International Journal of Engineering & Technology, 7 (4.7) (2018) 368-375

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paperResearch Paper

Woodworking Facilities: Driving Efficiency through Automation Applied to Major Process Steps

Garik Gasparyan[1], Ol'ga Kunickaya[2], Igor Grigorev[3], Viktor Ivanov[4], Olga Burmistrova[5], Andrei Manukovskii[6], Artem Zhuk[7], Edward Hertz[8], Lyudmila Kremleva[9], Oscar Mueller[10]

[1]*Doctor of Technical Sciences, Dean of Department of Forestry, Bratsk State University, 665709, ul. Makarenko 40, Bratsk, Irkutsk Region, Russian Federation. Email: garik.gasparian@yandex.ru*
[2]*Doctor of Technical Sciences, Professor of Department "Technology and equipment of forest complex», Yakut State Agricultural Academy, 677007, Sergelyakhskoye highway, 3rd km, house 3, Yakutsk, Russian Federation. Email: ola.ola07@mail.ru*
[3]*Doctor of Technical Sciences, Professor of Department "Technology and equipment of forest complex», Yakut State Agricultural Academy, 677007, Sergelyakhskoye highway, 3rd km, house 3, Yakutsk, Russian Federation. Email: silver73@inbox.ru*
[4]*Doctor of Technical Sciences, Head of Department of Reproduction and Processing of Forest Resources, Bratsk State University, 665709, ul. Makarenko 40, Bratsk, Irkutsk Region, Russian Federation. Email: ivanovva55@mail.ru*
[5]*Doctor of Technical Sciences, Professor of Department of Technology and Harvesting Machines, Ukhta State Technical University, 169300, Pervomaiskaya 13, Ukhta, Republic of Komi, Russian Federation. Email: oburmistrova@ugtu.net*
[6]*Doctor of Technical Sciences, Professor of Department of Industrial Transport, Construction and Geodesy, Federal State Budget Educational Institution of Higher Education "Voronezh State University of Forestry and Technologies named after G. F. Morozov", 394087, Timiryazev street, house 8, Voronezh, Russian Federation. Email: mayu1964@mail.ru*
[7]*Doctor of Technical Sciences, Professor of Department of Reproduction and Processing of Forest Resources, Bratsk State University, 665709, ul. Makarenko 40, Bratsk, Irkutsk Region, Russian Federation. Email: zhuk30@yandex.ru*
[8]*Doctor of Engineering, Professor of Department of Technologies and Equipment of Timber Industry, Ural State Forest Engineering University, 620100, Sibirskiy trakt, 37, Yekaterinburg, Russian Federation. Email: gerz.e@mail.ru*
[9]*Doctor of Technical Sciences, Professor of Department of Designing of Lifting-Transport and Process Equipment, Northern (Arctic) Federal University named after MV Lomonosov, 164500, Karl Marx street, ,63, sq. 41, Severodvinsk, Arkhangelsk region, Russian Federation. Email: kremleva67@mail.ru*
[10]*Doctor of Technical Sciences, Professor of Department of Ocean Technology and Power Machines, Northern (Arctic) Federal University named after MV Lomonosov, 164500, Karl Marx street, ,63, sq. 41, Severodvinsk, Arkhangelsk region, Russian Federation.*
**Corresponding author E-mail: ockar@mail.ru*

Abstract

The investment scenario applied to forestry development analyzes the fundamental changes in the production structure, among other things. These changes refer to the priority development of the pulp and paper industry through the chain of large-scale woodworking facilities, where pulp, paper and cardboard manufacturing plants are the key links. Such facilities include sawmilling facilities, wood-processing factories, and timber factories. Those provide a significant economic benefit, so improving them is one of the top priorities. Considering this priority is the purpose of this article. The goal was achieved using common and scientific research methods, including mathematical modeling.
Theoretical research resulted in three sets of formulas adapted for evaluating the pulpwood barking from theoretical findings on image recognition.

Keywords: *process automation, woodworking facility, energy intensity reduction, chip manufacturing, chipper performance*

1. Introduction

In the Russian Federation, priority lines of forestry development until 2020 are as follows: maximizing deep mechanical, chemical and energy wood processing capacities; accelerating investment, beginning with investments in the construction of new pulp and paper enterprises; updating the existing production facilities on large-scale; incorporating energy-saving technologies; and boosting labor productivity.
The investment scenario applied to forestry development analyzes the fundamental changes in the production structure, among other things. These changes refer to the priority development of the pulp and paper industry through the chain of large-scale woodworking facilities, where pulp, paper and cardboard manufacturing plants are the key links. Such facilities include sawmilling facilities, wood-processing factories, and timber factories.
The large-scale woodworking facilities producing wood products from deep wood processing are vertically integrated forest enterprises that provide thousands of employees with jobs, various budgets with nice revenues, and the locality with social leverage.
A stepwise increase in the efficiency of such enterprises will contribute to the achievement of goals and objectives outlined in the *Forestry Development Strategy of the Russian Federation until 2020*, as well as to national economic development.

Timber factories and pulp-and-paper mills (PPMs) use wood waste, more specifically technological chips from wood processing platforms of woodworking facilities. The quality of those chips are obviously dependent on quality of manufactured wood products and on the manufacture performance.

The standard wood chip production line is a chain of technologically connected steps. Bark removing drums are fed with raw logs, which are placed through the opening with a gate closing it. Barked logs are placed in a chipping machine and the chips are screened with a wood chip screen. The disadvantage of this process is that poorly barked logs are returned for re-barking manually by the operator after visual evaluation of barking result quality, which is typically done in accordance with the GOST. When the logs are returned for the second run, barking time is regulated by changing the size of exhausting system opening.

The process of making decision on logs with defects takes some time, but at the end, a significant amount of material is returned for re-barking.

Because the turnover of wood at woodworking facilities is significant and the physical and mechanical properties of raw wood are changing at high rate, manufacture performance is poor, resulting in excessive losses of wood and high energy costs [1; 2]. Current wood chip production steps are not optimal because of significant amount of waste left behind and high energy consumption, which need improvement [3].

From this prospective, improving the efficiency through automation applied to major process steps is a timely and relevant problem in Russian forestry.

The purpose of this research is to reduce energy intensity and wood waste in the wood chip production at woodworking facilities.

Research object are paths to major automated operations at the woodworking facility.

Research subject is the pulp chip production.

Research objectives:

- building a mathematical model for automatic evaluation of barking performed by barking drums to assess the extent of pulpwood bolt loosening;
- exploring the process of automatic evaluation of barking to pulpwood bolts by experiment;
- introducing a technology to improve the efficiency of chip production, through accurate automated evaluation of operations, productivity improvement, energy saving and reduction of wasted material.

Originality of this research us that a mathematical model built for automatic evaluation of barking performed by barking drums with a view to assess the extent of pulpwood bolt loosening opens new options for image recognition methods to use in logging.

2. Method

The theoretical research basis includes the leading domestic and foreign papers dealing with the issues of performance improvement at the wood yards.

In order to improve chip production, scientists working in the field of *Innovations in Lumbering Industry and Forestry* have introduced several solutions for automating the evaluation of barking performed in by a barking drum [4-8]. Their idea is to add a chip screen to an exhausting system by mounting it in the outfeed opening area and to synchronize it with the pull-of-device responsible for removing poorly barked logs from the line. This solution implies an automatic measuring of log area covered with bark.

3. Data, Analysis, and Results

The chip screen typically operates on the following algorithm: 1) object (bolt) identification on the picture; 2) image binarization to isolate as much unremoved parts as possible [9].

At the first stage, the image was processed to highlight only the background and the rooting bolt. The problem here was brought down to the search for two curvilinear cuts bridging the left and right edges of the image. Let us assume that a cutting line has only one pixel belonging to it in the column of pixels, while the boundary area between two columns along the cutting line cannot house more than K of pixels in vertical direction [10].

Let us designate the digitized image as $J(x,y)$ (x for horizontal direction, y for vertical direction). The width of the image (in pixels) will be written as W, and the height as H. After broking the picture into two images, their widths will remain W, but their heights will be H_1 and H_2. Let us introduce the functions $C_1(x)$ and $C_2(x)$ separating the object (bolt) and the background at the top and at the bottom, respectively. Thus, pixel data will be divided into subsets: U_1 (pixels "above" the $C_1(x)$ cut), D (pixels corresponding to the object at the D_1 and D_2 pixel's intervals) and U_2 (pixels below the $C_2(x)$ cut). From the latter conditions, it follows that:

$$\begin{cases} p(x_p, y_p) \in U_1 \\ y_p < C_1(x_p) \end{cases}, \tag{1}$$

$$\begin{cases} p(x_p, y_p) \in D \\ y_p \geq C_1(x_p) \\ y_p \leq C_2(x_p) \end{cases}, \tag{2}$$

$$\begin{cases} p(x_p, y_p) \in U_2 \\ y_p > C_2(x_p) \end{cases}, \tag{3}$$

Where: $p(x_p, y_p)$ – some point in the image vector with coordinates x_p and y_p.

Data set above are illustrated with a diagram shown in Figure 1.

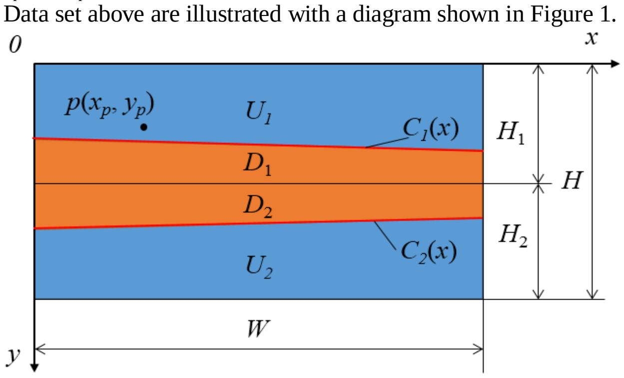


Fig. 1: Drawing Up Cutting Lines to Separate the Object and the Background Noise

Let us introduce an additional notation $\omega(M)$, the number of pixels corresponding to a subset, where M stands for any other subset (U_1, D_1, D_2 or U_2). Other additional notations will be for the sum of subset gray values, $S(M)$, and for the sum of squared gray values, $S(M)^2$. The symbol $\sigma^2(M)$ will denote the variance within the subset.

By definition, the variance equals:

$$\sigma^2(M) = \frac{\omega(M) \cdot S(M)^2 - (S(M))^2}{(\omega(M))^2} \tag{4}$$

The cutting lines were drawn up using the Otsu's criterion. With notations introduced, the criterion can be written as:

$$\sigma^2(U_1)\cdot\omega(U_1)+\sigma^2(D_1)\cdot\omega(D_1)\rightarrow\min, \quad (5)$$

$$\sigma^2(U_2)\cdot\omega(U_2)+\sigma^2(D_2)\cdot\omega(D_2)\rightarrow\min \quad (6)$$

The sum of square gray values of pixels will not change with the cuts, no matter the position of the cutting lines:

$$S(U_1)^2+S(D_1)^2=\text{const} \quad (7)$$

$$S(U_2)^2+S(D_2)^2=\text{const} \quad (8)$$

Hence, cut can be found as two maximums:

$$\frac{(S(U_1))^2}{\omega(U_1)}+\frac{(S(D_1))^2}{\omega(D_1)}\rightarrow\max \quad (9)$$

$$\frac{(S(U_2))^2}{\omega(U_2)}+\frac{(S(D_2))^2}{\omega(D_2)}\rightarrow\max \quad (10)$$

Maximums of functions (9) and (10) can be found by dynamic programming.

When drawing up the upper cutting line $C_1(x)$, pixels to the left of the pixel $p(x,y)$ located above the cutting line were denoted by U_{1xy}, while pixels to the left of the pixel $p(x,y)$, but located below the cutting line were denoted by D_{1xy}.

When drawing up the lower cutting line $C_2(x)$, pixels to the left of the pixel $p(x,y)$ located below the cutting line were denoted by U_{2xy}, while pixels to the left of the pixel $p(x,y)$, but located above the cutting line were denoted by D_{2xy}.

To store the number of pixels corresponding to a particular interval (U_{1xy}, D_{1xy}, U_{2xy}, D_{2xy}), the following variables were introduced: $\omega_{1U}[y][x]$, $\omega_{1D}[y][x]$, $\omega_{2U}[y][x]$ and $\omega_{2D}[y][x]$, respectively.

To store the gray levels of pixels from U_{1xy}, D_{1xy}, U_{2xy}, D_{2xy} variables $S_{1U}[y][x]$, $S_{1D}[y][x]$, $S_{2U}[y][x]$ and $S_{2D}[y][x]$ were introduced .

By substituting various variables intended for pixel data storage, which the number of pixels are stored, one can find formulas of the computed Otsu's criterion:

$$result_1=\frac{S_{U1}^2}{new\omega_{U1}}+\frac{S_{D1}^2}{new\omega_{D1}} \quad (11)$$

$$result_2=\frac{S_{U2}^2}{new\omega_{U2}}+\frac{S_{D2}^2}{new\omega_{D2}} \quad (12)$$

The maximum value for the Otsu's criterion is at some y_{prev}, which value was determined by enumeration.

As soon as the bolt is separated from the background, we can proceed to the second stage: highlighting the stripped and undressed areas. The bottom line here is that undressed areas can often be of low contrast with the stripped areas [11]. Thus, photo processing and analysis is about fine segmentation (dividing the image into parts with different homogeneity criterion for each) [12]. Let us consider three methods of image binarization until fine segmentation.

Method 1 is the thresholding method. Its idea is to compare gray values of pixels with the initial threshold value.

So can be done by dividing the image into two parts using the threshold. At the follow-up, segmentation is performed by step-wise scanning of each pixel: each pixel is attributed either to the object, or the background, by color depending on whether the threshold was overstepped or not [13].

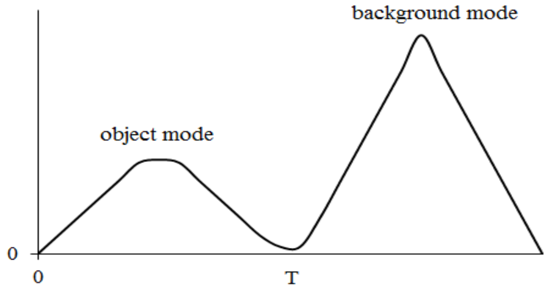


Fig. 2: A Threshold Value on a Bimodal Histogram

This simple method enables correct segmentation if the histogram has bimodal distribution: two types of pixels are relatively common to be allocated, and those are bright and dark ones [14]. In this case, humps are separated by a single threshold *T*, located in the valley between them (Figure 2).

Method 2 is the Otsu's method. The threshold value, in this case, is calculated to minimize the mean error of segmentation. The gray values are considered as random quantities, so the histogram of their distribution displays the density of random variables. With probability distribution densities known, the optimum threshold value can be determined for distinguishing the object (undressed area) and a background (stripped area) in the image.

The following assumptions and notations are introduced: 1) gray level of the image is divided into L values; 2) h_i is the number of pixels with a gray level i, i = 0, 1, ..., L-1; 3) H is the total number of pixels in the image; 4) image histogram is normalized and can be considered as a probability distribution:

$$p_i=\frac{h_i}{H},\ i=0,1,\ldots,L-1,\ \sum_{i=0}^{L-1}p_i=1 \quad (13)$$

5) pixel data are divided into two classes C_0 and C_1 by threshold t, where C_0 class contains pixels with gray levels at range (0, 1, ..., t), and C_1 class contains pixels with gray levels at range (t, t+1, ..., L – 1). The probability of belonging to each of two classes and the average gray-level value can be found by the following known formulas:

$$P_0=\sum_{i=0}^{t}p_i=P_t \quad (14)$$

$$P_1=\sum_{i=t+1}^{L-1}p_i=1-P_t \quad (15)$$

$$\mu_0=\sum\frac{ip_i}{P_0}=\frac{\mu_t}{P_t} \quad (16)$$

$$\mu_1=\sum_{i=t+1}^{L-1}\frac{ip_i}{P_1}=\frac{\mu_T-\mu_t}{1-P_t} \quad (17)$$

Where: $\mu_T=\sum_{i=0}^{L-1}\frac{ip_i}{P_1}$ – the overall average gray level.

For any t, the following relationship is correct:

$$P_0\mu_0 + P_1\mu_1 = \mu_T \quad (18)$$

Variance of each class is calculated by formulas:

$$\sigma_0^2 = \sum_{i=0}^{t} \frac{(i-\mu_0)^2 p_i}{P_0} \quad (19)$$

$$\sigma_1^2 = \sum_{i=t+1}^{L-1} \frac{(i-\mu_1)^2 p_i}{P_1} \quad (20)$$

The optimum threshold can be calculated by optimizing one of the following functions depending on the threshold value *t*:

$$\lambda = \frac{\sigma_B^2}{\sigma_W^2} \quad (21)$$

$$k = \frac{\sigma_T^2}{\sigma_W^2} \quad (22)$$

$$\eta = \frac{\sigma_B^2}{\sigma_T^2} \quad (23)$$

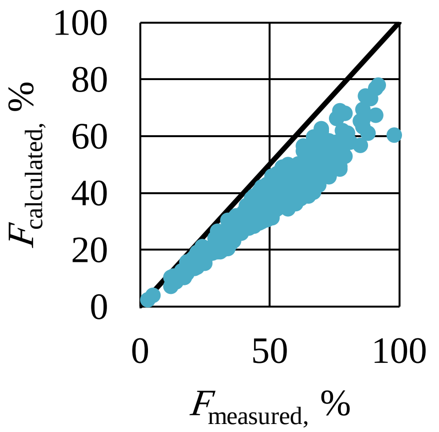
Where: $\sigma_B^2 = P_0(\mu_0-\mu_T)^2 + P_1(\mu_0-\mu_T)^2$ – inter-class variance, $\sigma_W^2 = P_0\sigma_0^2 + P_1\sigma_1^2$ – intra-class variance, $\sigma_T^2 = \sum_{i=0}^{L-1} \frac{(h_i-\mu_T)p_i}{P}$ – overall variance.

The overall variance does not depend on the threshold value *t*, but is calculated by:

$$\sigma_T^2 = \sigma_W^2 + \sigma_B^2 \quad (24)$$

The simplest measure that depends on the threshold value *t* is the inter-class variance. Thus, η value is a better measure of choice to find when it comes to calculating the optimum threshold:

$$t^* = \arg\left(\max_{0<t<L-1}(\eta(t))\right) = \arg\left(\max_{0<t<L-1}(\sigma_B^2(t))\right) \quad (25)$$



The Otsu's method implies a threshold *t* as a variable value, so let it be in the range from 0.5 to 1.5*t** by (25).

Method 3 is the Bernsen method, which works with the image by breaking into multiple parts of a given size. Further, each pixel in the edged area has a threshold, which value equals the mean of the minimum j_{low} and maximum j_{high} grey values in the local window:

$$t(m,n) = \frac{j_{high} + j_{low}}{2} \quad (26)$$

If the local contrast meets the relationship below:

$$G(m,n) = j_{high} - j_{low} \le \varepsilon \quad (27)$$

Where: ε is the set empirical threshold, then the neighbourhood consists only of pixels set either to the object or to the background.

One of the objectives set to be achieved during the experiment was the validation of developed algorithms of automatic evaluation of pulpwood barking process. Samples of pulpwood selected for the experiments were a May 2015 collection from the Kotlas Pulp and Paper Mill (KPPM).

Experiment

Pictures of samples were taken with a digital camera. After minimizing the background noise, images were processed using the three algorithms described above:

1. Thresholding;
2. Otsu's method;
3. Bernsen method.

Results of the image processing were compared with experimental measurements of well-barked and undressed areas. The measurement procedure was as follows: bolts were wrapped in transparent polyethylene and the undressed areas were highlighted with a pen. Then, the film was unfolded, and local dimensions were measured to find the area of interest.

Experimental data were processed using methods of statistical processing.

Digital data on undressed areas compared with measurements showed that:

- portions of undressed surface, allocated by thresholding, are lower than in measurement (Figure 3);
- portions of undressed surface, allocated using the Bernsen method, are generally higher than in measurement (Figure 4);
- Otsu's method gives portions that are both higher and lower than in measurement depending on the threshold value. And that, if the separation threshold is close to that calculated by (15), portions are close to measurements (Figures 5, 6; Table 1).

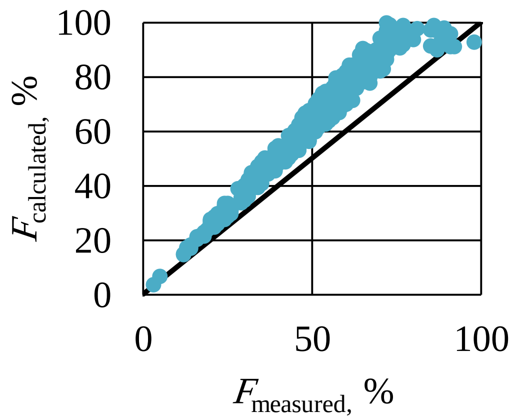


Fig.4: Locally Thresholded Undressed Portions by Contrast to Meas-

Fig. 3: Thresholded Undressed Portions by Contrast to Measurement urement

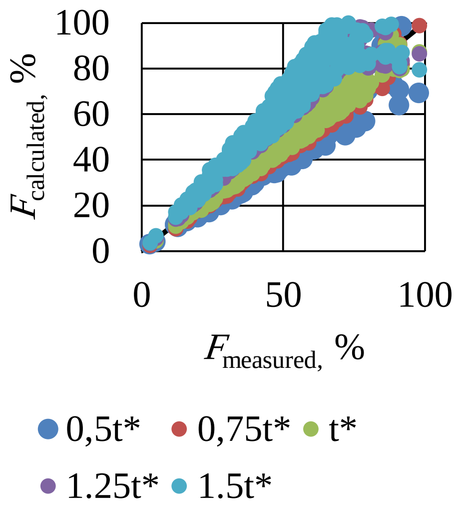


Fig. 5: Undressed Portions Thresholded using Otsu's method by Contrast to Measurement

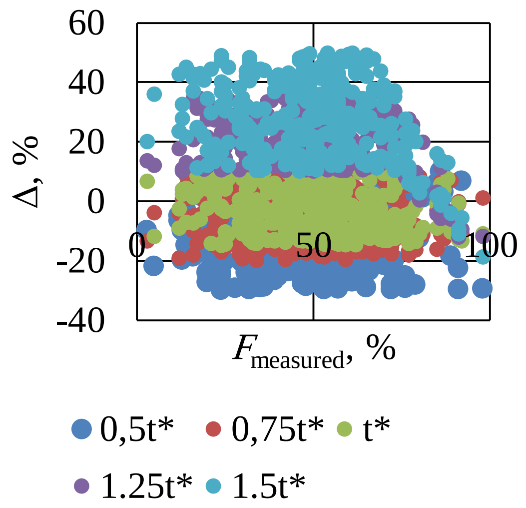


Fig. 6: Departure of Undressed Portions Thresholded using Otsu's method from Measurement

Table 1. A Summary of Digital Data Processing Results

	Thresholding	Otsu's method					Bernsen method
		0.5*t**	0.75*t**	*t**	1.25*t**	1.5*t**	
$\overline{\Delta}$	-25,5	-10.2	-4.7	-3.2	20.9	27.3	26.7
S^2	69.969	143.735	68.633	53.177	82.069	173.797	68.319
S	8.365	11.989	8.284	7.292	9.059	13.183	8.266
ε	16.5	23.6	16.3	14.4	17.8	25.9	16.3
v	0.328	1.179	1.764	2.265	0.434	0.482	0.310
[n]	167	215	282	295	292	36	149

From data in Table 1, it follows:

1. With thresholding, portions of undressed surface differ between the images and the measurements by -25.2% on average (CL: ± 16.5%);

2. With a threshold equal to the optimum by (15), the Otsu's method gives a difference in portions of undressed surface between the images and the measurements of -3.2% on average (CL: ± 14.4%);

3. The Bernsen method gives a difference in portions of undressed surface between the images and the measurements of 26.7% on average (CL: ± 16.3%);

4. The number of observations performed (n = 300) is enough to conclude a 95% confidence interval.

Applying Automation to the Process of Evaluating Chipper Performance in Wood Chip Production

In production, wood chip quality estimation is a problem. The job implies sampling of specification fractions after sorting, sorting through the sample using a laboratory analyzer, weighing and determining the percentage-based ratios between fractions. This takes time and labor. Firstly, long estimation time does not provide a rapid estimate on quality. Secondly, it does not allow monitoring the quality of chips on a constant basis. At this point, it will be hard to tell how much poor-quality wood chips have passed the stage, if another sampling shows a chip, which quality is not satisfactory.

From this perspective, chip quality estimation system should be automated. The main elements in the system are a laser and a detector. Together they compose a laser distance meter. The laser beam moves perpendicularly against the direction of conveyor belt at high speed, bounces off the surface and is caught be a detector. The set of distance readings from a single pass of the laser beam across the belt gives a local sectional view of the conveyor. As the belt moves, the laser scans the surface multiple times to give new views, which together give a complete picture of the state of the conveyor, namely – the presence of chips on it and their dimensions.

The stepper is a motor used to movement the laser beam. The PWM modulation technique will allow avoiding additional feedback to know the exactly position of a laser beam at each particular time. However, one cannot possibly know on what the conveyor belt drives and what the acceptable limits of speed deviation are. This is why the conveyor drive was equipped with an encoder so that the scanning laser module could work on an algorithm adapted from the information about the exact speed of the belt.

Feedback from the laser module and the encoder comes on the computer. Information about the states of the conveyor that comes from the laser module and distance readings from the encoder will allow drawing up the boundaries of each separate chip, calculating its area and setting it to either large, or small or specified size. From the statistics, one can conclude about the ratio between the fractions of wood chips of different sizes. Depending on the system position and set objectives, the operator is provided with information about the process operation, emergencies or situations when intervention in the operation of some mechanisms is needed.

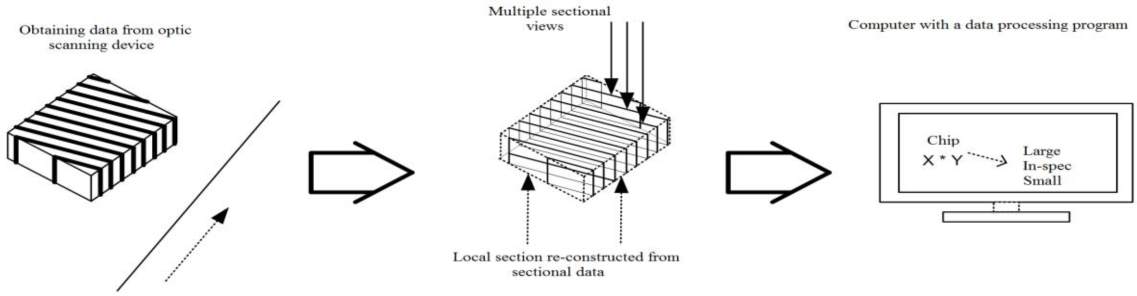


Fig. 7: Process Sequence of Given Feedback System

A phase method for distance measurement works on distances of up to 15 meters and gives accuracy to millimeter fraction, which suits the given purpose.

As an option, a scanning laser module to use can be a 2D laser triangulation sensor LS2D produced by Prizma, the R&D enterprise (Ekaterinburg). The sensor works for a conveyor width of 500 mm., and the Ethernet 10/100 interface allows synchronizing it with the computer without additional equipment involved. The sensor costs between 10 thousand and 20 thousand rubles. The conveyor belt movement can be traced using any incremental encoder in an assembly with a spring-loaded fastening arm and a rubber-coated measuring wheel. The number of pulses per revolution is 10.000 or more. Such a construction costs up to 20 thousand rubles. A Raspberry PI2 single-board computer is suitable for processing signals from the sensor and the scanner, featuring a 4-core ARM based processor running at 1GHz, 1GB RAM, an Ethernet 10/100 port for scanner, a BH-40 connector with I/O ports for encoder, and the Linux operating system. It costs 3500 rubles.

Advantages of the proposed system:

- high scanning speed;
- high accuracy;
- result not dependent on chip's position, shape and dimensions;
- no conveyor reconstruction needs (just equipment refining recommended).

This system will eliminate the stage of chip sample analysis. Considering the increased productivity of the apparatus and affordability of its components, the system will pay off in a few months. Scanning of wood chips prior and subsequent to sorting will give operating data on the state of chipper knives and chip screens, and on the amount of chopped wood and waste.

For this solution, an APM app was created to automate the evaluation of chip production [15].

4. Discussion

Device for Determining the Homogeneity of Physical and Mechanical Properties of Bark Biomass

Physical and mechanical properties of bark biomass depend on a many factors, including temperature, age, species and tree location [16; 17]. Bolts for barking are prepared by defrosting, if logs are frozen, or by soaking, if they are dry [18]. In mass production, however, preparation cannot give 100% of well-prepared bolts for chip production, in particular, for loosening in a barking drum. Thus, recommendation is to follow the operation principles of the following device [19].

The working element of a device is a platform with a perpendicularly mounted shaft in the center. Under the platform, spring-loaded needles are attached in the slot sections, where female contact are housed. The spring pressure is set depending on the required characteristics of bark biomass. Normally open contacts are connected under heels in a single circuit.

A wire, cased in the hollow shaft, connects the working element with a meter. When needles penetrate the bark biomass, some encounter less resistance on their path, and so do not press on the platform and do not activate the contact. With force applied to the handle, needles encountering great resistance will overstep the spring pressure and press on the female contacts, causing them to close.

The device can have several modifications. Figures 8 and 9 imply the use of a conventional pointer indicator (voltmeter/ammeter) for measuring the analog signal.

On the circuit diagrams, resistance R acts as a current limiter and is calculated from these considerations. However, its value is tied to the linear dependence of readings on the number of closed contacts so that relationship may be disturbed.

In the first case, if the internal resistance is neglected, the voltage measured by the voltmeter will be equal to:

$$U = \frac{E}{R + nr} \cdot nr \,, \qquad (28)$$

Where: n – number of open contacts.

Simplifying the graduated dial and maximizing the linearity of relationship between readings and the number of open contacts can by done on condition $R >> Nr$, where N is the total number of contacts. However, the device must be quite sensitive to meet this condition.

In the second case, current measured by the ammeter is calculated by:

$$I = \frac{E}{R + nr} \,. \qquad (29)$$

This case is an inverse nonlinear dependence of readings on the number of open contacts.

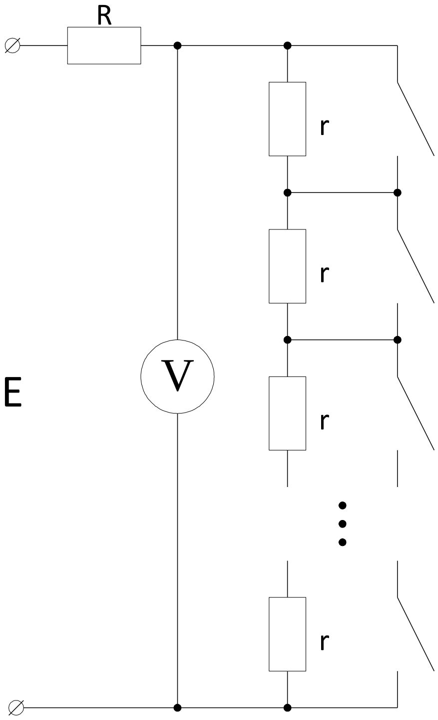


Fig. 8: Voltmeter Circuit Diagram

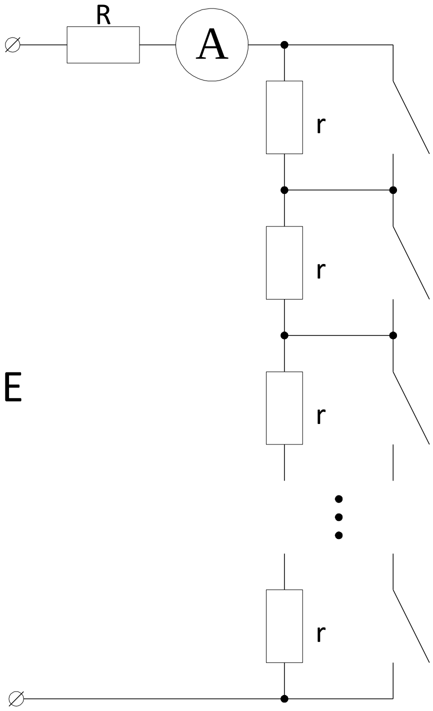


Fig.9: Ammeter Circuit Diagram

A digital device, which functional diagram in shown in Figure 10, seems quite effective and economically feasible.

This device is a universal register that can operate in several modes, including parallel loading mode and sequential reading modes. Data loading operation starts by pressing the SA button. The strobe signal passing through the signal-conditioning unit, placed there to avoid chatter, validates the inputs in a gate admitted from the contacts so that a device could record them.

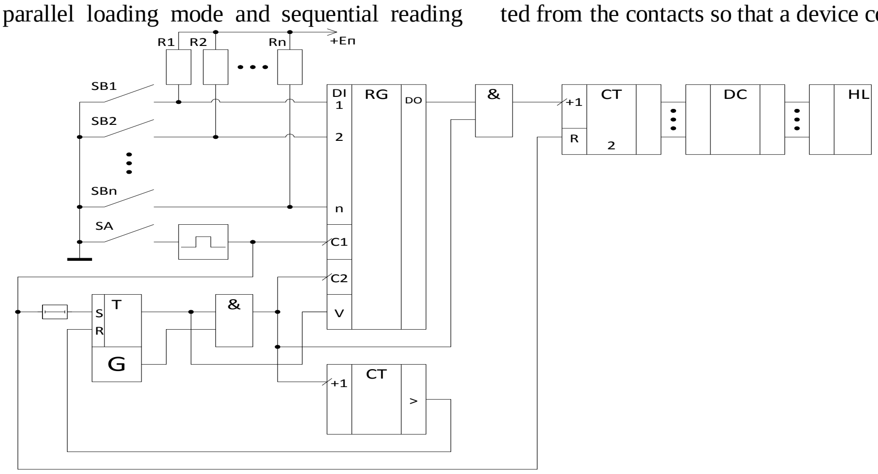


Fig. 10: Functional Diagram of Digital Device Intended for Counting Open/Closed Contacts

As a result, digital system becomes more resistant to interferences. The signal from the flip-flop switches the register to a sequential reading mode and opens the path front the generator *G* output to the logic gate *&*. The strobe signal from the generator validates the outputs of the register. Validated data come out of the RG register and are counted in units by the counter CT2. What was admitted from the register is sent to the counter by routing its pass through the logic gate *&*, opened by strobes of the generator. Decoded in a DC decoder CT2 counter readings are displayed on the 7-segment LED display HL. Good CT2 counter uses cascaded binary coded decimal counters. The CT1 counter minimizes the number of pulses from the generator by the register capacity. In the case of overflow, this counter switches the flip-flop, blocking the output of the generator. The register changes to parallel recording mode. Depending on the application and measured value, the circuit can have inverted gates, so the system will count 0, not 1.

Thus, introduced technical solution for determining the homogeneity of physical and mechanical properties of bark biomass allows improving the efficiency of bolt preparation for barking in barking drums.

5. Conclusion

1) Modern wood yards and woodworking facilities cannot perform with significant benefit without a sufficient level of process automation.

2) Current process technologies and equipment intended for wood chip production do not meet modern requirements for efficiency (energy and material saving), as described in numerous works of scientists.

3) The latest introduced configurations of chip production line are expected to improve process efficiency by making quality estimation and production activity control stage continuous, as these measures will reduce waste and energy costs.

4) Considered technology implies the use of optical means of monitoring and recognizing images (bark on the log, chip size, foreign bodies in the chip), but the problem of reasonability of methods used in the research for image recognition remains open.

5) Modified approaches and algorithms for image recognition based on equations (11)-(12), (14)-(20), (23), (25)-(27) allow the mechanism to distinguish well-barked sections of the log from those below specification. This allows determining the total area of stripped and undressed surfaces and automatically deciding on the percentage of barking completed for a separate log and the batch of striped logs.

6) With thresholding, portions of undressed surface differ between the images and the measurements by -25.2% on average (CL: ± 16.5%).

7) The Otsu's method is an optimal method for estimating the percentage of undressed surface, since it gives a mean deviation of -3.2% (CL: ± 14.4%). The Bernsen method by contrast gives a difference in portions of undressed surface between the images and the measurements of 26.7% on average (CL: ± 16.3%).

8) Automation solution together with the created and registered APM app allow automating the evaluation of chip production.

9) Introduced technology allows determining the homogeneity of physical and mechanical properties of bark biomass that goes for chip production at the woodworking facilities.

References

[1] Zhang, F., Johnson, D. M., & Wang, J. (2015). Life-cycle energy and GHG emissions of forest biomass harvest and transport for biofuel production in Michigan. *Energies*, *8*(4), 3258-3271.

[2] Lowenstein, M. Z. (2014). Biomass for energy in the forest products industry. In *Energy Applications of Biomass*. 46-54.

[3] Niquidet, K., & Friesen, D. (2014). Bioenergy potential from wood residuals in Alberta: a positive mathematical programming approach. *Canadian journal of forest research*, *44*(12), 1586-1594.

[4] Grigoriev, I. V., Lokshtanov, B. M., Kunitskaja, O. A., Kunitskaja, D. E. (2015). The way of automation of the degree turn the knifes cutter-type chippers. Handbook. *An Engineering journal with appendix, 6(219),* 56-60.

[5] Grigoriev, I. V., Lokshtanov, B. M., Gulko, A. E., Kunitskaya, O. A., Orlov, V. V. (2011). Technological Chip Production Line. Utility Patent No. 108001.

[6] Grigoriev, I. V., Kunitskaya, O. A., Kunitskaya, D. E., Lanskikh, Yu. V., Chuvashev, E. S., Perevozchikov, A. A. (2015). A Device for On-Line Automated Evaluation of Barking Quality and Controlling the Return of Poorly Barked Logs for Re-Barking. Utility Patent No. 151533.

[7] Xiao-xu, L. I., & Li, L. I. (2010). Developing Trend and Application of Woodworking Tungsten Carbide Cutting Tools [J]. *Forestry Machinery & Woodworking Equipment*, *8*, 003.

[8] Grzegorzewska, E., & Stasiak-Betlejewska, R. (2016). Development of the woodworking industry production potential in poland–the economical dimension. *The Path Forward For Wood Products*, 43.

[9] Pałubicki, B., & Rogoziński, T. (2016). Efficiency of chips removal during CNC machining of particleboard. *Wood Research*, *61*(5), 811-818.

[10] Grigoriev, I. V., Kunitskaya, D. E. (2016). Binarizing the image of a barked bolt. *In the Proceedings of Scientific and Technical Conference: Forests of Russia: Politics, Production, Science, and Education*. Saint Petersburg State Forest Technical University, 109-112.

[11] Kunitskay, O. A., Grigoriev, I. V., Lokshtanov, B. M., Kunitskay, D. E., Lukin, A. E. (2016). Automation of evaluation of the quality of debarking wood in the debarking drums. Handbook. *An Engineering journal with appendix, 7(232),* 56-64.

[12] Ratajski, J., Gulbiński, W., Staśkiewicz, J., Walkowicz, J., Myśliński, P., Czyżniewski, A., ... & Warcholiński, B. (2009). Hard coatings for woodworking tools–a review. *Manufacturing Engineering*, *37*(2), 668-674.

[13] Grigoriev, I. V., Kunitskaya, D. E. (2015). Model of barked bolt recognition in a digital image. *Research Trends in the XXI Century: Theory and Practice. 3(5-4)*, 283-287.

[14] Kunitskaya, D. E., Grigoriev, I. V., Khitrov, Ye. G. (2015). Algorithm for bolt recognition in a digital image. *Trends in the XXI Century: Theory and Practice. 3(9-2)*, 197-201.

[15] Kunitskaya, O. A., Kunitskaya, D. E., Lanskikh, Yu. V., Lapikhin, A. V., Grigoriev, I. V., Nikiforov, A. A. (2016). Computer program for analyzing fractional composition of technological chips. *Registration Certificate No. 2016616382 of 09/06/2016*.

[16] Kunitskaya, O. A., Kolesnikov, G. N., Kunitskaya, D. E., Lukin, A. E. (2015). Drum barking of long-cut timber: the effect of tapering in log assortments. *Engineering journal of Don, 3,* 80-96.

[17] Gazizov, A. M., Bukhtoyarov, L. D., Grigoriev, I. V. (2016). Matlab calculation of a functional block diagram for a rotary debarker. *Bulletin of the Bashkir State Agrarian University, 3 (39),* 82-88.

[18] Nan, S. C., & Fu, W. S. (2004). Brief discussion on the application of CNC technology in woodworking machinery [J]. *Wood Processing Machinery*, *1*, 008.

[19] Grigoriev, I. V., Lanskih, Yu. V., Rudov, M. E., Perevozchikov, A. A., Kuunitskaya, D. E., Lanskikh, A. M., Nikiforova, A. I., Lanskih, V. G., Grigoryeva, O. I. (2015). Instrument for determining the reinforcing ability of root systems in forest harvesting areas. *Utility Patent No. 152844.*