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INSPECTION AND QUALITY CHECKING OF CERAMIC CUP USING MACHINE VISION TECHNIQUE: DESIGN AND ANALYSIS

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Graphical abstract

Abstract

The development of inspection and quality checking using machine vision technique are discussed where the design of the algorithm mainly to detect the sign of defect when a sample product is used for inspection purposes. There are several constraints that a machine need to be improved based on technology used in vision application. CMOS image sensor as well as programming language and open source computer vision library were used in designing the inspection method. Experimental set-up was conducted to test the proposed technique for evaluate the effectiveness process. The experimental results were obtained and represented in graphical and image processing form. Besides, analysis and discussion were made according to obtained results. The proposed technique is able to perform the inspection process using good and defect ceramic cup based on detection technique. Moreover, based on the analysis gathered, the proposed technique able to differentiate between good and defect ceramic cup. The result shows that there is a difference frequency by 236 which is 2% of total value in pixels frequency. The frequency indicated as pixel frequency of image using histogram method based on scaled value of image.

Keywords: Inspection, quality checking, machine vision, defect detection, image analysis

1.0 INTRODUCTION

During the middle of 19th century, computer vision with aids of vision camera was introduced and being implemented in various field of application. It was then experienced large improvement with respect to the improvement of both image sensor and processing chip. Computer vision generally also known as machine vision but they both differ in terms of technology used [1]. Traditionally, manufacturing plantation conducts inspection process which require human's physical capability known as human's vision system to conduct product checking and classify it whether the product falls within acceptable range or not. Normally, mass production line often requires labor to work more than normal shift hour to help production rate [2].

In addition, inspection by relying on human is unreliable due to eye failure that can always occur due to human error. The vision blurred which happens on labor can cause health problem such as visual strain [3]. CMOS sensor acts as vision camera to assist the operator and conduct inspection without relying on human.

The paper introduce the study conducted for inspection and quality checking by using machine vision technique which involves the design and development of a technique that can determine any sign of defect through the process of reading the pixels from the digital image acquisitioned from image sensor. Through the design of inspection algorithm, there are some common method used by [10-13] which it involves pixel calculations.

2.0 METHODOLOGY

Inspection system by using machine vision technique often require vision camera which is normally a sensor that is used to capture images of product and represent the image as digital image. Besides, it does involve numbers of important factors that can affect the effectiveness of the design [4-5]. Throughout the progress study, each significant criterion of an inspection process was concerned and conducted with step by step sequential flow. Hence, the following section illustrates the key steps for development of procedure design. A lot of techniques had been applied using machine vison technique in road sign application [6-9].

2.1 Image Sensor

While conducting the experimental setup, CMOS (Complementary Metal Oxide Semiconductor) sensor was used as it has its specific performance as compared to others such as CCD (Charged-Coupled Device). The Figure 1 illustrated the architectural design of a CMOS sensor [5].

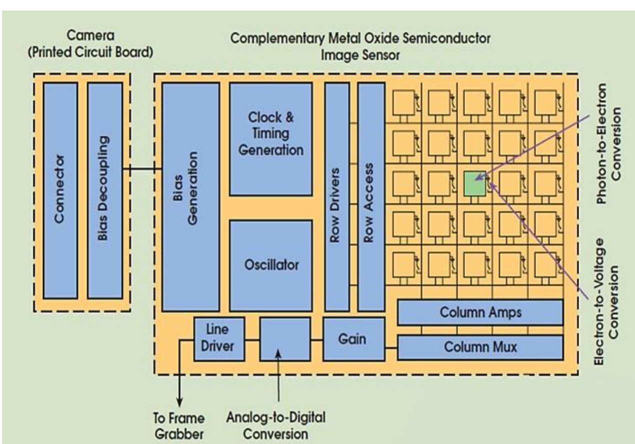

Figure 1 Architectural design of CMOS sensor [5]

2.2 Illumination and Surrounding Environment

This step is crucial during the inspection process as illumination can give useful information to the digital image produced by CMOS sensor. Poor illumination setup tends to cause poor image results and poor effectiveness of the inspection process. The proposed setup system is required to block other unnecessary light source and excessive light intensity that will direct to the product or sample. Excess light intensity can produce very bright spot and probably glare effect on the image produced. Therefore, a specific background color was used while conducting the experiment.

2.3 Algorithm Design

To inspect a certain object, a suitable algorithm is required to determine whether the sample inspected is good unit or defective unit. Once the digital image is captured by the sensor, the image will then undergo image processing which includes object recognition and detection via Python programming language. Besides, a computer vision library for image analysis and processing of an Open-source computer vision library (OpenCV) is needed to develop the algorithm for inspection process. The design of algorithm is based on process flow as shown in Figure 2.

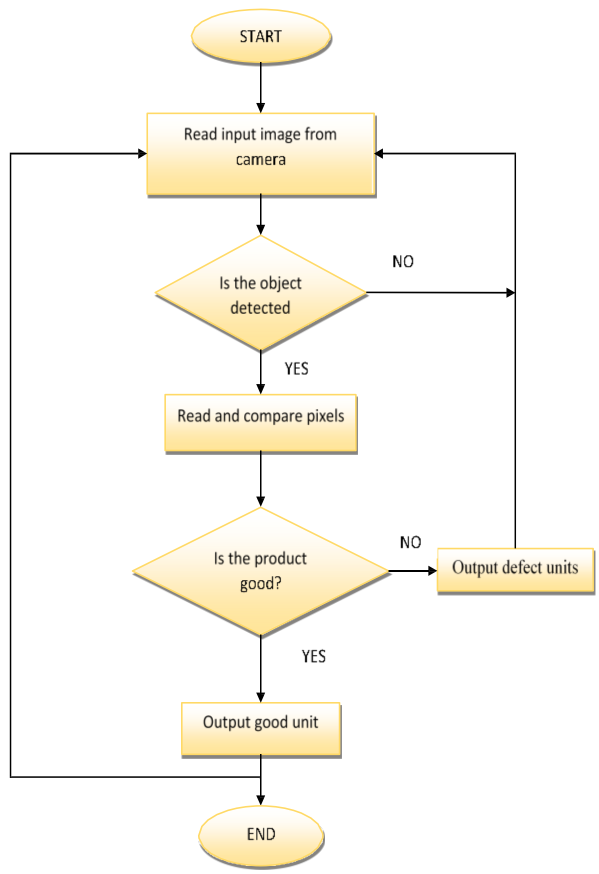

Figure 2 Flow chart algorithm

In addition, the algorithm designed are highlights the inspected region of the object with green color line. In order to compare the product, a sample of good unit image is to be stored in a memory as a reference image with its specific digital image characteristic in term of color, shape and size so that for every time inspection and checking process occurred, the input image will be used to compare with the reference image.

2.4 Defective Product

Before creating the algorithm, proper understanding about defective product is essential as this is to ensure the algorithm is able to interpret the product detected whether is a good product or defective one. Normally, in product inspection, product with visible scratches on the surface is considered as defect unit. Similarly, unwanted marks or color on the surface are also considered as color defect where it will be considered as defect product. Another criterion for defective product is shape defect. Shape defect is defect caused by the shape of the product does not match with the desired product. Thus, the proposed technique designed using ceramic cup and defect ceramic sample respectively.

2.5 Noise Removal Method

To detect the sign of defection, pixel values are used to determine whether the product contains unwanted sign or mark that forms on the surface of a sample. Once the camera capture the image of a product that passes through the frame of a camera pixel, pixel value will be calculated to inspect if there is any sign of product defect. For the captured image, the region of the inspected product detected will then undergo pixelated and analysis process. Color pixel of the digital image normally represented with the combination of red, green and blue (range from 0 to 255). The comparison is conducted based on the following equation:

Number of pixel change = Total sample pixel – total reference image pixel

$$Pixel\ changes = \frac{Number\ of\ Pixel\ Change}{Total\ Reference\ Pixel} x100\% \qquad (1)$$

If the pixel changes result exceeds the desired value, then it will be considered as defect unit was detected. The desired value should not be considered as zero as the noise produced can be fluctuated by the pixel values. Hence, adjustment need to be made so to increase performance while reduce the process tolerance factor.

However, using pixel calculation may cause failure in detection process during image acquisition product occurred. It happens due to image noise that causes the fluctuation on pixel changes occur. Thus, a blob detection method was used in the design so that the system able to detect and trace the unwanted mark or color on the product surface. This blob detection method is to detect portions of colored pixel other than the color of product and return defect outputs to user interface (computer monitor).

Other than the mentioned method, in order to ensure the shape of the product is match with the reference unit; the object recognition of the algorithm was considered. As the product enters the frame of camera, the algorithms will compare the product's shape with the reference image to see if the shape matches. Once the shape matches with the reference unit, then only it further the inspection by using the method mentioned above.

2.5 Image Processing

The image obtained is required to undergo image processing as the image without being processed consists of unwanted noise. This noise produced due to various factors while conducting the design. In nature, vibrational waves are nearly impossible to be eliminated even though the camera stays at rest on a static surface. This vibrational energy exerted on camera can then produce noise and pixel fluctuation. Hence, image processing can reduce the noise and improve the quality of image captured. Noise filtration and image thresholding was introduced into the algorithm. In addition, this process may improve the performance of the algorithm of inspection method.

2.6 Experiment and Test

Once the algorithm is designed, the set-up of an experiment is conducted to test the performance of the algorithm. Figure 3 briefly explained the experimental set-up method that was used to test the designed algorithm. Based on analysis and good approach the experimental analysis should be applied to evaluate the system performance [10].

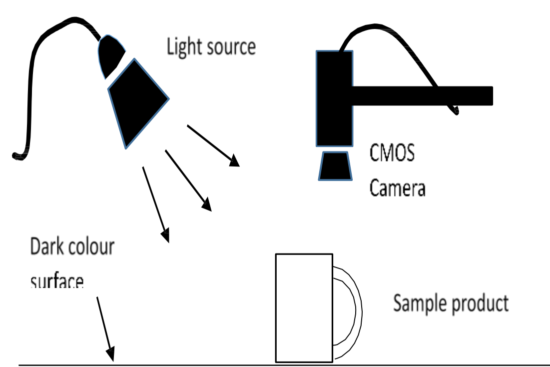

Figure 3 Experimental set-up

The algorithm was then tested by using a simple white ceramic cup with one with cracked surface as defective unit and without cracked surface as good unit. Figure 4 shows the image of simple white ceramic cup used as the test sample.

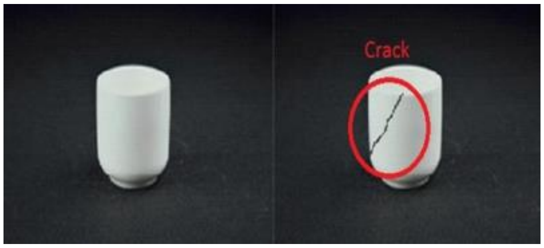

Figure 4 Sample of (a) good ceramic cup and (b) cracked ceramic cup

2.7 Histogram Analysis

To perform analysis on the result obtained, histogram method is used to plot the result. This happens due to the digital image acquired from CMOS sensor are representation of 2 Dimensional and with the set of finite digital value known as pixels. Hence, histogram is suitable to be used as it can present clearly the pixel value obtained during the inspection process. Since the product sample of this study is white ceramic cup and the background is black, the suitable type of histogram chosen is level of brightness that range only 0 to 50 in x-axis rather than plotting the histogram using greyscale value in which its x-axis range from 0 to 255. By using level of brightness, the 0 value represent absolute black color pixel and 50 as white color pixel which is similar to greyscale value which is 0 represent as black and 255 as white. However, they are different in term of graphical smoothing effect. By using level of brightness, the chart of histogram plotted is smoother as compared to normal histogram [14-15].

3.0 RESULTS AND DISCUSSION

3.1 Image Analysis

After testing the algorithm, the result obtained as the simple ceramic cup is used to test the performance. Once the cup enters into the frame of camera, the plotted histogram indicates the total number of pixel versus the level of brightness of the inspected ceramic cup. The histogram plotted in Figure 5 shows the level of brightness of raw image which has not undergone image thresholding. The x-axis of the histogram represent the level of brightness (range from 0 to 50, with 0 as black and 50 as white pixel) of captured image whereas y-axis indicates the frequency or number of pixels.

Figure 5 and 6 show the result histogram for both good and defect sample which has not undergo image thresholding technique. From the result, it is clear that there are continuous level of brightness occur which represent the contrast of the image captured. The number of pixel range from level of brightness 0 to 10 indicates the dark colored pixel detected and it is continuous pixel. Meanwhile, the number of pixel detected at level of brightness 30 to 50 indicates the color pixel that represents the color of ceramic cup. From the two histograms, it was difficult to generate the difference between good and defect in term of the color pixel detected by CMOS camera. Through thresholding then only it redistribute the pixel whether level 0(black) or level 55(white) depending on the threshold value.

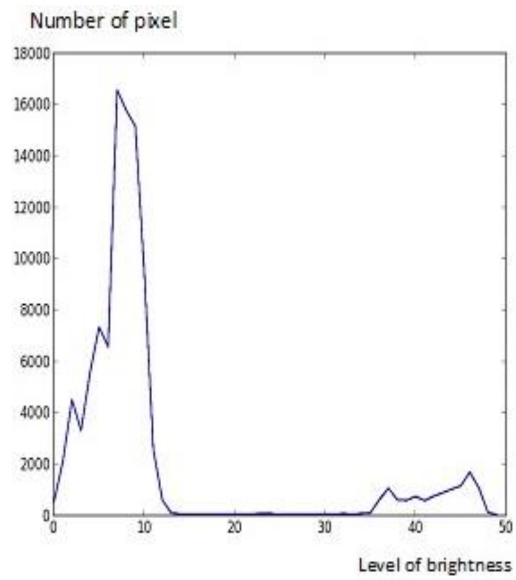

Figure 5 Histogram of good ceramic cup

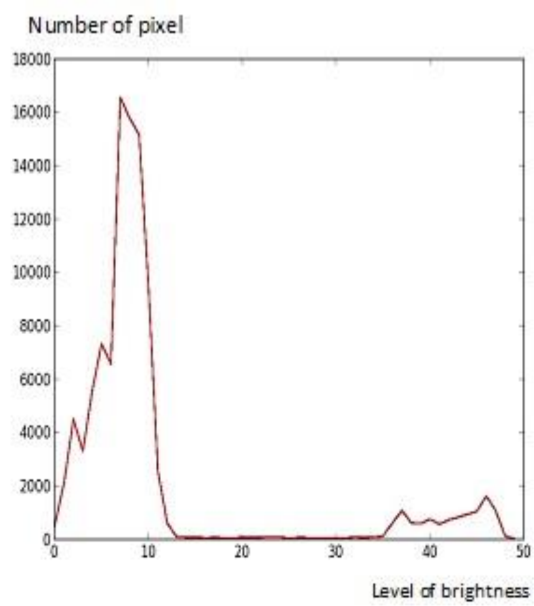

Figure 6 Histogram of cracked ceramic cup

Figure 7 Threshold image of (a) good ceramic cup and (b) cracked ceramic cup

Figure 7 illustrates the threshold image produced through the algorithm. Based on Figure 5 and 6, both the image of good ceramic and cracked ceramic cup undergoes thresholding process using the proposed technique. The outer green line is actually the line drawn to show the inspected region. Meanwhile, the image on the right (Figure 7) shows the dark line across the white region indicates the crack detected by the algorithm. Through thresholding, there are certain portion of the surface of ceramic cup are not able to detect especially the region at the bottom of the cup. It happens because the shadow formed at the bottom of the cup results in dark region which make the pixel value of that portion fall below the threshold value. Hence, that particular region is not inspected by the proposed technique.

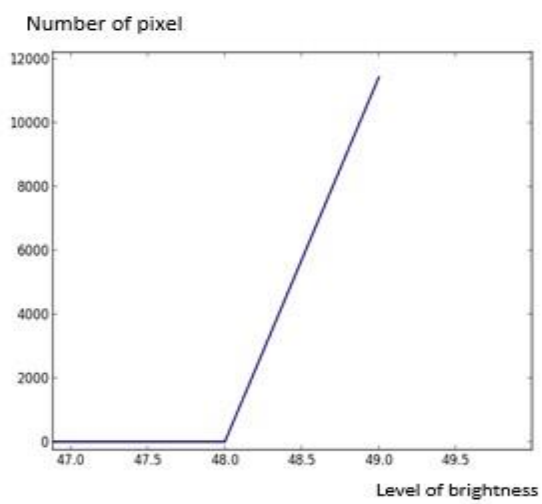

Figure 8 Histogram of threshold image at level of brightness 50 for good ceramic cup

After the images undergo image thresholding process, the histogram of both the image is plotted. However, to see the difference in pixel value, the region of white color pixel is considered (level 50) and the dark color pixel indicates the background of the product. Therefore, Figure 8 shows the part of histogram for good ceramic cup that shows number of white pixel which allocated the end region of the entire histogram.

Plotted the threshold histogram stated that, both the pixel value of good ceramic cup and cracked ceramic cup are quite similar to each other for the number of pixel in the histogram as well as graphical pattern. However, by zoom in at the very end and upper part of the line then only it can show the difference for both good ceramic cup and the defect cup. Thus, Figure 9 shows the scaled down of the histogram for both the sample used.

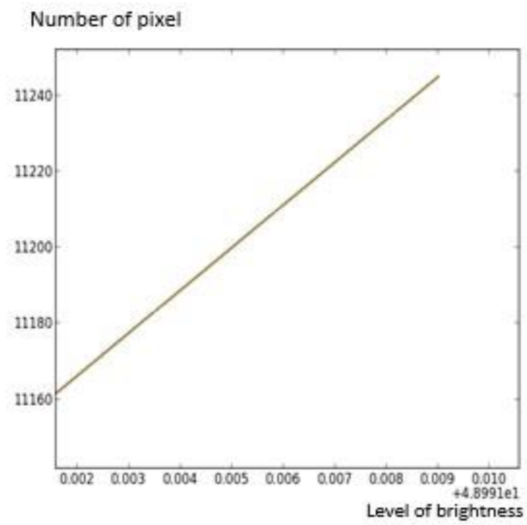

Figure 9 Scaled down of histogram at level of brightness of 50 for fine ceramic cup

Based on the scaled value of histogram, the number of white pixel or frequency for fine ceramic was 11481, whereas for the defect ceramic showed 11245. From these two values, it is clearly that there is a difference frequency by 236 which is 2% of total value in pixels frequency. Frequency indicated the pixel frequency of image using histogram method based on scaled value of image. The algorithm then displays the inspected region as in with green line at boundaries.

4.0 CONCLUSION

To sum up, the designed algorithm able to detect if there is sign of defect occurs on the sample product during an inspection process. Moreover, the designed algorithm also able to detect and highlights the region of inspected product and displays it. In addition, the acquisition process also redistributes pixel value according to threshold value to perform inspection in order to improve the effectiveness during the inspection process.

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References

[1] T. Brosnan and D. W. Sun. 2004. Improving Quality Inspection of Food Products by Computer Vision-A Review. *J. Food Eng.* 61(1): 3-16.

[2] C. L. Phillips. 1993. Eliminating Traditional Inspection from the Electronics Manufacturing Process. *Proc. Eighth Annu. Appl. Power Electron. Conf. Expo*. 244-248.

[3] T. Muraoka. S. Uchimura and H. Ikeda. 2016. Evaluating Visual Fatigue to Keep Eyes Healthy within Circadian Change during Continuous Display Operations. *Journal of Display Technology.* 12*:* 1464.

[4] B. C. Jiang, C. C. Wang, and H. C. Liu. 2005. Liquid Crystal Display Surface Uniformity Defect Inspection Using Analysis of Variance and Exponentially Weighted Moving Average Techniques. *Int. J. Prod. Res.* 43(1): 67-80.

[5] D. Litwiller. 2001. CCD vs. CMOS. *Photonics Spectra*. 35(1): 154-158.

[6] N. M. Ali, M. S. Karis, A. F. Z. Abidin, B. Bakri, N. R. Abd Razif. 2015. Traffic Sign Detection and Recognition: Review and Analysis. *Jurnal Teknologi*. 77(20): 107-113.

[7] N. M. Ali, Y. M. Mustafah, N. K. A. Md Rashid. 2013. Performance Analysis of Robust Road Sign Identification. *IOP Conference Series: Materials Science and Engineering*. 53(1): 012017.

[8] N. M. Ali, M. S. Karis, J. Safei. 2014. Hidden Nodes of Neural Network: Useful Application in Traffic Sign Recognition. *IEEE Conference on Smart Instrumentation, Measurement and Applications (ICSIMA)*. 1-4.

[9] N. M. Ali, N. K. A. Md Rashid, Y. M. Mustafah. 2013. Performance Comparison between RGB and HSV Color Segmentations for Road Signs Detection. *Applied Mechanics and Materials*. 393: 550-555.

[10] M. S. Karis, N. Hasim, N. M. Ali, M. F. Baharom, A. Ahmad, N. Abas, M. Z. Mohamed, Z. Mokhtar. 2014. Comparative Study for Bitumen Containment Strategy using Different Radar Types for Level Detection. *International Conference on Electronic Design (ICED)*. 161-166.

[11] N. M. Ali, Y. M. Mustafah, M. Rashid, N. K. Alang. 2013. Performance Comparison between ANN and PCA Techniques for Road Signs Recognition. *Applied Mechanics and Materials*. 393: 611-616.

[12] N. M. Ali, N. M. Sobran, S. A. A. Shukor, M. M. Ghazaly, A. F. T. Ibrahim. 2013. Individual Processing Speed Analysis for Traffic Sign Detetion and Recognition. *IEEE International Cofenrence on Smart Instrumentation, Measurement and Application (ICSIMA 2013)*. 1-5.

[13] N. M. Ali. 2014. Automatic Road Sign Identification System with Robustness to Partial Occlusion. Master Science Thesis. International Islamic University Malaysia (IIUM).

[14] A. H. A. Eissa and A. a. A. Khalik. 2012. Understanding Color Image Processing by Machine Vision for Biological Materials. *Struct. Funct. Food Eng*. 227-274.

[15] O. Marques. 2011. Histogram Processing. *Practical Image and Video Processing Using MATLAB*. Florida, John Wiley. 176-180.