Real-time Product Quality Inspection Monitoring System using Quadratic Distance and Level Classifier

Norhashimah Mohd Saad[1], Nor Nabilah Syazana Abdul Rahman[1], Abdul Rahim Abdullah[2] and Norhizam Abdul Rahim[3]

[1]*Center for Robotics and Industrial Automation, Faculty of Electronic and Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia*

[2]*Center for Robotics and Industrial Automation, Faculty of Electric Engineering, Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia*

[3]*Stevia Industry Sdn. Bhd., Kawasan Perindustrian KEDA, 08300 Gurun, Kedah, Malaysia*

norhashimah@utem.edu.my

***Abstract*—Automated product quality inspection has become a very important process in industries to maintain high product efficiency. This paper presents a real-time product quality inspection monitoring system for beverages product. The proposed system used Internet Protocol (IP) camera to capture the image of the bottle through computer network in order to inspect color concentration and water level of the bottle. Quadratic distance technique is applied for color concentration analysis based on a combination of Red, Green and Blue (RGB) histogram. The vertical and horizontal coordinates technique is used to inspect three conditions of the level, which are passed, overfill and underfill. The proposed system has achieved 100% accuracy using 246 samples.**

***Index Terms*—Color classification; Level classification; Product quality inspection; Quadratic distance classifier.**

I. INTRODUCTION

Recently, most industries have been replaced with their inspection system from manual to automatic inspection in order to inspect the quality of the product [1]. The automated inspection has made industry to control the quality of the product with low cost and fast delivery to the customer [2]. The problem is associated with a manual inspection that is done by a human. The human inspector contributes to low production efficiency. It is because of inconsistency, fatigue and illness that comes from human. Some reviews are made from previous studies to compare the inspection system method.

Bama *et al*., (2011) proposed inspection system to inspect shape, color, and texture of plant images. It uses HSV conversion and Scales Invariant Feature Transform (SIFT) techniques to analyze the image. The result obtained is 97.9% accuracy. However, the system is less accurate to recognize HSV image [3].

Studied made by [4], design a system to inspect color level for medicine using thresholding technique. The experimental result shows the proposed system better performance to inspect the color of the medicine. But, the system is less capable of differentiate several color between medicine because of the standardizes average value is not set by the system.

In the paper by *Dave et al*., (2015) the real-time monitoring system is developed to inspect liquid level and cap closure for bottle using image processing. Vertical and horizontal reference line technique is proposed to detect liquid level. The system shows it has the ability to complete all process in shorter time. In opposite, the system cannot separate background image and the object accurately. [5]

Pithadiya *et al*., (2010) propose liquid level inspection system based on machine vision for the bottle image. It uses ISEF edge detection to detect liquid level in the bottle. The system is simple and low cost. The disadvantage of this system is not converting the color image into grey image that will increase accuracy of the system [6]. The previous techniques are summarized in Table 1.

Table 1
Summary of Previous Research

Author	Method	Limitation
Bama *et al*.	- HSV conversion - Scale Invariant Feature Transform (SIFT	- Less accurate to recognize HSV image.
Zheng *et al*.	- Threshold color value	- Less capable to differentiate color between medicine.
Dave *et al*.	- Vertical and horizontal reference line	- Cannot separate background image and the object accurately.
Pithadiya *et al*.	- ISEF edge detection	- Not converting the color image into grey image that will increase accuracy of the system.

This paper is presented to design the real-time product quality inspection monitoring system using quadratic distance classifier technique and level classifiers to inspect color concentration and water level. Besides, this paper is analyzed image analysis technique for design quality inspection system for Small and Medium Enterprise (SME). Graphical User Interface (GUI) for the automatic inspection system is also developed. Figure 1 shows the layout of the automated visual inspection process.

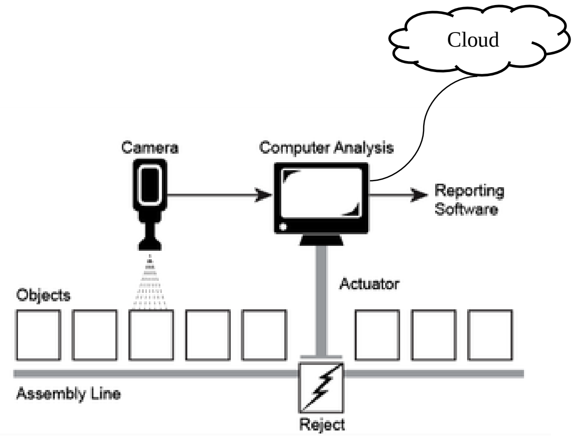

Figure 1: Automation visual inspection process layout

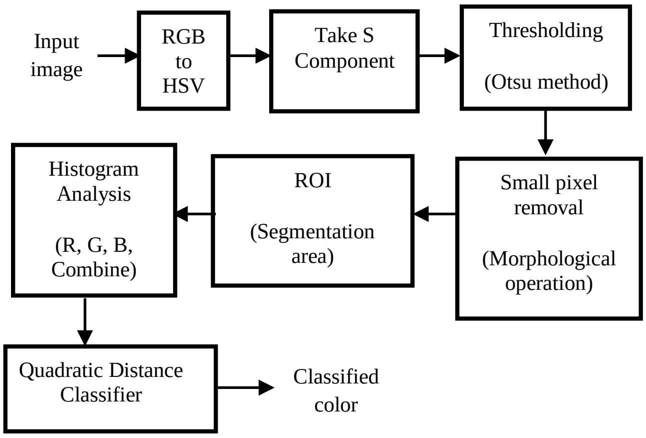

Figure 2: Color classification process

II. METHODOLOGY

Matlab software is used for software development because its provide image processing toolbox that suits for image analysis.

A. Image Acquisition

IP camera is an Internet Protocol camera which is connected to Ethernet or Wi-Fi [7]. It is used to capture the image and send or receive data via computer network and Internet. For this system, the smartphone is used as IP camera by installing the Android application in smartphones. IP camera is applied for this system to capture the image of a soft drink bottle.

In this system, conveyer is used to move the bottle from one place to another place. The component of conveyer includes DC motor and belt. The motor is the low speed with high torque so that the conveyer can move slowly with a heavy bottle.

Apache is widely used in Web server and it is distributed under open source license. For the proposed system, it is used to store and replace the image on the server. The reason for choosing Apache server is because of the open and free source, faster to send and receive data, and safety to store the data. It also can be modified for different extensions and modules [8]. Five types of flavors are used which are Strawberry, Tropical, Root Beer, Grapes and Orange. 246 samples are analyzed using a Matlab software.

B. Color Analysis Framework

Figure 2 shows the color analysis framework for the bottle image. The process starts with the conversion of RGB color to Hue, Saturation, Value (HSV) color. It is because HSV color space is more suits to the human eye and not complex to be received by the human eye in terms of hue and saturation [9]. In the process, only Saturation component takes for the thresholding process using Otsu's method. The Morphological operation will remove the small pixel to make the image become more clear and sharp. Then, Region of Interest (ROI) is segmented and has been used for the histogram analysis. The classification of color is classified by using the Quadratic Distance technique.

C. Pre-Processing

Pre-processing is the first important process to normalize the pixel of the image. It is needed to correct and improve the image intensity, remove unwanted distortion, and enhances image features for another analysis [10].

D. RGB to HSV

The conversion of RGB to HSV is based on color characteristics such as tint, shade, and tone. The hue (H) is from 0 to 360º inside a hexcone while saturation (S) is purity of color that from 0 to 1. So, S=1 to make it pure color. For value (V), it is also from 0 to 1. But, the brightness of V is 0 which is black [11].

E. Otsu's Method

Otsu' method is one of the image thresholding process used to transform the gray level image into a binary image. The function of Otsu's to maximize the separated classes in gray levels [12]. It is also used variance function to calculate the ideal threshold value for each image. The use of Otsu's method because it can reduce noise very well and an efficient method to segment the image [13].

F. Color Classification

The Quadratic Distance technique is used to classify color concentration of the bottle. The RGB image is represented in histogram form to get distribution data for three color channel which are red, green and blue. The histogram is normalized to get the value from 0-1. Each of red, green and blue color is divided into 10 bins. Next, each color will be combined to form the RGB histogram which is 30 bins for overall bins. This technique is simple as well as provide high efficiency and accuracy for system application [14]. Equation 1 shows the formula of Quadratic Distance to calculate the color threshold value.

$$Vthresh = \sqrt{[P1(i) - P2(i)]^2} \quad , i = 1,2,3,..,30 \qquad (1)$$

Where P_1(i) is a reference image and P_2(i) is a test image from the histogram bins. Figure 3 shows the process of green color of the reference image.

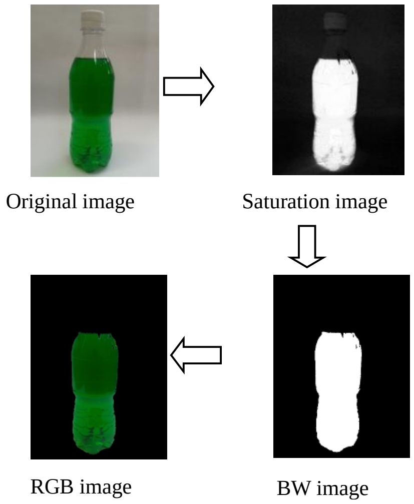

Figure 3: Color process of reference image

G. *Level Classification*

The level classification process has used vertical and horizontal coordinates technique to detect the level. This method is easy to be implemented and not involve any complex algorithm [15]. Three conditions of level are inspected which is a level pass, level overfill, and level underfill. Two points are marked on the bottle such as point 1 and point 2. Point 1 is represented as a red color while point 2 is represented as a blue color. The level is passed if the water is between point 1 and 2. If the water is above point 1, the level is overfill and if the water is below than point 2, the level is underfilled. The conditions are shown in Figure 4 to Figure 6.

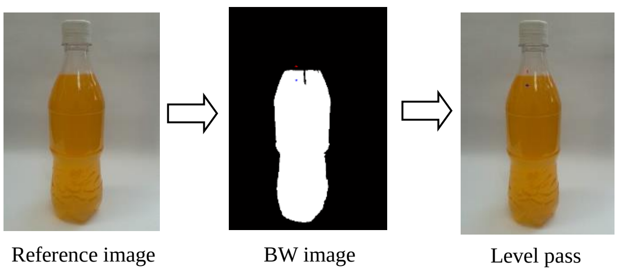

Figure 4: Level Pass

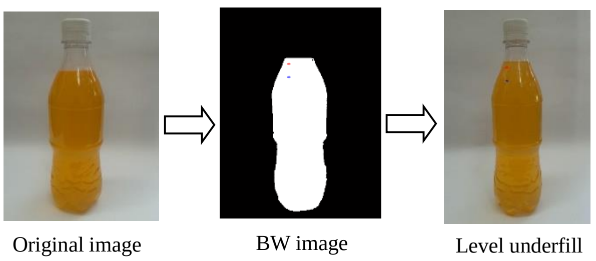

Figure 5: Level Overfill

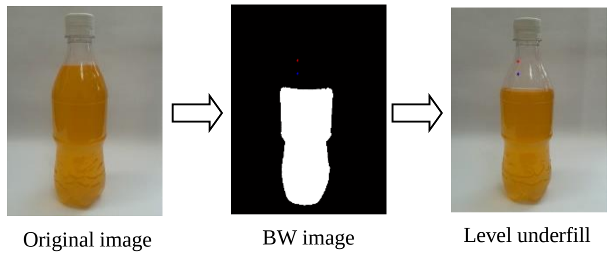

Figure 6: Level Underfill

H. *Hardware Development*

The hardware development consists of IP webcam and conveyer. The system is started by placing the bottle on the conveyer. Once the conveyer is running, the IP camera will capture the image and store the image in the Apache server. The timer is used to capture the image by IP webcam. The process is repeated until 246 samples. The image store in Apache server will be used for further analysis. Figure 7 shows the complete system of product quality inspection.

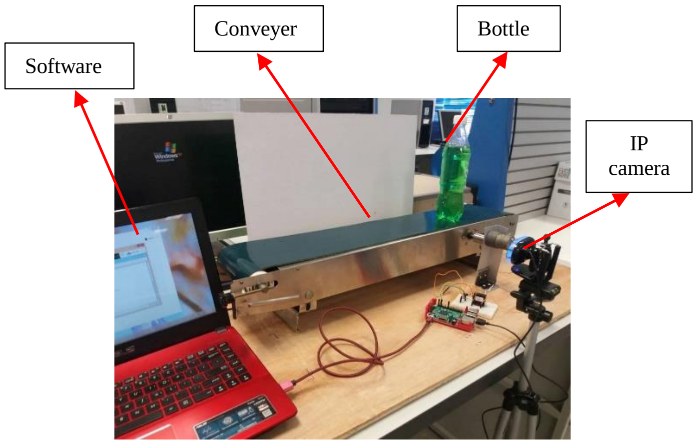

Figure 7: Complete system

III. Results

Figure 8 shows five types of sample images which are used as a reference image for classification part. Figure 9 shows a test image for color classification failed.

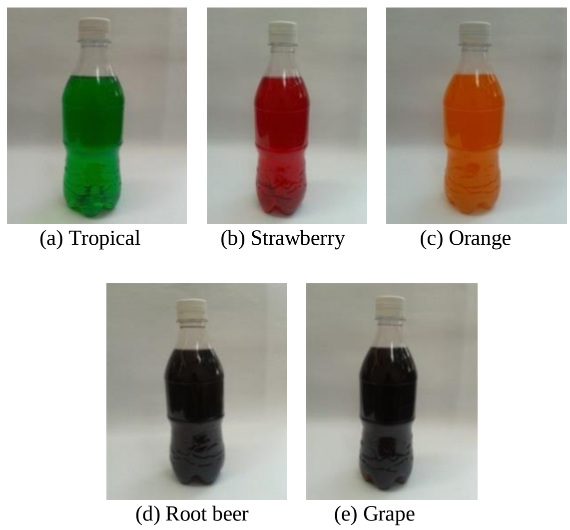

Figure 8: Five types of reference image

(a) Tropical

(b) Strawberry

(c) Orange

(d) Root beer

(e) Grape

Figure 9: Five types of test image

Figure 10 and Figure 11 show the RGB histogram distributions for the color intensity of reference and test image in Figure 8 (b) and Figure 9 (b), respectively.

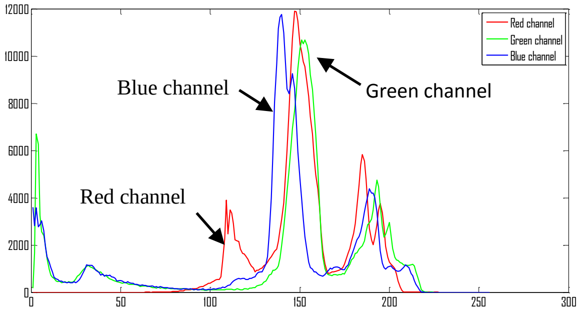

Figure 10: RGB combine a graph of the reference image

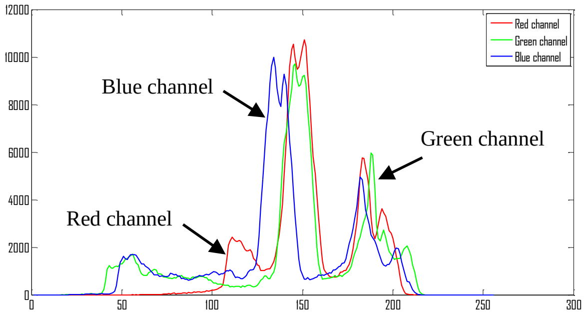

Figure 11: RGB combine a graph of the test image

The 8-bit of Red, Green and Blue histograms are represents in 10 bins for each color is shown in Figure 12 to Figure 14 using reference images from Figure 8 (b).

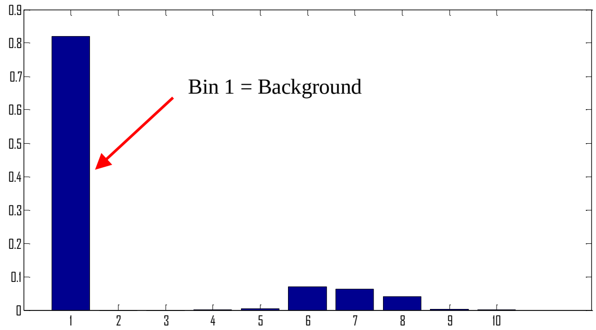

Figure 12: Red histogram of reference image

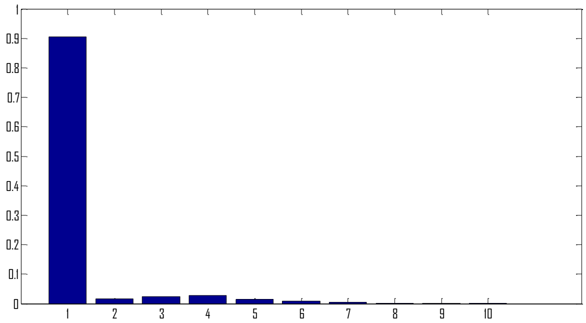

Figure 13: Green histogram of reference image

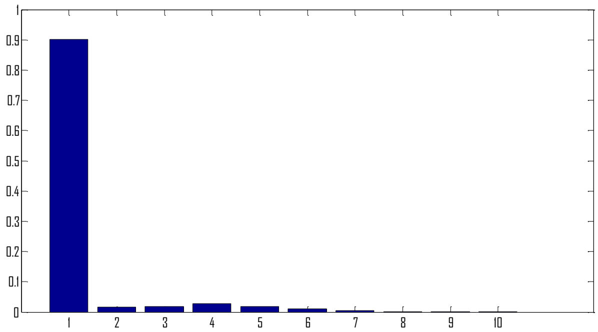

Figure 14: Blue histogram of reference image

The first bin for each histogram is the value of background image which is a black color while the rest bins show the value of different color in the image. For the analysis, only bin 2 to 10 are taken to be processed. Figure 15 and Figure 16 show the combination of three histograms which are red, green and blue histogram for the classification process.

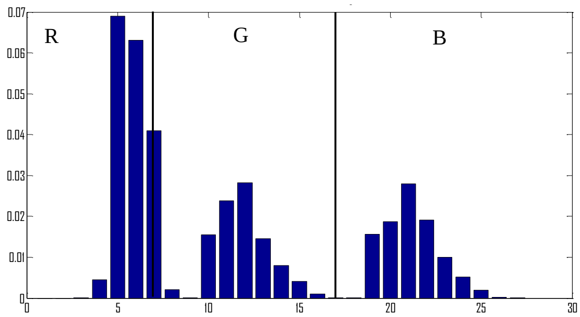

Figure 15: Combination of RGB histogram for reference image

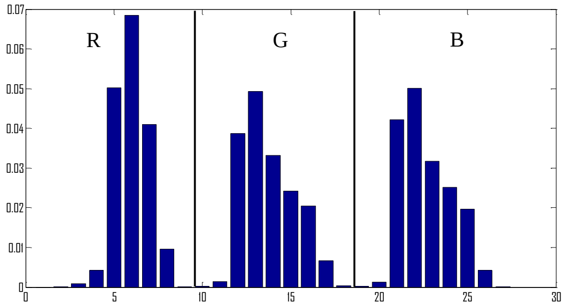

Figure 16: Combination of RGB histogram for test image

From Figure 15 and Figure 16, the red component is from bin 1 to bin 9, the green component is from bin 10 to bin 18 and lastly for the blue component is from bin 19 to bin 27. Bin 28 to bin 30 is neglected because of those bins is the background color. Therefore, only the value of bin 1 to bin 27 is used to calculate the distance between each color in order to get the threshold value between the reference image and the test image.

The distance value between reference image, $P_1(i)$ and the test image, $P_2(i)$ for each bin of RGB histogram is calculated by using the Quadratic Distance formula as shown in Equation 1. This distance value will be used as a threshold value for RGB color. Figure 17 shows the color classification flow.

$$Vthresh = \sqrt{[P1(i) - P2(i)]^2}$$

0.5091 ⇨ Reject

Threshold value = 0.2

Greater than 0.2 = REJECT

Lower than 0.2 = PASS

Figure 17: Block diagram of color classification process

The threshold value is set by 0.2 which is for color PASS according to experimental results obtained. If the distance value greater than 0.2, the color is REJECT. If the distance value is less than 0.2, the color is PASS. Figure 18 and Figure 19 show the layout and complete Graphical User Interface (GUI) for the proposed system.

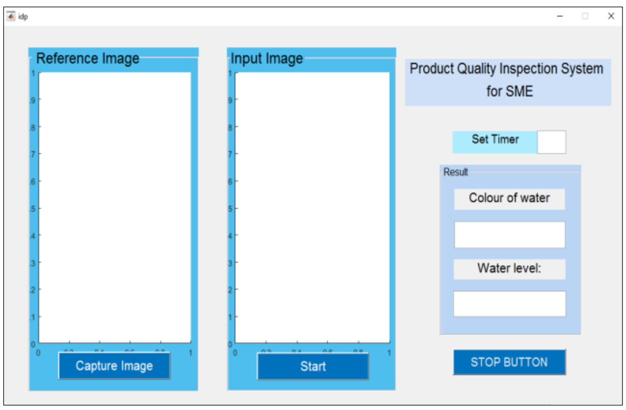

Figure 18: GUI layout

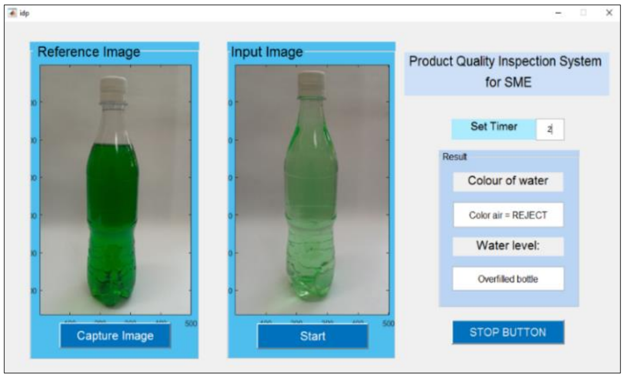

Figure 19: Complete system of GUI

The system is demonstrated in real-time and 100% accuracy is achieved for 246 samples as shown in Figure 120.

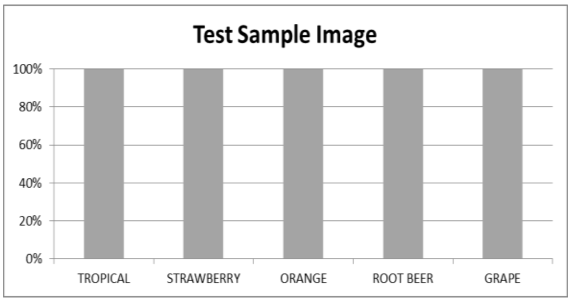

Figure 20: Accuracy graph

IV. Conclusion

In this paper, a real-time monitoring system for product quality inspection is presented for Small and Medium Enterprise (SME) purposes. The analysis of the image includes thresholding, segmentation, feature extraction, and classification. The color is classified based on Quadratic Distance technique from the histogram analysis. For level classification, vertical and horizontal coordinate technique is used to classify level according to three conditions which are a pass, overfill and underfill. In this system, IP webcam is used to capture the image and stored in the Apache server so that it can be replaced at any time. The Graphical User Interface (GUI) is designed to make use is easier to monitor the system in real-time. In order to get high accuracy, the system is tested with 246 samples and 100% accuracy is achieved. Hence, this system has been proved that it can be used for SME application to maintain and control the quality of the product

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