Selected Method of Image Analysis Used in Quality Control of Manufactured Components

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Abstract **– The paper deals with the quality measurement process using the KEYENCE® industrial monochromatic camera and its calibration to determine the dimensions of the component under quality control process. The threshold value determines the shape of the component and the histogram method determines the number of pixels of the selected analyzed area. After calibrating the camera with a scale and changing the camera's distance to the object, a general equation was obtained from the measured points. Using this equation, it is possible to determine the size of the measured object from pixels. The average relative error of the object's dimensions was: length - 1.94 % and the width of 100 components was: 1.31 %. In quality control, monochrome cameras can be used to measure product dimensions, along with image processing principles and with other measure methods.**

Keywords **– Automated visual inspection, machine vision, quality control.**

1. Introduction

The concept of quality control can be generally defined as a system whose job is to maintain the required quality level. This level can be achieved by comparing specific characteristics of the quality of a particular product with the reference. If a deviation from the required status is detected, corrective measures are taken to restore the target, required quality. To ensure efficient and successful production, manufacturers must rely on systems that ensure quality control. Machine vision systems in quality management are currently indispensable elements of manufacturing processes [11]. They play a growing role in modern manufacturing quality control systems. One of the reasons explaining this growth is that quick, accurate noncontact measurement and complex feature analysis can now be performed by low-cost machine vision systems [3, 4]. In some cases, it is possible to use it to recognize the characters of man's ability. However, this can lead to inefficiency, low production as to tedious work. The inspection system gains a picture of the controlled product mostly in digitized form. This goes through the control phase, which must match the pattern that determines the resulting product quality. In the verification and control phase, the system uses computer image processing [1]. Finding edges or contour of an object usually belongs to the last image processing step. There are currently many digital image processing techniques and algorithms [12, 13]. In the pre-processing step of the digital image, unwanted information such as noise can be removed, which can be filtered by various methods, where the Gaussian filter or median filter is most commonly used. The pre-processing process provides a higher quality digital image for the next step in the algorithm where object properties are extracted, such as edge or significant areas of the object, using the Threshold method to separate the required pixels of the image carrying the requested information from the background. Machine vision, and systems that are related to the quality control process, provide innovative solutions in the direction of industrial automation and quality control. These systems are used largely in the production of electronic components where high precision of dimensions is required. It is required when components are installed into device. Through the inspection systems, the metalworking industry checks the necessary shape of the manufactured part as well as the measurement of the necessary parameters. Other areas of industry include, for example, the textile

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industry where it is necessary to determine, in addition to shape and colour, the differences in fabrics. Specific areas are the glass industry where glass has a high surface reflectance and some systems could not be used for quality control. Another area is also the printing industry where there are plenty of colours and high print quality and colour fidelity [9]. The control and evaluation system usually consists of several units. The basic part is a computer that processes a digitized image using image analysis algorithms [13]. The digital image is captured by a camera placed in many cases statically above the sensed objects. These cameras are mostly adapted to their industrial conditions. The principle of the sensor portion of such cameras (chip or scanning electronics) is similar to devices conventionally used in the consumer sphere, including a web camera or Kinect camera. These devices may also be used for research purposes related to machine vision or image analysis. The use is described in many works [6, 10, 14], where industrial cameras are mainly used to control the shape of objects, counting quantities, measuring objects [6, 8].The camera's position does not change during the control process. Light source illuminates the colour light source to ensure a constant light intensity at the control site to prevent disturbing external light effects. The paper deals with the use of a monochrome industrial camera designed for inspection purposes to check quality in order to obtain the necessary digital image data to determine the dimensions of the product being inspected.

2. Material and methods

The purpose of digital image processing is to process produced continuous image. Continuous representation may also be required for processing outputs. In machine vision, as well as in image analysis, we use digital images. It is possible to process images form video as a video stream or separate pictures. In processing a digital image, the sampling interval and the quantization interval are important parameters [5]. The basic difference between signal processing and image processing is dimension [2]. Digital representation of image is necessary for further processing. This is expressed by two dimensional function *I(x,y)*, which is described by a matrix, where *x* represents columns and *y* represents rows. The size of the matrix depends on the maximal image resolution. Image filtration operations are the most used image processing operations. General meaning of image filtration means image modification operations, with output of image information with wanted quality. This means finding united segments, objects, entity, etc. with the use of different principal methods. Segmentation of image is the most important process for the next image information analysis. The process of segmentation splits image into objects. The target of this process is a separate object from each other, i.e. distinguishing a background, because the background is not important for further processing. The method of threshold works with information, that object and background have different level intensity of brightness. A constant *T* must be defined, called the threshold and every pixel is compared with this constant. The threshold could be also done by setting two threshold values, the lower limit and the upper limit. We then have a new rule as follows, with the lower threshold value *T1* and the upper threshold value *T2*. An image with 8 bit image depth is used for thresholding, which is the output of the digital camera used. Pixels with lower value of luminance than the threshold are defined as background and every other pixel is object. As a threshold, the global image segmentation technique is used. The threshold is determined using a histogram.

$$g(i,j) = \begin{cases} 1, & if\ \ T_1 > f(i,j) > T \\ 0, & otherwise \end{cases} \qquad (1)$$

Image analysis is performed for several selected objects, which represent produced component in laboratory conditions. These objects are intended for image analysis to obtain the necessary information about the positions of the component in the image. For calibration purposes, a normalized scale is used indicating the length of the object and the distance between the camera and the object. Based on this, image data are obtained to determine the size of the component using pixels. In our case, the length *l* (eq. 1) and the width *w* (eq. 2) of the component are determined.

$$l = \sum_{i=1}^{c} P_x \qquad (2)$$

$$w = \sum_{i=1}^{k} P_y \qquad (3)$$

The dimensions of the object are determined by pixels P_x and P_y under the selected analyzed area, which is determined by the line in the analyzed image. The indices *i*, *c*, *k* determine the order of the analyzed pixel in the accumulator (line vector).

As a monochromatic digital imaging device used for image capture is designed for industrial usage for product detection and control of the quality. The KEYENCE®IV-H500MA monochromatic camera features scanned scene lighting and the digital camera image is sent by Ethernet standard to the PC where the image processing software evaluates the information. The software can set the important parameters needed to inspect the manufactured components. Important is the selection of the scanned part of the product in which the shape or the positions with the reference sample are compared. Output control data includes data on the number of the scanned pieces of components, the number of noncompliant components and the number of the components that correspond to the quality standard. The camera system can be installed directly into a part of the production line to ensure immediate process of product quality monitoring and then send important information to a computer or PLC (programmable logic controller) after setting the parameters. After this installation, it is possible to control the entire production and control process with minimal human intervention. The manufacturer recommends installing the camera at a height of 50 mm to 500 mm to ensure correct focus on the subject being inspected. The digital video output with 8 bit depth from the 752 x 480 pixel camera can be processed by image analysis. The camera's scanning chip is a monochrome 1/3 inch CMOS chip. In the industrial process of control by camera systems, it is often required to constantly illuminate the area in which the object is located. The camera is equipped with infrared illumination of the monitored object, which is provided by four red color LEDs. The full specification of the camera system is described in the manufacturer's catalog list [7]. Object detecting in a scanned image is a sequence of several steps. The first step is to capture an image with a camera and store a monochrome image with an 8 bit image depth into a file. Such images are then manually processed by image analysis, and the standard histogram thresholding methods are verified. Threshold values are set manually to gain the contour of the object under control. Together, 100 identical components (connectors) are measured and their length and width dimensions are checked. The camera software allows you to set up features that ensure object tracking and object sweep.

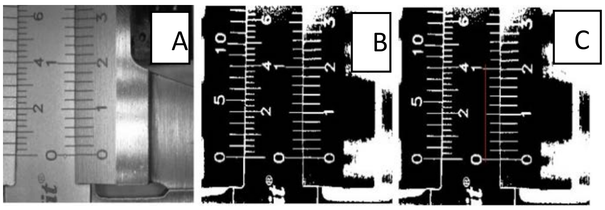

Figure 1. Input image processed by image analysis and determination of the pixel count. Preprocessing the digital image by the threshold method where the C picture the red line area between measure point on object where the number of pixels is determined by histogram method. The line is manually selected.

The monochrome image acquired by camera, which is located at a height of 60 mm above the subject (scale), is stored in the computer for further processing by image analysis using camera software. By the software is adjusted the brightness and the focus parameter is in fix-focus mode to obtain the desired image quality, in this case the brightness setting is 50 lx and the focus is 60 mm. Such an image can then be processed by a thresholding method whereby the lower boundary of the threshold 45 and the upper boundary 168 obtain the necessary contours of the object (scale). After this step of image processing, a new image is created, which we consider to be monochromatic with 8 bit image depth, as black points acquire values of 255 and a white space of 0. The thresholds are also set in this range. With the use of analyzed pixel profile (Figure 2.) by ImageJ software, we determine the pixel coordinates corresponding to the minimum and maximum thresholds (0-255). From the differences of minimal values, according to the profile of the analyzed image, we determine the number of pixels of the monitored object, resp. of the analyzed part of the image. A standard image analysis tool is used, which is able to count the number of pixels of the selected analysis area. We can start from the general fact that when an observer from the object goes away, the observed object appears to be diminished. By increasing the observer's distance from the object, it appears smaller. If we change the height of the camera above the object and determine the number of pixels in the object, it will change the number of pixels depending on the location of the camera to the object. Once we know the focal length of the lens, it is possible to determine the size of the object by means of a transverse lens enlargement. In our case, the focal length is unknown and therefore the procedure is chosen when the number of pixels is determined at a different height from the object, and the size of the object being surveyed can be determined. If we determine the length of the object and change the distance of the camera, within the operation range of the camera, then we can obtain the values for displaying the function dependence between the height of the camera and the number of the pixels.

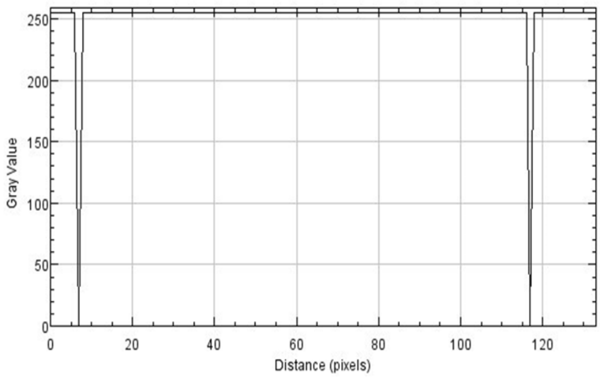

Figure 2. Input image processed by image analysis and determination of the pixel count

3. Results and discussion

Measurement and analysis were performed several times, each time when the camera distance was changed from the object. The length scale was used to check the dimensions of the component and compare the data measured by image analysis. Changes in camera height were performed from 40 mm to 500 mm, always with 20 mm shift, followed by measurement. The manufacturer sets minimum height of the camera above the subject to 50 mm, where the optics can focus, so the quality of the resulting image has sharp limits around the pixels. Measures may produce low-quality images that are subject to noise, either exposed or undershot. This image could not be used for quality inspection purposes when it is impossible to determine the exact boundaries of the shape of the object and thus to set the necessary values of the elements to detect the shape of the object or its rotation. Some shortcomings of the digital image (noise) can be compensated by a Gaussian filter.

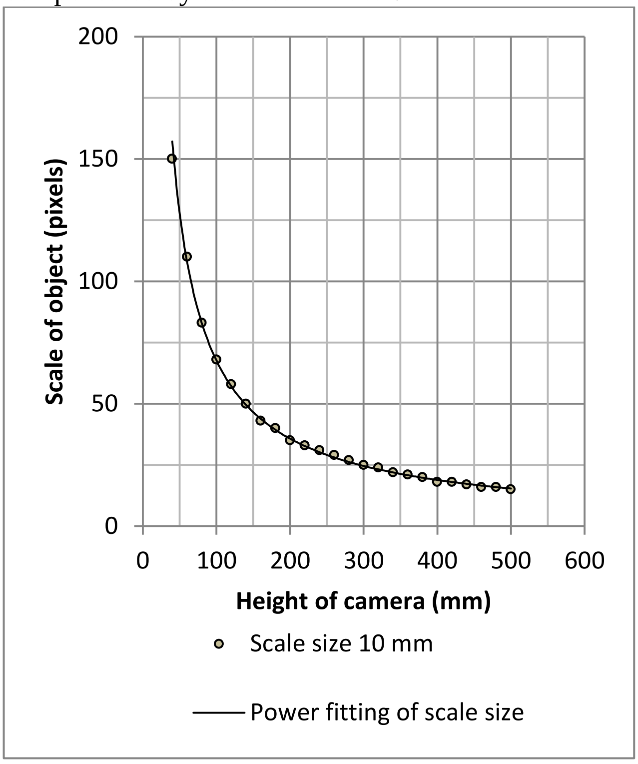

Figure 3. Dependence of the number of the pixels of the object from the perpendicular height of the camera to the object

By measuring the height of the camera to the object at specified intervals, we obtained dependence (Figure 3.) that represents a change in the number of pixels of a 10 mm length when changing the height of the camera. Dependence is an approximate power function:

$$h = 4680{,}1 \cdot Pcount^{-0{,}92} \tag{4}$$

where: h is perpendicular height of the camera from the top of the object and the scale (mm), P_{count} is number of pixels (pixels). Coefficient of determination: R^2 is: 0.9986. By approximation, it is possible to determine the general relationship for calculating the number of pixels of an object Γ if we know the height of the location of the given camera above the object.

$$\Gamma = \left(\frac{h}{c}\right)^{\frac{1}{k}} \tag{5}$$

The constants c, k are founded by regression analysis of the measured values. It is possible to determine the dependence that reflects the change in the number of pixels in relation to the change in the distance of the camera at a given height. The dependence is linear, with the camera's decreasing height relative to the scale (object) increasing the number of pixels associated with the object, thereby increasing the accuracy of the measurement. The component measured was a ten pin connector used in electronics used in a printed circuit board.

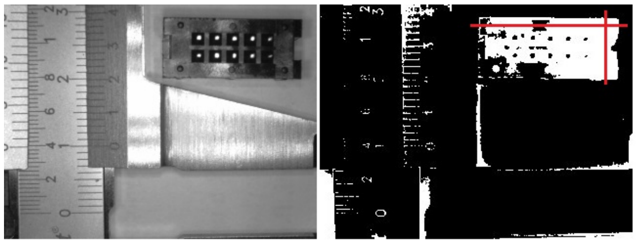

Figure 4. Measuring component dimensions. The red lines show the measured dimensions of the component. A standard image analysis tool is used, which is able to count the number of pixels of the selected analyzed area. On the test sample, the threshold values were set manually as well as the boundaries of the measure areas of the object.

In quality control, the inspection software evaluates the location of the individual contact in the case and identifies their presence in the position. When checking, the basic dimensions of the connector (width and length) can also be measured by image analysis. By manual measurement, dimensions were measured: length 20.3 mm, width 8.9 mm. Measurement by image analysis of pixel counting in millimeters when setting the camera at a height of 100mm above the object has the following dimensions: length 20.7 mm, width 9.1 mm for one random sample processed by the image analysis in which the dimensions were found. 100 frames were used to determine the relative error of measurement by image analysis. The average relative error for the object length was: 1.94 % and the average relative error for the object width was: 1.31 %. The measurement of component dimensions in the quality control process by image analysis can be used in the initial stages of product inspection. To increase the accuracy of the measured component dimensions, it is also suitable to use systems that work on a different principle than a digital camera, such as the laser scanner.

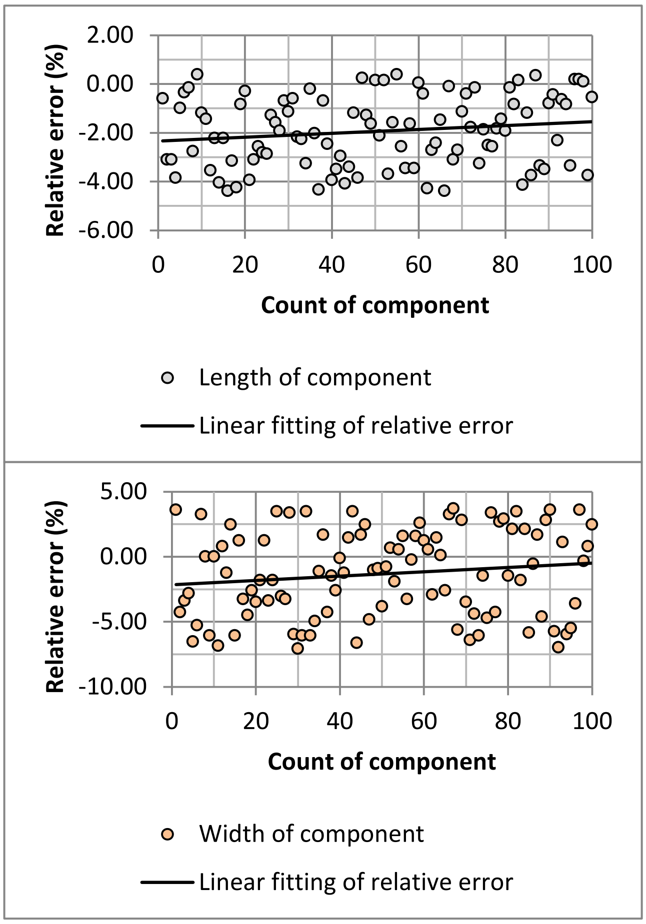

Figure 5. A Relative errors in measuring the dimensions of the component being checked by image analysis. The perpendicular height between camera and object was 100 mm.

4. Conclusion

The field of vision, along with image analysis algorithms with industrial systems, bring innovative quality control solution to manufacturing different components. Using monochromatic cameras and image processing software, as well as inspection software, it is possible to determine the type of the product on the basis of its shape and thus to identify possible shortcomings. Another benefit of computer vision is to determine the size of the components based on the height of the camera and to convert the pixels to the length. This method is appropriate to be applied at product inspection stage, with sufficient precision to determine the basic qualitative characteristics of the component produced.

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