Automated Monitoring and Control System for Forestry Enterprises

Artem Kruglov
Ural Federal University
62000, Yekterinburg,Mira st., 19.
avkuglov@yandex.ru

Abstract

The article gives a description of a package solution for monitoring and control of forestry enterprise activity. The solution consists of manufacturing execution system (MES) and mobile application for roundwood volume control in situ. The system enables on-line workflow monitoring at the low landing as well as roundwood acceptance and shipment on line monitoring. This solution provides full automation of gathering data about raw material logistic at each processing stage till delivery.

1. Informational support of business processes for a forest enterprise

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.

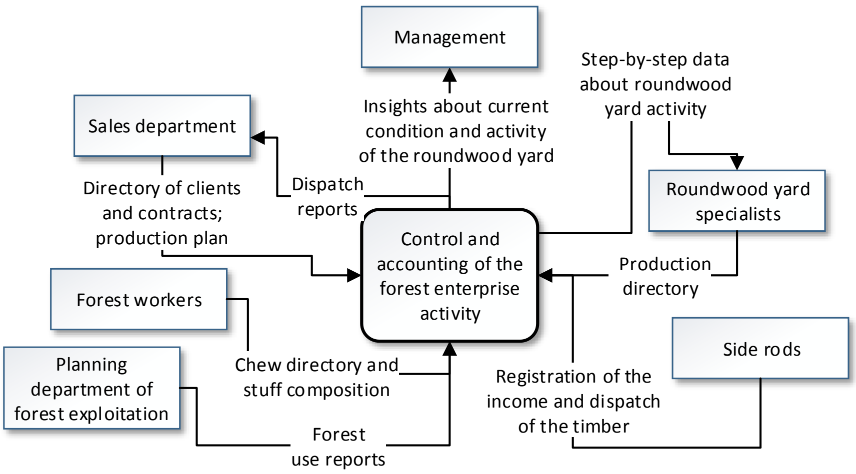

Fig. 1 –Model of the automation objects

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-a958a41049f0",
    "driver": "c93a8e70-dd42-4958-8794-2439fc34fae2",
    "forest_declaration_area": "6e193c4c-9f60-48b1-a8fb-0d9a23f9b072",
    "load_operator": "aa313f4c-4327-4a44-9d02-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-bc1df3b5ed05",
    "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 key feature of the software. Automatic detection is performed independently; result of the operation is displayed to the user immediately after algorithm execution.

One of the most common deterministic methods is the Hough transform (HT) method. On the basis of this method, the algorithm of probabilistic pair voting (PPV) for fast and reliable detection of circular objects is proposed [1]. The algorithm guarantees reliable recognition for overlaps, noise and moderate deformations of the shape. In work [2] an algorithm for recognizing incomplete ellipses based on iterative randomized Hough transform (IRHT) is considered. This method is resistant to strong noise, but it has a high cost of computation and works with objects of a strictly elliptical shape. The authors of the paper [3] developed an algorithm for the localized Hough transform to analyze the Cherenkov radiation, which significantly reduce the time costs for performing Hough transform. In [4], Hough transform is used to estimate the parameters after determining the assumed ellipses by the arc selection strategy.

Other methods for recognizing ellipses include the static RANSAC method described in [5]. In [6], the authors proposed a new scheme for recognizing ellipses using curve segments. A similar algorithm was proposed in [7], where the detection of ellipses is implemented by combining the edge contours according to curvature and convexity.

The method proposed in [8] is a randomized iterative workflow that uses the geometric properties of the isophot curve in the image to select the most significant edge pixels and classify them into subsets with an equal curvature. In [9], the BFOA algorithm was considered using the example of circle recognition, and its modification was proposed for recognizing a set of figures in the image.

In [10] authors considered algorithms for tracing automobile wheels for the task of constructing an automatic classifier of vehicles. In this paper, a modified algorithm of Viola and Jones is proposed with the construction of a basic feature set over vector gradient map. The method provides good resistance to various lighting conditions and noise with no type II errors.

The best result during the tests were obtained by ELSD algorithm [11]. This algorithm effectively detects elliptical arcs and also excludes type II errors.

The ELSD algorithm is a three-step process:

1) at the first stage of the heuristic method - candidates for the desired figures;
2) then each candidate goes through a validation phase (validation of candidates);
3) Finally, to select the best geometric interpretation, a model selection stage is required.

The first step is based on the greedy (heuristic) approach, which was proposed in the algorithm for recognizing LSD segments [12]. The authors declare that a heuristic approach should be applied without applying critical parameters with the maximum resolved feature. The step of validating candidates is based on the probabilistic method of the opposite [13]. This operation provides effective protection against false positives. Similar to the second step, the principle of model selection is based on selection criteria. The principle of the algorithm is the following:

Algorithm 1: ELSD
Input data: grayscale image *x*.
Output parameters: None.
Output data: L_f – list of structures tested (segments, circular arcs, elliptical arcs).
grad <– compute_gradient(x);
foreach *pixel p_i in x* ***do***
    R <– region_grow(p_i, grad);
    C <– curve_grow(R, grad);
    line <– fit_rectangle(R);
    circle <– fit_circular_ring(C);
    ellipse <– fit elliptical_ring(C);
    (NFA_{line}, NFA_{circle}, $NFA_{ellipse}$) = NFA(line, circle, ellipse);
    NFA_{min} <– min(NFA_{line}, NFA_{circle}, $NFA_{ellipse}$);
    if *$NFA_{min} \leq 1$* ***then***
        add function, corresponding to NFA_{min}, in L_f *list*;

end

end

The flow chart of the algorithm is given in Fig. 2.

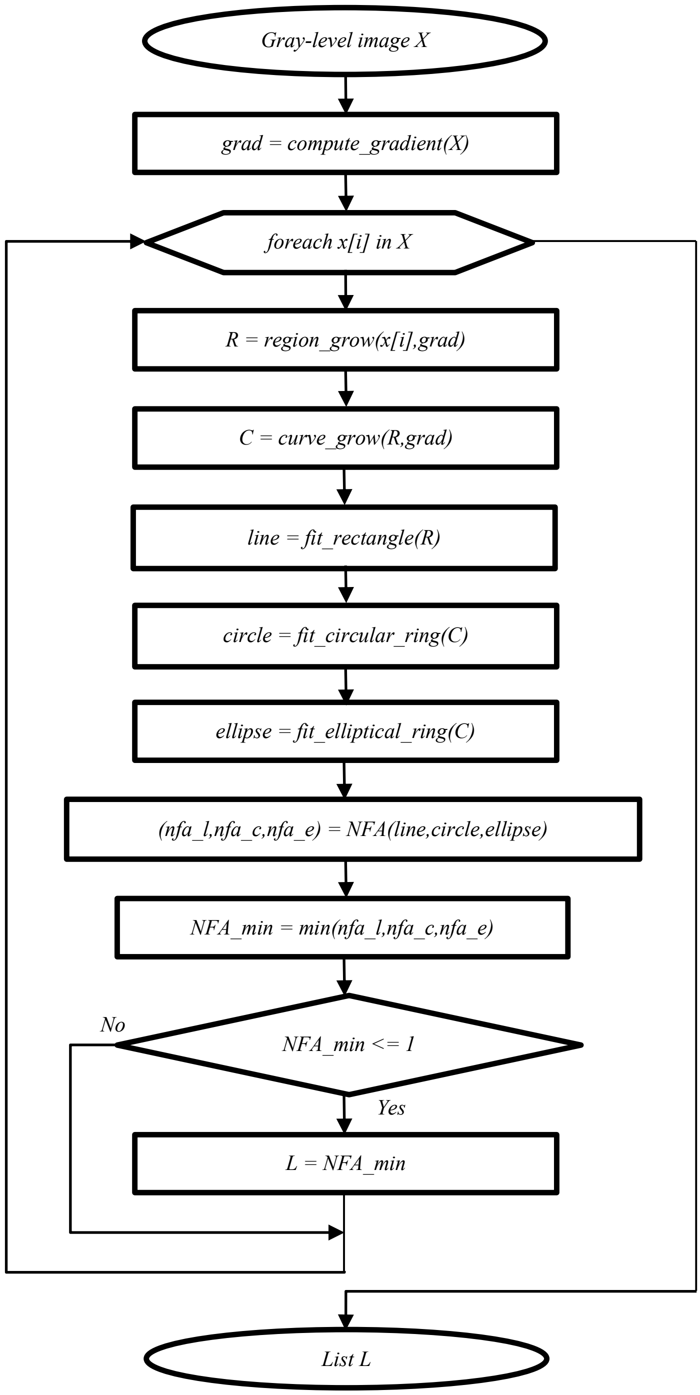

Fig 2. ELSD algorithm flow chart

To apply the ELSD algorithm in the log abut detection the following changes were needed:

- Discard detection of linear segments which is unnecessary for the given task.
- Discard elliptical and circular arcs with the minimum curvature of the line, since these contours describe linear fragments.
- Discard contours with anomalously minimal and maximum radii after analyzing the radiuses of the arcs. Generally the log abuts in the image have approximately equal radius, and any significant deviation from this range indicates obvious foreign objects in the image.
- Discard segments of curves with small lengths after analyzing the lengths of the arcs as far as these arcs generally belong to the background objects (grass, sawdust).

- Major arcs are completed to a full ellipse or circle.

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

a b c

Fig. 3 – 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 stuff 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 ±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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