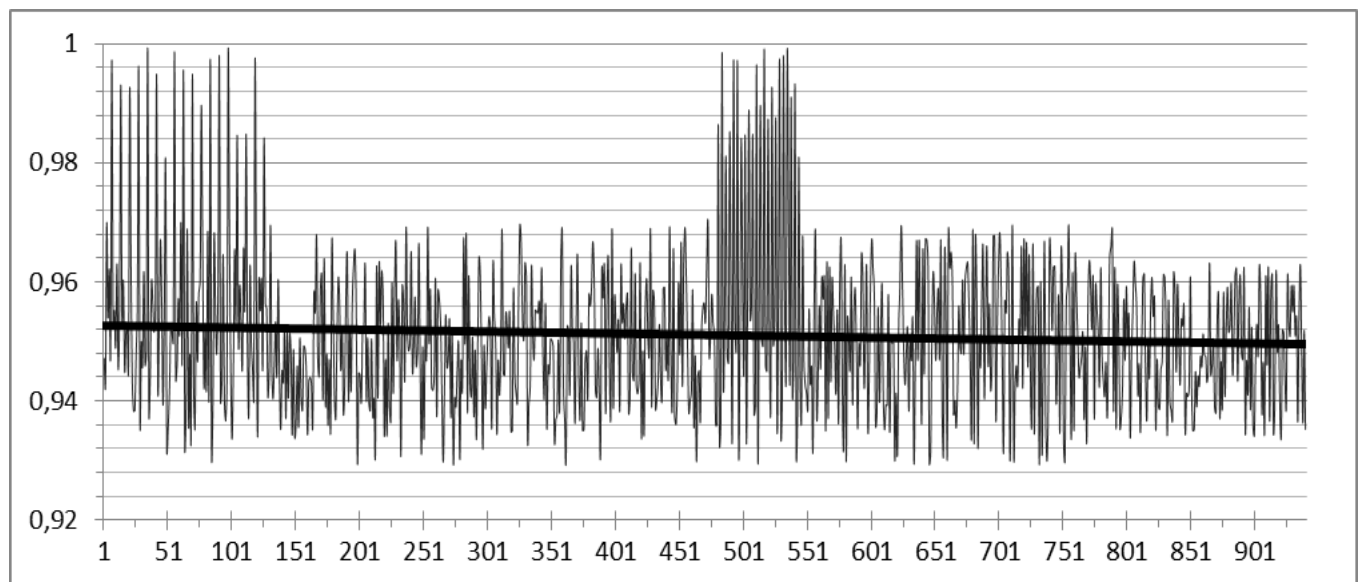
Fig. 11 log piles volume measurements

Fig. 12 relative accuracy of the algorithm output in comparison with manual piece-by-piece measurement

V. CONCLUSION

The software for the mobile measurement of the round timber was tested on 940 images of 400 different samples (packs, bundles, piles up to 200 logs), the measurements were carried out from February 19, 2016 to March 31, 2017 (coverage of the full calendar year). According to the testing results, the maximum error of the algorithm for the log pile photogrammetry measurement is less than 9.2% with an average error of 5.14%. The tolerance of the measurement of the same log pile from the different viewpoints is less than 1%. Thus, a method of the log piles photogrammetry measurement using the developed algorithm can be successfully applied in

the activity of forest enterprises as far as industry standards establish the maximum volume measurement error for the round timber accounting in the range between ±3% and ±12%.

As a result of the proposed methodology, the measurements of the round timber will be made faster in comparison with other approaches (manual measurement, weighing), whereas their results will become more reliable (re-verification of the measurement, reducing the possibility of falsification). Mobility and speed of the given solution allow user to perform measurements in places of logging, on the truck, during the shipment-acceptance or sending for further processing. That is, to account for raw materials at every stage of its life cycle. Implementation of the developed software makes it possible to

automate previously unavailable parts of the production process, which leads to higher labor discipline of personnel, lower costs for traditional (paper) communications between company divisions (an average of 67%) [19] and a decrease in the time of accounting operations (an average of 36% , in the range from 0 to 90%).

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