Estimating the Width of an Oblong Shape Using a Single Camera

Vladimir Sibinovic[1]

Abstract – **In this paper a hypothesis is tested that a single, cheap web camera can be used to estimate the width of an oblong shape, e.g. wire or thread. The designed system is calibrated and tested under controlled parameters. The goal is to achieve the error in estimation less than ±0.1 mm.**

Keywords – **Camera, Image processing, Estimation.**

I. INTRODUCTION

Manufacturing industries rely on real-time data input for continuous and unattended process optimization [1]. Because this is a crucial part of the production process, expensive and precise laser sensors are usually used for on-line and non-invasive width measurement. With the availability of cheap electronics nowadays, many simple processes are being automated with the focus being on price. With that in mind, we try to estimate the width using cheap CMOS camera and image processing.

For the purpose of this paper a testing rig has been created to provide a fixed distance between the camera and target plane. The rig was printed on a 3D printer and is shown on Figure 1. Camera is position at 30mm from the base which is used as the target area. This distance was chosen arbitrary as a lowest distance at which the camera produces clear images.

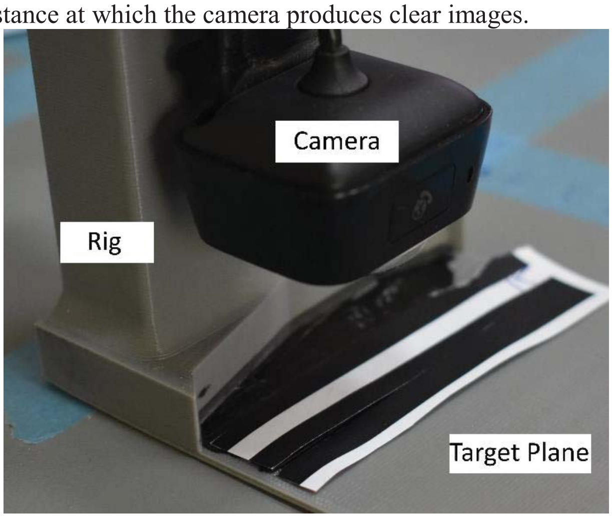

Figure 1. Testing rig for the system

[1] Vladimir Sibinovic is with the Faculty of Electronic Engineering at University of Nis, Aleksandra Medvedeva 14, Nis 18000, Serbia, E-mail: vladimir.sibinovic@elfak.ni.ac.rs

Camera is positioned so that the oblong shape target, e.g. white line on a black background is on the vertical centre of the image and spans across the whole image on the horizontal axis.

II. SETUP

The system is based around Microsoft LifeCam-5001 HD web camera, and its parameters are shown in Table 1.

TABLE I
CAMERA PARAMETERS

Resolution	1280 x 720
Field of View	66°
Communication	USB 2.0
Sensor	OV9712

The camera uses OmniVision CMOS sensor that has image area of 3888 µm x 2430 µm, with a pixel size of 3 x 3 µm.

The area that the camera can capture at the distance of 30 mm, from camera front, was experimentally determined to be 43 x 24 mm. From this and the vertical resolution of the camera we can calculate that 1 pixel represents 0.033 mm on the target plane.

By using simple geometry shown on Figure 2, and trigonometry we can calculate the exact distance of the sensor from the target plane.

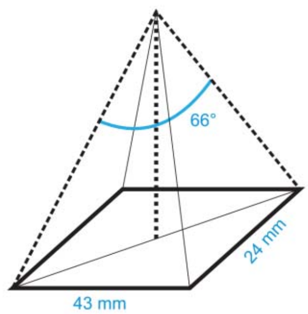

Figure 2. Field of view geometry

The determined distance is 37.9 mm. Which correlates to the camera geometry, as we defined the distance of 30 mm from the front of the camera and the camera sensor is about 8mm inside of the camera.

III. IMAGE PROCESSING

Image processing was done using OpenCV library implemented on a PC in C++ programming language. First a picture is loaded in grayscale. Since the effect of color is not the scope of this paper, we have chosen a white object on black background to provide maximum contrast. Next, a Gaussian blur was applied. This blurs the sharper edges, and has proven to increase the accuracy of the system.

After a detailed analysis of different thresholding options [2], the best results, for the given problem, were achieved using binary threshold with Otsu's method [3]. After the preparation of the image the user moves the region of interest and positions it over the area where the estimation is needed. User can define the length and width of the ROI window using the provided GUI. The key objective here is to select a ROI that has the target represented as white pixels. Figure 3 shows the GUI and Figure 4 shows a typical ROI.

Figure 3. Graphical User Interface of the system

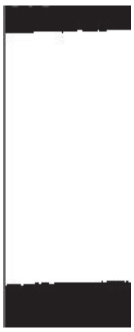

Figure 4. Typical extracted ROI from which the system computes the width of a shape

After selecting the ROI, the user starts the estimation process. On the ROI the system goes through all of the pixels in each column and calculates the number of white pixels in each column. When it reaches the end of ROI it calculates the mean value of the width of the white pixels in the ROI. These values are then used for calibration and later for estimation.

IV. CALIBRATION

To calibrate the system, we first take known widths, and calculate the relationship between the mm and pixels. For setting referent values we used Wurth Digital Venire Caliper that has an accuracy of 0.02 mm in the range from 0 to 100 mm. A range from 1mm to 4 mm was used as referent values. A sample step of 0.2 mm was used, with an exception of the region from 2.6mm to 3mm, where the sample step was 0.1 mm. This is a special region of interest for further work and that was why the sample step was lowered. Figure 5. shows the gathered data and the fitted line with R^2 of 0.9998 and can be represented as Eq. 1:

$$y = 35.084x + 0.9808 \tag{1}$$

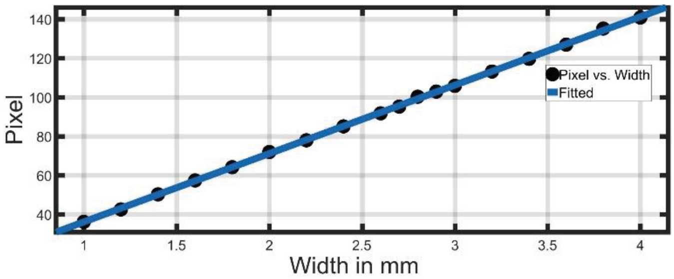

Figure 5. Calibration data and fitted line

By using Eq. (1) to calculate the width we can determine the error of fitting. The results are shown in Figure 6.

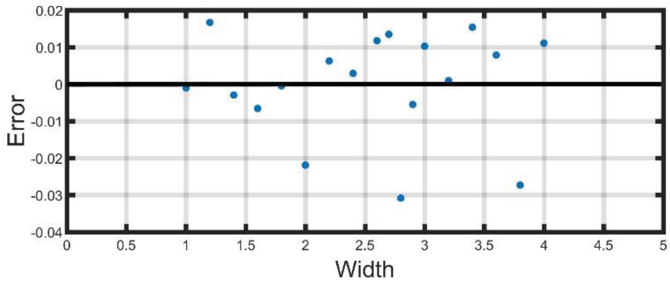

Figure 6. Error of fitting

The average absolute value of the error is 0.011 mm and the maximum positive error is 0.017 mm and the minimal negative error is -0.031 mm. This is satisfactory as a fitting error.

V. TESTING

Testing was done using two different test sets. The initial test was done using a range from 1 to 5 mm of width with a step of 1mm. And the second test sample was larger with a smaller step size of 0.3mm. The results from the first test gave and absolute average error of 0.037 mm, which encourage us to test on a larger sample. The error in estimation from the second test is shown in Figure 7.

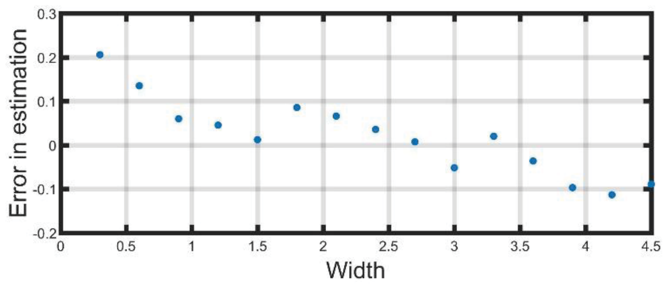

Figure 7. Error in estimation

The error of estimation is in the range from -0.113 mm to 0.206 mm. The error is larger at the beginning of the range and at its end. In the region from 1mm to 4 mm the error is within ±0.1 mm. For testing 10 different points ware used for each measurement, and the mean was used as a final estimation.

Using one arbitrary image the system was tested for continuity along the x-axis of the image. A sliding window of 20 pixels was positioned at 10 different positons along the x-axis and the estimation of width was done. The results are shown in Figure 8.

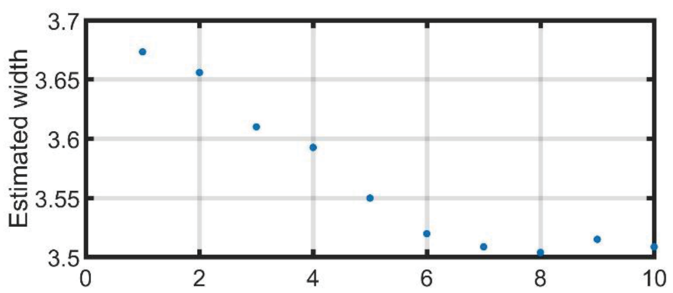

Figure 8. Estimation at different points along the x-axis.

From this we can conclude that the x position plays a role in the estimation error. The error is large when working with the left part of the image. This will be investigated further, but our opinion is that it may be from the calibration. During the calibration of the system the calliper used was positioned so that it is in the right part of the image. For the y-axis all of the pictures taken ware so that the centre part of the image is in line with the target. In this paper we assumed that the camera lens is centred and symmetrical, but the provided data suggest otherwise. This will be further investigated determining intrinsic camera parameters by means of camera calibration [4].

VI. Conclusion

In this paper a system for width estimation of an oblong shape has been designed and tested. The system has proven that it has potential to achieve the required estimation error of less than ±0.1mm.

The results from the initial tests show that the system has a small error of estimation, but upon further investigation the error has shown correlation with the position of measurement along the x-axis. This system can be used as a cheap non-invasive on-line width measurement system for processes where the tolerances are not the vital.

For further work other cameras will be tested against the same datasets, and intrinsic camera parameters will be investigated for their role in the process of estimation.

Another direction that we hope to investigate is the use of the proposed method as a basis for roundness estimation, as this is also a parameter that needs to be measured in the production of wire, pipes, filament, and etc.

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