

Assessment of the effectiveness of computer vision using the OpenCV package in finding the centre of a drilled hole in wood-based materials

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Abstract: *Assessment of the effectiveness of computer vision using the OpenCV package in finding the centre of a drilled hole in wood-based materials.* Small diameter holes made in wood-based materials were scanned by non-professional scanning equipment and then analysed to determine the location of the hole. The quality of the hole centre estimation was evaluated by a survey of 21 people. It has been shown that the evaluation using the HoughCircles function has an error of less than 0.05 mm in 18 out of 28 cases.

Keywords: computer vision, wood-based panels, machining

INTRODUCTION

Computer techniques, computer processing power and the popularity of computer vision means made digital methods used in an increasing number of industries. Computer vision is a relatively young field and gives an interesting perspective. Many useful solutions have no theoretical justification, and many theories are proved useless.

Computer vision covers topic like: data acquisition, image creation, recognition of shapes and objects using geometric information and probabilistic techniques. (Forsyth, Ponce 2002)

The analysis of phenomena depends primarily on the quality of the obtained data. While using image acquisition for measuring shape and size, crucial is the detail of the gained images. The parameter characterizing the detail is the resolution given in units of dpi (dots per inch). The image consists of the so-called pixels – the smallest unit of colour representation. Consequently, image analysis is vulnerable to various types of disturbances that hinder their analysis, such as finite image resolution, noise, poor lighting or distortion of geometry due to the nature of the material – e.g., wood fibres.

An example of image analysis packages is free OpenCV. One of OpenCV's goals is to provide an easy-to-use computer vision infrastructure which helps quickly create relatively advanced video applications. The OpenCV library contains over 500 functions covering many areas of view, including factory product control, medical imaging, security, user interface, camera calibration, stereo vision, and robotics. Because computer vision and machine learning often go hand in hand, OpenCV also includes a full, universal machine learning library (MLL). The sub-library focuses on statistical pattern recognition and grouping. MLL is very useful for vision tasks at the core of the OpenCV mission, but it is generic enough to be used for any machine learning problem. (Bradski, Kaehler, 2008).

OpenCV libraries offer two features detecting characteristic shapes useful for drilling holes detection: SimpleBlobDetection and HoughCircles.

The first one is used to detect droplet shapes. The first step is the conversion of the image into binary images using thresholds (the number of images and threshold values are set by the parameters minThreshold, maxThreshold, and tresholdStep). Then, for each image thus obtained, the contour is searched and the centre of shape calculated. Close centres form one group corresponding to one object. The final spot centres and their rays are estimated based on the groups. Shapes can be filtered by colour, closeness to the circle, and surface. The default parameter values are chosen to extract dark round spots.

The Hough transform is a method of finding lines, circles, or other simple forms in an image. The original Hough transformation was a linear transformation, which is a relatively fast way to search binary lines for straight lines. The transformation can be further generalized to cases other than straight lines. Most often in Hough's transformation are used images converted with Canny's edge detection (Fig. 1).

Detection of lines by the Hough method consists of determining all lines passing through each non-zero point (every specified angle). If a given line will be detected a minimum number of times from different points - it is considered the edge in the image. Transformation to detect circles works similarly, but this time each non-zero point a circle of a certain diameter is "drawn". The place where the minimum number of circles meets is considered the centre of the searched object of a given diameter. (Bradski, Kaehler, 2008).

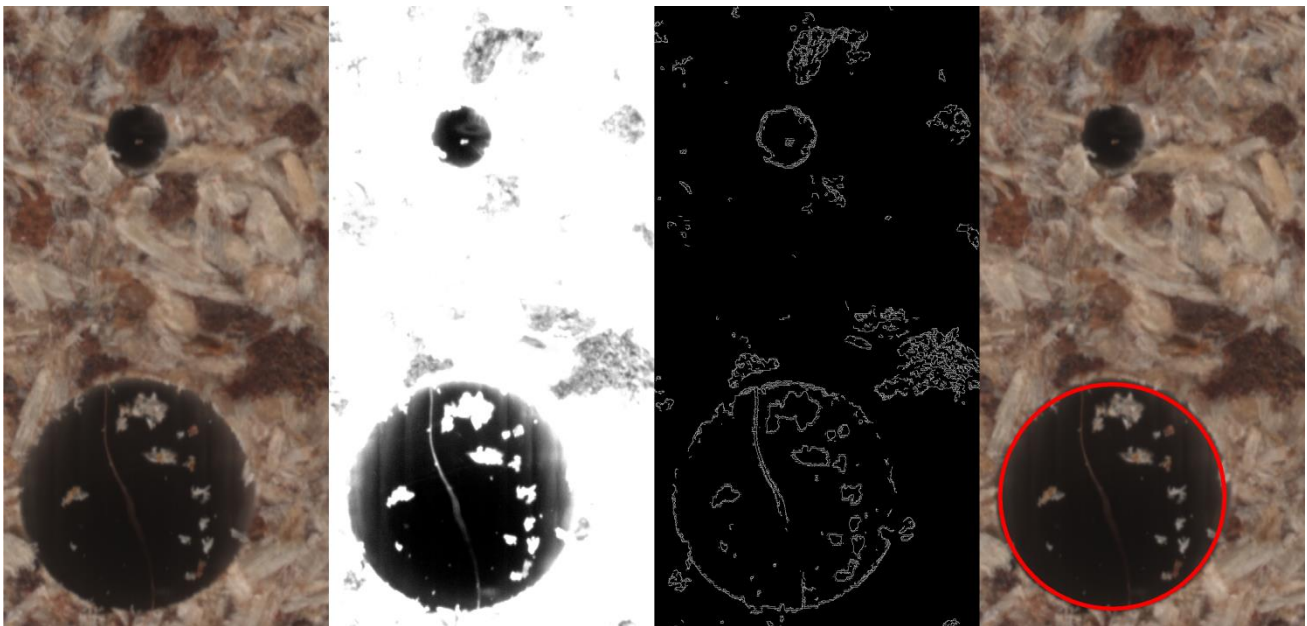


Figure 1. Stages of Hough preparation and analysis. From the left: the original image, after the contrast has been shifted and after using Canny edge detection and the detected hole.

Measurement of the small objects or features sometimes presents technical problems - it requires precise, ready-made tools or their manufacturing. Image analysis systems can replace these tools, provided that the test materials are properly prepared. In the case of two-dimensional objects, you can scan them, which allows to obtain their high-resolution images without incurring the significant costs of purchasing specialized equipment.

Currently, manufacturers use two types of analog-to-digital converters for image acquisition in scanners: CCD (Charged Coupled Device) and CIS (Contact Imaging Sensor). The principle of operation of both types is shown in Fig. 2.

CCD technology consists of illuminating the image and transferring. It uses mirrors and lenses and sends it to a sensor with a width significantly smaller than the size of the scanned element, which results in distortions caused by the lenses. Subject to CIS technology, the reflected light falls directly on the sensor segments under the image - here the consequence is the inconsistency of images on the border of the sensor segments (tavco.net).

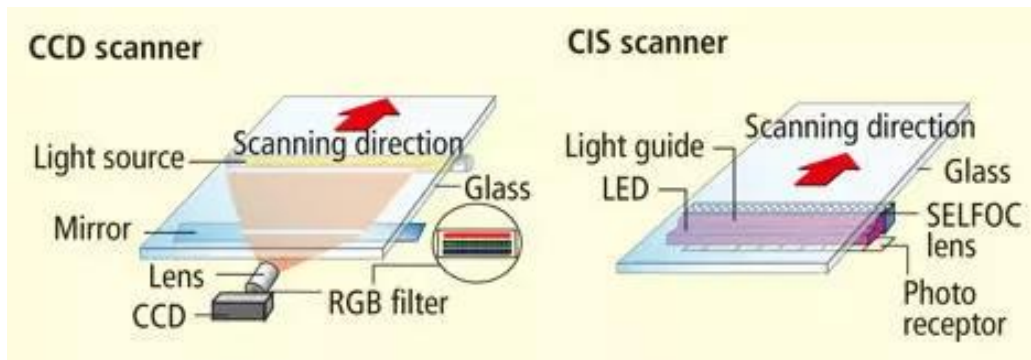


Figure 2. CCD and CIS explanation [tavco.net]

Materials of natural origin - such as wood or wood materials are characterized by a heterogeneous structure. In the case of chipboards, this is evident primarily in the form of various types and shapes of chips. This applies in particular to surface layers where the chip surface is relatively small. In the case of fibreboards (HDF, MDF), the consequence may be uncut fibres. The consequence of this inconvenience is the difficulty in correctly recognizing the edges of the hole (Fig. 3).

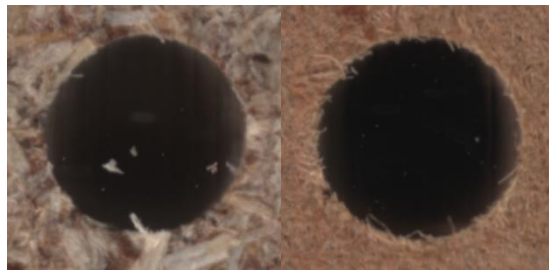


Figure 3. Apparent distortion of the hole geometry in particleboard and HDF.

The purpose of this study was to analyze the effectiveness of digital tools from the OpenCV package and non-professional scanning devices to determine the coordinates of 1/8" holes made in typical wood-based materials.

MATERIALS AND METHODS

The samples used for the tests were made on a CNC milling machine intended for precise machining. The machining program was written in a way that the last movement of the spindle before making the hole relative to the workpiece was made in accordance with the direction and turn of the X-axis. The holes were made to a depth of 4.064 mm (0.16") for HDF boards and 8.128 mm (0.32") for other materials at a speed of 50.8 mm/min (2"/min) with a drill bit with a diameter of 3.175 mm (1/8"). The holes were drilled 10.16 mm (0.4") apart.

The samples were scanned on 4 different scanners: HP PSC-1350, HP PSC-2410, Konica Minolta, C204, Canon LiDE, HP LaserJet Pro MFP M125nw (tab. 1). The quality of the received images was arbitrarily assessed and on this basis, a Canon LiDE 200 scanner was selected for further research. In order to avoid the consequences of using CIS sensors in these scanners, the samples were scanned in such a way that the scanned holes were not above the contact points of the CIS sensors.

All image processing and image analysis operations were performed using the Octave 4.4.1 program (a free Matlab alternative) and OpenCV 3.4.1 installed using mexopencv.

The samples were scanned at maximum colour resolution to a lossless format, and then pre-cut to size covering one hole - also in a lossless way. All images, regardless of the method used, have undergone operations to change the contrast with functions `imadjust(im)`, `imadjust(im, [0 0.3])` and `cv.cvtColor(im, 'RGB2GRAY')` (Fig. 1). The HoughCircles test was performed in a function loop

`cv.HoughCircles(im, ...)`, where the circle size included the range 295-305, `param1` – 180-240, `param2` – 4-9 (these parameters were selected based on the effects of the function `cv.Canny(im, ...)`). From the results, those that were most common was marked as HC1, and those that most often occurred in the second-order - HC2. The SimpleBlobDetector test was also carried out in a loop using the `cv.SimpleBlobDetector(im, ...)` function where the `TresholdStep` was from 16 to 255 (every 16), `MinTreshold` - 0-120 (every 8), `MaxTreshold` - 88-255 and `FilterByArea` - min: 10000, max: 1,000,000. From the selected values, the one closest to the HC1 value was selected and marked as SBD. Also HCA value was calculated as average, but not presented to respondents.

Table 1. Parameters of scanners used to scan samples

Model	HP PSC-1350	HP PSC-2410	Konica Minolta C204	Canon LiDE 200	HP LaserJet Pro MFP M125nw
Sensor type	CIS	CCD	CCD	CIS	CIS
Resolution	600 dpi	1200 dpi	600 dpi	4800 dpi	1200 dpi
Pixels/mm	23.6	47.2	23.6	189.0	47.2
Quality	1, 2	1b, 3	1, 3	2	1b, 2

1a - Very low resolution

1b - Low resolution

2 - Image incomplete due to the use of CIS sensors

3 - Image distortion resulting from the use of lenses

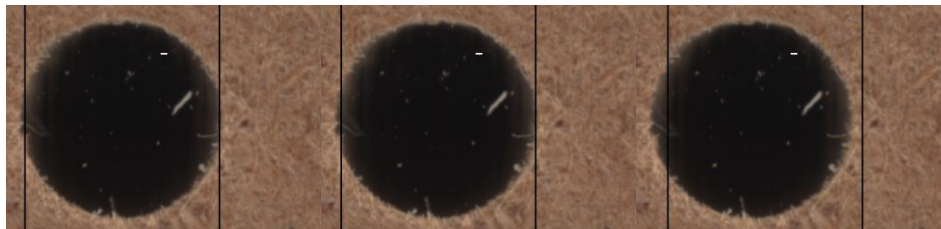


Figure 4. Sample images for the survey.

The survey was conducted online. The respondent's task was to choose the best estimate of the centre of the hole (in the horizontal axis) or select the "None" option if none of the holes was detected well (the margin of error exceeded to 0.05 mm). The estimates were marked with two vertical lines equidistant from the centre of the hole and arranged from the smallest to the largest (Fig. 4). 10 samples for each type of material were presented to the respondents in random order.

RESULTS AND DISCUSSION

21 people responded to the survey. If the assay difference between HC1 and HC2 was ± 3 px (0.016 mm), it was treated as one response. Two holes out of 30 were rejected due to similar results for all three variants. 18 of the 28 received at least 13 votes for the HC1 variant, 6 holes at least 12 votes for HC2, 4 holes at least 10 votes for the "None" option, the other two holes did not have a clear winner. None of the holes obtained the majority of votes in the SBD variant (maximum number of votes up to 1).

The holes had apparent edge distortion (Fig. 3) or chips obscuring the hole in the variants respondents considered incorrect. In the case of holes which HC2 markings the respondents considered the most correct difference between HC1 and HC2 was ± 7 px (0.038 mm) except for one, where the difference was 11 px (0.058 mm). The average difference between the HC1 value and the one chosen by the respondents was 1.125 px (0.007 mm), while the standard deviation 3.44 px (0.018 mm), which means that over 99% of cases are subject to an error of not more than 10.32 px (0.055) mm). The

average difference between the HCA value and the one chosen by the respondents was 0 px, while the standard deviation was reduced to 2.45 px (0.013 mm), which means that over 99% of cases are subject to an error of not more than 7.35 px (0.039 mm). As well results suggests there are no universal values for param1 and param2.

CONCLUSIONS

1. Non-professional high-resolution scanning equipment can be used to acquire small diameter hole samples in wood-based materials. Scanners based on CCDs may be subject to an error due to image distortion resulting from the use of lenses. Scanners based on CIS technology may be affected by an error resulting from a gap between sensor segments. To scan samples for distance measurements, it is recommended to use scanners with CIS sensors, however, the possibility of gaps in the scanned area should be taken into account.
2. The OpenCV and Octave free software package can be used to mark the location of holes made in wood materials.
3. Determining the centre of the hole using the SimpleBlobDetector function cannot be considered effective regardless of the selection of parameters. In contrast, the HoughCircles function is in most cases burdened with an error of less than 0.05 mm, in the least favourable about 0.1 mm (raw data). Choosing a single param1 value should be replaced by calculating the average of HoughCircles results for a certain range of param1 and param2
4. The HoughCircle function of the OpenCV package can be considered effective as a tool for determining the location of small diameter holes (3.125 mm).

REFERENCES

1. BRADSKI G., KAEHLER A. 2008: Learning OpenCV. O'Reilly Media, Sebastopol, USA
2. FORSYTH D. A., PONCE J. 2002: Computer Vision: A Modern Approach. Second Edition. Prentice Hall Professional, New Jersey, USA
3. tavco.net (access 9.04.2020): <https://www.tavco.net/wide-format-plotter-scanner-blog/bid/107329/compare-ccd-vs-cis-scanner-technologies>
4. WALKER C. F. 2006: Primary Wood Processing Principles and Practice. University of Canterbury, Christchurch, New Zealand 2nd edition

Streszczenie: *Ocena skuteczności widzenia komputerowego przy użyciu pakietu OpenCV w znajdowaniu środka wierconego otworu w materiałach drewnopochodnych.* Otwory o małej średnicy wykonane z materiałów drewnopochodnych zostały zeskanowane nieprofesjonalnym sprzętem skanującym, a następnie przeanalizowane w celu ustalenia jego lokalizacji. Jakość oszacowania środka otworu została oceniona w ankiecie przeprowadzonej wśród 21 osób. Wykazano, że ocena przy użyciu funkcji HoughCircles oszacowanie wykazuje błąd mniejszy niż 0,05 mm w 18 z 28 przypadków.

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