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AUTOMATIC VISUAL CODE QUALITY EVALUATION FOR WOOD INDUSTRY

Põlder, A.; Abiline, I. & Tamre, M.

Abstract: *This paper gives a short overview of different factors which influence the readability of the code marked on saw material in the sawmill, describes saw material and visual code quality parameters which can be evaluated with a machine vision system and outputs this kind of reading system quality model.*
All the mentioned work is part of EU- 6th Framework Project Indisputable Key.
Keywords: Traceability, machine vision, quality evaluation, saw material, wood industry, measurement model.

1. INTRODUCTION

This paper describes a work which is a part of the EU- 6th Framework Project Indisputable Key. The main objective of the Indisputable Key (IK) project is to develop and integrate a methodology and advanced technologies that can improve the use of wood as a raw material and optimize the forest production through the chain of transformation, minimizing environmental impacts [1]. This is partly achieved by introducing recurrent traceability in the wood supply chain.
An important part of the project is to ensure traceability in sawmill. The problem is considerably wider to ensure products traceability in today's production in general. To achieve the traceability in sawmill from green sorting through kiln to final sorting the automatic marking reading system was developed. The 18 by 8 2D Data Matrix code is used as information carrier [2]. It is automatically marked on the board ends with developed marking system based on Markem 9064 Touch Dry inkjet printer [3] and identified in latter positions by developed machine vision system containing SICKIVP M1122 IVC-2D smart-camera [4]. All the data from marking and reading positions are collected into the database from where it is possible to query necessary traceability information. This information will be used for example analyzing the effectiveness of the saw mill sorting lines, fine-tuning processes on production efficiency and finding the origin of the boards.
Due to different board end visual parameters and problems in marking the readability and therefore traceability is relatively volatile. In many cases the source of the unsuccessful reading is not known and it is not discovered instantly, making it hard to optimally improve the readability.
To improve readability and ensure codes quality the board end and code quality parameters are introduced. By evaluating the quality parameters automatically it is possible locate the source of the problems (for elimination) and implement alarm system which helps to decrease the amount of codes which are not read.
This kind of quality evaluation system can be adapted and generalized on any similar visual marking and reading system. It can be adopted to estimate different types of codes or backgrounds.

2. MAIN FACTORS WHICH INFLUENCES CODE READABILITY

To automatically evaluate board end and code marking quality it is necessary to know the main sources of board and code quality problems [5].

First group of parameters which influences the code readability is saw material visual parameters.

The ideal board end should be relatively bright and even in the visual point of view. In some cases the board end is darkened, it is not a considerable problem if the contrast between code and background remains in an appropriate level and has even distribution. Another source for uneven board end brightness is the partial board end clean cut which results in very strong contrast between different parts of the code background.

Other group of problems is related to branches, wood gains and existing old codes on the board end. All of them affect the board end visual quality depending of the size and contrast by disturbing the code locating and measuring the code elements values.

Ice and dirt on the board end and saw material surface roughness will result in high contrast between different parts of the code background (not to mention scattered code when the ice is melted underneath it) which again obstructs the code finding and measuring its elements values.

Second group of problems are originating from saw material behavior during marking the code.

It is very important to position the saw material correctly before it reaches the marking system, otherwise the code can be marked too close to the board end edge (even partially in the air) or the code density can be decreased because of wrong printing distance. It is quite hard to ensure the correct positioning because of different vibrations and yawns in the saw line and different properties of the boards. For example in many cases the boards are curved and therefore in front of the printer the board end is in lower or higher position than it should be resulting in partially lost code or the board is bounced away from the print-head and printing density is decreased.

Saw material vibrations during the marking forms another source of quality problems. The board end vibration can be divided into vertical (propagates in vertical direction) and horizontal (propagates in horizontal direction) vibration. Board end vibration during the marking results in wavy code either in left or right or upper or nether edge of the code. Depending on the amplitude of the vibration it can make reading of the code impossible.

3. EVALUATING BOARD END AND VISUAL CODE QUALITY

To increase the readability of the marked codes and reduce the risk of inferior marking or marking low quality boards it is necessary to automatically evaluate the board end and marked code quality. This kind of evaluation system in collaboration with the reporting system will increase the readability and makes it easier to figure out why some of the codes were not read.

For quality evaluation it is necessary to find the parameters which can be measured with a machine vision system, estimate the acceptable variance of those parameters and use only the parameters which have strongest influence on readability (to save processor time).

It should be considered that this kind of code reading application is not a precise measurement system. In general it rather compares acquired image with specified values and ranges. That means that the code quality evaluation outcome is not a precise value but rather imprecise estimation. The quality evaluation tuning is complicated because of the code and its reading algorithm characteristics, sometimes the good code is not read (knots and burls underneath the code data area) and totally unacceptable code is read (code error correction). Evaluation of the code data area is complicated because it is not uniform (each code is different).

Different quality parameters are found to be useful by using captured images from sawmill. In this particular case 1656 images from sawmill are used as basis for the analysis. Different parameters are measured and after the optimal values of each parameter are found. In many cases the chart is used for rough estimation of the parameter. The results are sorted by read code so that the 1061 read codes are in the beginning of the chart x axis and rest of them comes in the end so it is possible to see the acceptable value.

3.1 Board end quality parameters

To make sure that the board end is correctly positioned within the camera field of view (FOV) it is necessary to measure the board end size, location and angle. These parameters are already measured by the reader algorithm [6] and this makes easy to use them latter. Board end size has to be slightly bigger then the presumable code size to ensure that part of the code is not printed in the outside the board end (Table 1).

Board end	Min	Max
Width	520	1024
Height	115	768
Mean intensity	120	160
Histogram standard deviation	0	2500
Histogram total difference	-30000	30000
Horizontal standard deviation	0	10
Horizontal angle	-2	2
Vertical standard deviation	0	15
Vertical angle	-5	5
Visual code		
Width	520	580
Height	115	125
Left & right edge standard deviation	0	10
Left & right height difference	-5	5
Cell fill mean	40	60
Cell fill standard deviation	40	50
Nr of black cells	40	60
Nr of gray cells	0	5

Table 1. Quality parameters range

Board end location and angle in the camera FOV does not affect the readability until the board end is not partially outside of it and therefore these parameters are not used for quality estimation. Same thing came out from the analysis of test results- there were no relation in between successful read and board end position and angle.

Board end mean intensity indicates the brightness of the board end. Its value is influenced by the code on the board end. This means that when the board end is relatively small the mean intensity will have the lower value then in a case of bigger board end. The acceptable value of this parameter lies in between 120 to 160 (Table 1).

In the mean intensity chart (Fig.1) it is possible to see that most of the read codes mean intensity lies between those values.

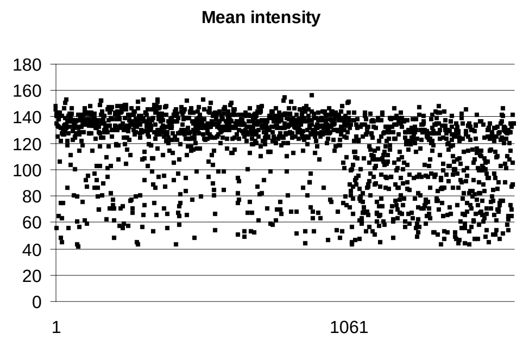

Fig.1. Mean intensity chart

This is rough estimation because there are boards which are in the not read part of the chart but have acceptable mean intensity.

Board end histogram describes the distribution of pixel intensities. From the tests it is seen that the acceptable board end with a good code has a specific histogram. Based on the several acceptable codes (in this case 8) the good code lookup histogram can be created (Fig.2).

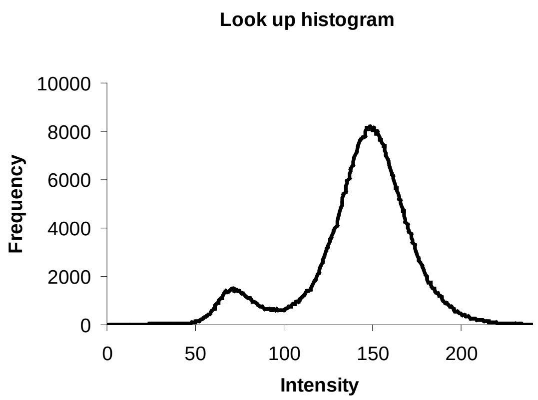

Fig.2. Look up histogram

To compare each histogram with a lookup table several statistical tests can be used, for example χ^2 test. In this work these tests are not covered, but in the future work something in this direction will be implemented.
From the histogram (Fig.2) it is possible to see two peaks. Smaller one belongs to code pixels and higher belongs to board end background. Histogram does not have strong correlation with readability (because code error correction and algorithm strenghtness). It is good for estimating overall board end brightness and its distribution.
For estimating histogram each pixel intensity value (0-255) difference standard deviation and total difference with the lookup table is calculated. If standard deviation is low then it means that the histograms are similar, if it is high then the difference is bigger. Total difference shows how different two histograms are. The acceptable value of the standard deviation is approximately from 0 to 2 500 and total difference is from -30 000 to 30 000 (Table 1).
The histogram shows only the distribution of pixel intensities, but it does not give any information about how the pixel intensities are distributed over the board end area. To describe this it is useful to describe the distribution over x and y axis.
For that the board end is divided into vertical or horizontal stripes of regions of interest (depending on which direction distribution is measured). The difference of each beside ROI is measured and standard deviation of the value is calculated also the mean angle is calculated. The acceptable value for horizontal standard deviation is from 0 to 10 and for vertical from 0 to 15 (Table 1). The acceptable value for horizontal angle is from -2 to 2 and for vertical is -5 to 5 (Table 1). If this value is low then the different pixels are distributed evenly on board end, if it is high then unevenly. This parameter, like histogram does not have strong correlation with readability. In large scale it enables to estimate the location of areas with irregular brightness.

3.2 Visual code quality parameters

Visual code quality problems indicate mainly problems with printing. Visual code quality evaluation is more complicated then board end evaluation. The code evaluation is based on the measurements which are obtained from the code reading process. When the code is found correctly then those values are valid, in a case when there are some problems in locating the code or its edges the evaluation is not reliable anymore.
First thing to evaluate on the found code is its size and location. Since the marked codes size is always in certain range (the distance between the camera and board end varies a little) code size can be evaluated by checking that it is in that range. In the test case the acceptable width is 550±30 and height is 120±5 pixels (Table 1). If the code is not located correctly then it directly affects code size, this means that it is not necessary to express that value.
When the board is vibrating during marking process it probably results in corrugated edges and misaligned elements of the code. To evaluate if the vertical (vibration propagates in vertical direction) vibration occurred the code left and right edge is found on 8 different rows (code height is 8 rows of cells and each row edge is found anyway). The mean value and standard deviation of this value is found. The mean value is used for calculating the width of the code and standard deviation shows the straightness of the edge. From the test is occurs that the acceptable value for standard deviation is from 0 to 10 (Table 1).
Code upper and nether edge straightness evaluation is much more simplified because the vibrations in this direction occur rarely (special ski on the saw line eliminates most of them). This means that only the difference between the height of the left and right side of the code is found;

its acceptable value is from -5 to 5 pixels (Table 1).

After the code exact locating each code cell can be located and percentage of each cell fill with pixels which are considered as dark code elements can be measured. Mean value and standard deviation of all cells fill percentage indicates if the code is normal. The mean value should be in between 40% to 60% and standard deviation from 40% to 50% (Table 1).

After measuring all the code elements, their distribution is rescaled on 3 levels which indicates black, white and unknown (gray) cell value. The cells which are converted to gray are close to the turning point from black to white. Form the test it occurs that usually the amount of black cells is in between 40 to 60 and number of gray cells is in between 0 to 5 (Table 1).

3.5 Board end and visual code quality grade

To get a better overview of the parameters described on the previous chapters and to describe all the quality parameters with one or few values it is useful to construct a model which describes influences of the quality parameters.

One possibility to describe the quality parameter $X_{b\&c}$ is to separate it into board and code quality parameters:

$$X_{b\&c} = w_b \cdot X_b + w_c \cdot X_c \qquad (1)$$

Where

w_b - board scale coefficient

X_b - total board quality parameter

w_c - code scale coefficient

X_c - total code quality parameter.

Scale coefficients let us to scale the influence of certain parameter and quality parameters indicate the % value of the parameters. Quality parameter $X_{b\&c}$ will be fitted into the reading system measurement model.

Both parameters X_b and X_c can be broke down similarly into fragments. In those cases the scale coefficients would describe parameters influence on readability and quality parameters would give the percentages from their ideal values. The 100% responds to certain acceptable range of the parameter and 0% responds to certain minimal value of the parameter.

In this paper this is not described deeply because of early stadium of the work. The introduced model is very first approximation, development and testing of the approach is continuing.

4. DESCRIPTION OF MEASUREMENT MODEL

The board end and visual code quality evaluation parameter $X_{b\&c}$ can be used in the general reading system measurement model. For that the general reading system measurement model has to be constructed.

All measurements are affected by some influencing factors, which have to be taken into account in the evaluation of results of measurement. In order to find out how different factors affect the result of code reading, which might be considered as a specific type of measurement, we need to know physical reason for the influence. We need to identify the physical quantity that causes the influence and establish the relationship between it and the measured *Y* (the output quantity).

We can finally establish the relationship between *Y* and *N* input quantities, that need to be considered in the given measurement task. This equation – the measurement model – can formally be expressed as:

$$Y = f(X_1, X_2 ..., X_i, ...X_N) \qquad (2)$$

Thus to obtain the estimate *y* of *Y*, we need estimates x_i of all the considered quantities X_i. In our measurement task the measurement model can be expressed:

$$y = x_1 + x_2 + x_3 + x_4 \qquad (3)$$

where

x_1 - estimate considering the measuring method

x_2 - uncertainty derived from the measuring device (camera)

x_3 - uncertainty derived from the measuring object

x_4 - uncertainty caused by the environment

Component x_2 includes the board end and visual code quality grade $X_{b\&c}$.

The described measurement model is general and in future it will be totally merged with the board end and visual code quality grade. Also all the other coefficient which affects reading system operation will be specified and implemented.

5. CONCLUSIONS

This paper consists of description of main factors that influences the board end and code quality, description of different code quality parameters which can be evaluated by the machine vision system and introduction to the code quality evaluation model. The results of the described work gives the knowledge of different board end and visual code quality parameters and their affect on the readability, the basis of the quality evaluation model and therefore the basis of full reading system measurement model.

Next steps of the work would be to improve the described quality evaluation model, complete the quality evaluation algorithm for the reading system and integrate all the quality parameters with measurement model.

5. ACKNOWLEDGMENTS

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8. DATA ABOUT THE AUTHORS

Põlder Ahti, Department of Mechatronics, Ehitajate Tee 5, Tallinn 19086, Estonia,
ahti.polder@ttu.ee
+372 620 3207