



Conference Paper

Implementation of Information Technologies in Forest Industry

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Abstract

The article is devoted to the development and implementation of manufacturing execution system (MES) for forest enterprises in context of automatic generation of the primary data about logistics processes of roundwood. The system enables on-line workflow monitoring at the low landing as well as round wood acceptance and shipment on line monitoring. The automation of this process is achieved through the use of specific software for mobile roundwood measurement based on photogrammetry. It implicates the usage of automatic processing and analysis for the images of logs' abuts. The main advantage of MES is its complete integration with the given software.

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1. Informational support of business processes for a forest enterprise

The manufacturing execution system (MES) "Plateau" for forest enterprises is dedicated for dispersed data processing for the purpose of forest enterprise operations management, i.e. automatic processing of such operations as:

- Accounting of incoming timber products from the declared cutting areas as a result of the logging team output and wood skidding.
- Accounting of the timber processing operations at the roundwood yard connected with transportation and crosscutting.
- Accounting of the timber shipment in terms of vendor contract and destination.
- Low landing stockpile analysis
- Generating of the shipping document.
- Generating reports on productivity of logging chews, handling chews and truckers.

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The aim of the system is the increasing of the confidence level and operational efficiency of the production process data. The automation objects for the developed system are workplaces of side rods, responsible for preparation of data about timber income, transport and shipping, and personnel who prepare cumulative information about enterprise activity. The flow chart of automation objects is given in Fig. 1.

The typical processes at the roundwood yard are referred to shipment, discharge, measurement and production of the timber. The roundwood intake is implemented after logging operations, i.e. transportation of the timber assortments or logs from a logging block to the roundwood yard.

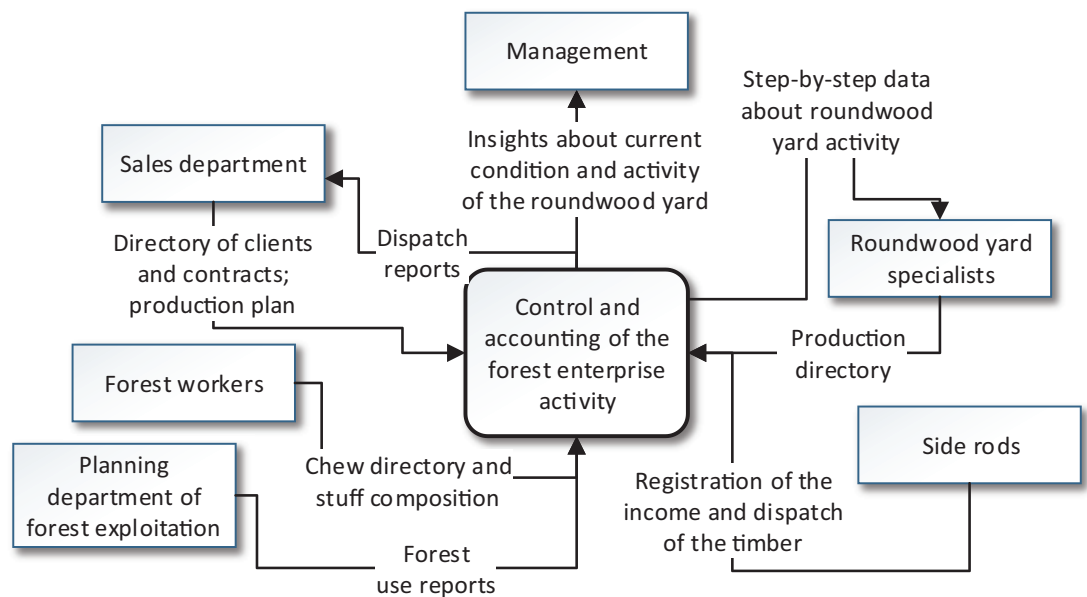


Figure 1: Model of the automation objects.

The application for round timber cubic capacity measurement "FoRest" is designed and suitable for calculating a volume and geometry of the logs stacked in a pile. The operation principle is based on the image processing algorithms. "FoRest" application allows operator to generate in automatic mode the information about the following operations accounted in the MES "Plateau":

- Assortments income
- Assortments discharge
- Logs income
- Logs discharge
- Jumbled timber income

These operations are stored in form of specifications. The specifications are uploaded to the system's server in the.json text format. The transmitted package also includes inner image which is used for the measurement and further visual validation of the volume and quantity of the processed roundwood. The example of the package is listed below.

```
{
  "datetime": "2017-04-19T07:55:45",
  "device_id": "54b1ea3ca62185bc",
  "dictionaries": {
    "contract_sale": "e17ec2f1-833f-443b-8116-aaa91e97118c",
    "depot_master": "841c3aa8-5fdd-460c-9fa6-a958a41049fo",
    "driver": "c93a8e70-dd42-4958-8794-2439fc34fae2",
    "forest_declaration_area": "6e193c4c-9f60-48b1-a8fb-od9a23f9b072",
    "load_operator": "aa313f4c-4327-4a44-9do2-e8fcd69a75fd",
    "outcome_type_enum": "Log truck",
    "railway_carriage_text": "",
    "railway_route_text": "",
    "team_sortiment": "2f288591-9fb9-4a57-a109-61ca85ded806",
    "team_wood": "",
    "unload_operator": "0475a24e-99fc-4dd7-8442-bc1df3b5edo5",
    "wood_outcome_deriction_enum": "",
    "wood_sortiment": "50c53bb9-3144-4a91-9590-ee14c0966071",
    "wood_type": "",
    "wood_type_enum": "",
    "woodcutter": ""
  },
  "images": ["image array"],
  "operation_type": 0,
  "reporter_name": "Last name, First name",
  "specific_id": "1492588545754",
  "specific_name": "Specification",
  "sum_logs": 0,
  "sum_volume": 0.0,
}
```

```
"timbers": []  
}
```

The data exchange between "FoRest" software and the main system is realized through assigned in the system's settings catalogue titled "FoRest downloads" – that is network resource for downloading files from the software. This folder must include folder "processed" for storing files which are processed and taken into account by the system.

2. Round timber automatic measurement

"FoRest" is designed to conduct operations with maximum possible automatic performance, however, it provides tools for manual editing of the processing result. The software is designed for mobile devices under Android OS ver. 4.3 or above. 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. 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.

2.1. Automatic analysis

Automatic analysis and editing module is the main authority of the software. Automatic detection is performed independently; result of the operation is displayed to the user immediately after algorithm execution.

There are a few methods for the round timber volume measurement [1-4]. The methods for the abuts detection described in these papers can be divided into two

categories. First category includes methods based on the machine learning. In [3] 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) [5] in combination with Haar features and local binary patterns (LBP) at the stage of the log abut detection. Gutzeit and Voskamp in [2] 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 used the assumptions of the form and size of logs [1, 4]. In general, these methods are based on the Hough transform [6, 7] or its modifications and used to detect log abuts in the image in the form of circles or ellipses. The base method for the automatic abuts detection in the "FoRest" software is the fast radial symmetry transformation [8]. This method show high efficiency for the images with a priory known radii, low level of the form distortions and upon condition that the searching radii spread in a small range. However, some modifications of this method are to be implemented in order to fulfill the requirements of the given task.

The algorithm splits the set of search radii into non-overlapping ranges to provide invariance to the image scale and target objects form distortions. Each range covers the specific scale interval and has its own size of the filter. The size of the filter is selected with considering the size of the target object and its permissible form distortions. It is evident that the greater radius of the object the more significant contribution into the local maximum of the orientation projection will be made by its boundary points. On the other hand, intensity variation near the local maximum in the accumulator increases with greater radius of the target object or its form distortions ratio relatively to the circle. Thus the projection of the greater radius should be scanned with aperture of the larger size. Thereby it was decided to calculate the specific size of the scanned aperture as function of search radius according to the formula

$$A_r = \begin{cases} [\log_{10} S_{q_r}] & \text{for odds} \\ [\log_{10} S_{q_r}] + 1 & \text{otherwise} \end{cases} \quad (1)$$

where $[\]$ – integral part of a number, S_{q_r} - area of the circle of radius r .

The idea of the optimal threshold selection is that it can be evaluated from the result of the algorithm implementation to the image of the same size and brightness arrangement as the initial one but containing no radial symmetry objects. The random permutation of the rows and columns of the initial image was implemented, thereby

the information about spatial location of the circular objects is hidden although intensity and direction of each pixel are stored.

The value of the optimal threshold depends on initial image entropy, thereat the threshold for the segmentation of the initial image orientation projection can be selected as following:

$$T_r = \max(\tilde{O}_r) + A_r^2 \quad (2)$$

where $\max(\tilde{O}_r)$ - global maximum of the «noise» projection image scanning with the aperture A_r

A_r can be interpreted as correction scale coefficient. The descriptor of the region of interest of specific radius r with the scale invariance is calculated as following

$$D_r(x, y) = O_r(x, y) - T_r \quad (3)$$

where $O_r(x, y)$ - local maximum with coordinates (x, y) in the projection image of radius r scanning with aperture A_r , T_r - optimal threshold for the radius r .

Inasmuch as cross-correlation of the near-by search radii has negative impact on the result the filter function which considers the mutual overlapping of the circles according to their weights should be implemented. Also the log cuttings can have prominent medulla. In order to eliminate this effect another filtering function which analyzes coaxial circles (which assumed to be boundaries of log cutting and medulla) and gives priority to the one with greater radius is necessary. In the view of above the filtering algorithm is the following.

The meanshift clustering [9] is implemented to the output transform of the modified detection algorithm. The point is that for set of descriptors $\{d_i\}$ the density function is defined as

$$f(d) = \frac{1}{nh^2} \sum_{i=1}^n K \left(\frac{d - d_i}{h} \right) \quad (4)$$

where h - aperture, it is equal to the minimum radius of the abut R_{min} , $K(d)$ - kernel. In this case the Epanechnikov kernel [10], which has the radial symmetry, is implemented.

The idea is to shift the points in the direction of the local density increasing. In order to estimate this shift the gradient $\nabla f(d)$ is applied to the density function:

$$\nabla f(d) = \frac{2}{nh^4} \sum_{i=1}^n g \left(\left\| \frac{d - d_i}{h} \right\|^2 \right) \cdot m(d) \quad (5)$$

where $g(\|d\|^2) = -K'(\|d\|^2)$, $m(d)$ - meanshift vector.

Vector $m(d)$ is always directed toward the maximum increasing of the density. Descriptors $\{d_i\}$ clustering procedure is the following:

1. Calculating the meanshift vector for each descriptor d_i ,
2. Shift by $d_i \rightarrow d_i + m(d_i)$,
3. New iteration until the stable equilibrium of mass center is reached ($m(d_i) \rightarrow 0$),
4. Descriptors with the same mass center compose cluster.

The average weighted radius is calculated for each cluster:

$$r_{aw} = \sum_{i=1}^n r_i \omega_i \cdot \left(\sum \omega_i \right)^{-1} \tag{6}$$

where n – cluster cardinality, ω_i – weight function:

$$\omega_i = l_{r_i} \cdot n_{r_i} \tag{7}$$

where l_{r_i} – radius, n_{r_i} – number of radius of given length in the cluster.

Result of the automatic detection is shown in Fig. 3.

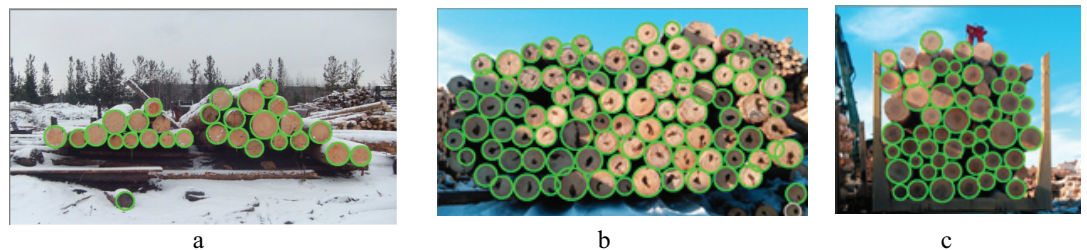


Figure 2: Result of the automatic detection.

Detected abuts are highlighted with color marker. The volume measurement is performed according to the requirements document (GOST 32594-2013 and GOST 2708-75). The particular measurement method is selected in the global settings.

2.2. 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. Deleting of the objects is implemented by selecting “-” tool and clicking objects in the image, whereas the tool “+” should be selected to add new object. Addition of the objects is implemented on the basis of the Lee algorithm [6]. 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. 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.

3. Conclusion

It is manufacturing execution system "Plateau" that stores the overall information on the manufacturing processes at the low landing, obtained from various sources including the mentioned software. It allows the key indicators of the forest enterprise performance to be analyzed for any period, planning the further management strategy. MES system enables 24/7 access from anywhere through its implementation over the web. Self-service concept allows the management and the staff to get all information required without any prior training and special skills.

The software "FoRest" operating principle involves the automatic detection of the logs' cross-cut ends of the image, calculating the diameters of each cut using calibration coefficients and, finally, cubic capacity of the measured pile based on the obtained data and prior information about the average length of the log pile. The result of the measurement is formed as a report and copied into the data store of the analysis system with following tags: type of operation, raw product (tree trunk/wood assortment), timber species, connected staff (crew, driver, tallyman). Approbation of the software was performed in the logging enterprise under the manufacturing conditions. According to the testing results the average error for the log pile photogrammetry measurement is of 5.14% with maximum error of 9.2% in comparison with manual measurement. Industry standards establish the maximum volume measurement error for the round timber at the level of $\pm 12\%$. Thus, a method of the log piles photogrammetry measurement using the developed algorithm can be successfully applied in the activity of forest enterprises. "FoRest" is successfully used at the forest enterprises of the Ural Federal District at the moment

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