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Shape Defect Detection using Local Standard Deviation and Rule-Based Classifier for Bottle Quality Inspection

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Abstract

This paper presents shape analysis using Local Standard Deviation (LSD) technique to detect shape defect of the bottle for product quality inspection. The proposed analysis framework includes segmentation, feature extraction, and classification. The shape of the bottle was segmented using LSD technique in order to obtain higher enhancement at the low contrast area and low enhancement at the high contrast area. The contrast gain that was applied in Adaptive Contrast Enhancement (ACE) algorithm, was presented inversely proportional to LSD in order to detect and eliminate background noise at the bottle edge. After the segmentation process, the parameters of the bottle shape such as height, width, area, and extent were extracted and applied in classification stage. The rule-based classifier was used to classify the shape of the bottle either good or defect. The offline experimental results exhibit superior segmentation on performance with 100% accuracy for 100 sample images. This shows that the LSD could be an effective technique to monitor the product quality.

Keywords: *Shape defect detection; Local Standard Deviation; Adaptive Contrast Enhancement*

1. Introduction

In the history of development and growth economics, visual inspection is widely used to monitor the product quality and reliability in manufacturing industries [1]. The automatic visual inspection is often being utilize by the industry because it provides high efficiency and accuracy during production and inspection processes [2]. Many commercial products such as textile, food, beverage, and medicine employed visual inspection to maintain their product quality. Product inspection in the industry is important because poor product quality will influence customer loyalty and it is not good for long-term marketing [3, 4].

The manual inspection in most manufacturing process mainly depends on human operator to inspect and monitor product quality. However, this traditional method is prone to human error during the inspection process due to fatigue, illness, dull and careless [5]. Generally, the Small and Medium Enterprise (SME) companies were fully utilized the manual inspection in the production line to produce products at low cost in short period of manufacturing process [6]. Therefore, an effective shape detection technique using image processing could enhance the manufacturing process and product quality because it provides high consistency, high accuracy and cost-effectiveness [7].

In shape detection technique, it is important to classify the shape of the object. Previous studies have reported a comparison between shape detection technique to select a proper technique in order to detect shape defect. Shape detection techniques such as adaptive thresholding, morphological operation, and edge detection were used to segment the object in the image [8]. Roy *et al.*, (2014) discovered adaptive thresholding was not capable to segment in the high illumination area of the image and bright image [9]. Meanwhile, morphological

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operation and edge detection techniques were less accurate and high in computational complexity for high-resolution image [10, 11].

In a study carried out by Cvetkovic *et al.,* (2007), Local Standard Deviation (LSD) is an effective technique to reduce noise in the image [12]. Thus, the image can be well segmented although there is an interruption such as illumination level during image acquisition. This paper presented the analysis of shape defect technique using LSD to obtain the precise shape for image segmentation. LSD offers contrast enhancement technique to improve the low contrast image. It is also low in computational complexity for image segmentation compared to the morphological operation and edge detection [13].

2. Research Method

The image was analysed using the Matlab software in detecting the defects of the bottle shape. Figure 1 shows the analysis framework using image processing technique. The sample image of the bottle (*n=100*) was obtained using digital camera. The image was then converted from RGB color into grayscale color. The shape of the bottle was segmented using LSD technique to extract the height, width, area, and extent of the bottle. The rule-based classifier was finally implemented to classify the shape defect of the bottle.

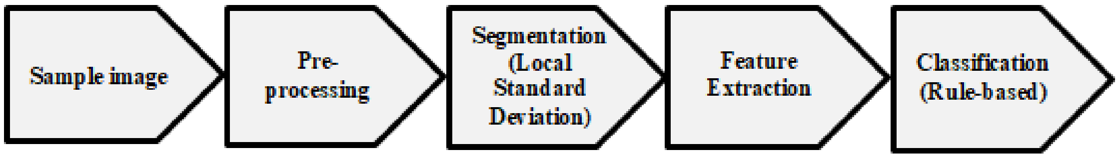


Figure 1. Analysis framework

2.1. Pre-Processing

Nikon D3100 digital camera with 14.2 Megapixel was used to capture the sample image in RGB color format. In the pre-processing stage, the RGB color was converted into grayscale color without changing the pixel value [14]. The brightness of the image pixel was adjusted to be the same value for all pixel's due to the uneven object illumination [15]. The smoothing process was carried out during the pre-processing stage to eliminate noise and enhance the image for further analysis [16].

2.2. Segmentation using Local Standard Deviation (LSD)

The LSD technique was applied in Adaptive Contrast Enhancement (ACE) algorithm. ACE algorithm is known as an unsharp masking technique that used for low-frequency component of the image [17]. ACE general equation is represented by.

$$f(i,j) = m_x(i,j) + G(i,j)\left[x(i,j) - m_x(i,j)\right] \quad (1)$$

where $m_x(i, j)$ is the local mean, $G(i, j)$ is the contrast gain and $x(i, j)$ is grayscale value for the image pixel.

The function of LSD used in ACE algorithm was to correct the low contrast of an image. Singh *et al.,* (2012) observed image enhancement with high contrast gain may cause ringing artifacts and noises to the image. Therefore, the contrast gain in ACE was presented inversely proportional to LSD in order to increase the LSD value and reduce the contrast gain value which detect and eliminate background noise at the object edge [18]. The used of different gain will reduce over enhancement in the image [19]. The LSD information can be expressed as.

$$f(i,j) = m_x(i,j) + \frac{D}{\sigma_x(i,j)}\left[x(i,j) - m_x(i,j)\right] \quad (2)$$

Where $x(i, j)$ is the grayscale value of the image pixel, $f(i, j)$ is enhanced value of $x(i, j)$, $m_x(i, j)$ is the local mean, $\sigma_x(i, j)$ is the LSD and D are a constant value. From equation 2, LSD is automatically controlled to set proper contrast gain value for the image. The function of grayscale value is shown in Figure 2(a) while the function of LSD is illustrated in Figure 2(b).

(a) (b)

Figure 2. Bottle image (a) Grayscale image, (b) LSD image

2.3. Feature Extraction

The feature of the bottle shape such as height, width, area, and extent were extracted from the binary image to obtain the details information. In this study, extent parameter was used to determine the ratio of the bottle because of its capability to obtain a similar ratio value of an object although the image has different pixel value [20], [21]. The extent formula is presented by.

$$Extent = \frac{Area\ of\ the\ object}{Area\ of\ bounding\ box} \quad (3)$$

The shape of the bottle was represented in the white pixel as 1 while background image was shown in the black pixel as 0. The area of the object was calculated from the binary image based on the value of 1 (white pixel). Meanwhile, the area of the bounding box was determined by.

$$Area\ of\ bounding\ box = height\ x\ width \quad (4)$$

Figure 3 shows bounding box dimension for a rectangle shape. The width and height of the image were measured within the range of x and y axes.

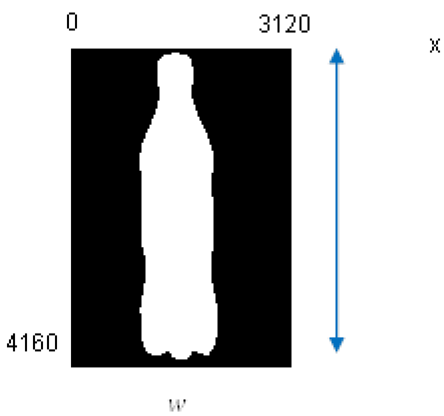


Figure 3. Bounding box dimension

2.4. Rule-based Classifier

The rule-based classifier was implemented in this study to classify the shape defect of the bottle. This is because rule-based offers simple algorithm, easy to understand and high classification performance in detecting the defects based on the given features [22]. In comparing with K-nearest neighbour (k-NN) classification, rule-based classifier can obtain high accuracy for the classification stage and low computation complexity [23]. While k-NN classifier is high computational complexity when increase the number of training data [24]. The shape of bottle is classified as defect condition when the extent value is less than x value or higher than y value. If the extent value is in between the range of x and y value, the bottle shape is in pass condition. The process of classification is illustrated in Figure 4.

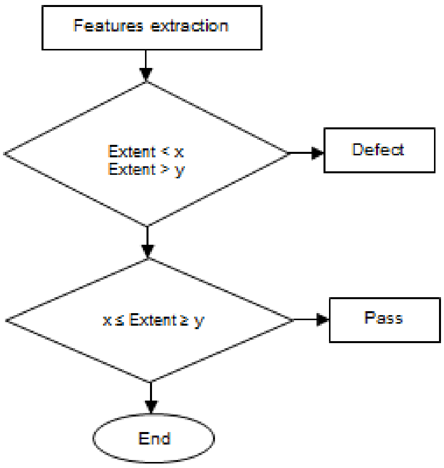


Figure 4. Classification process

3. Results and Analysis

The 100 samples of bottle image, consists of 50 good shape images and 50 shape defect images were analysed using image processing technique. Figure 5 and Figure 6 show the example of the good and defect shape of the bottle.

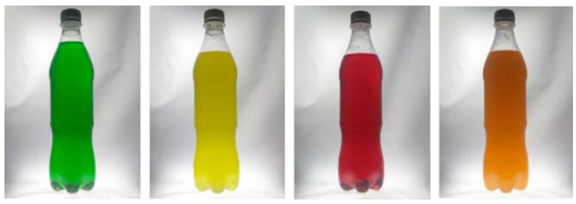


Figure 5. Examples of good shape of bottle image

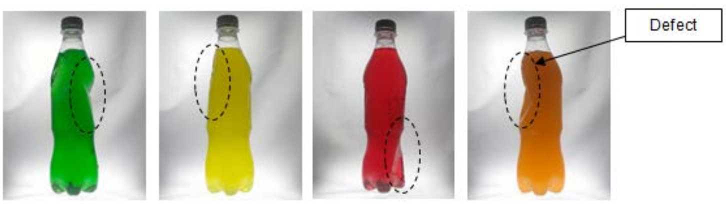
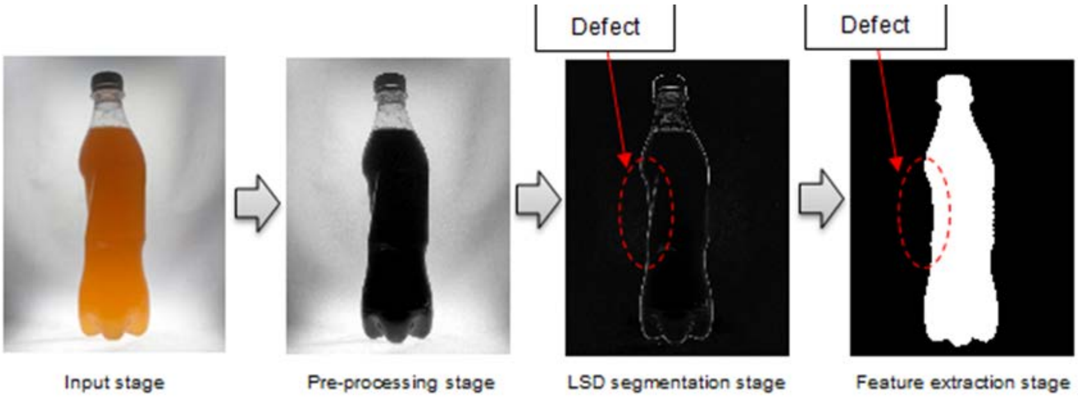


Figure 6. Examples of defect shape of bottle image

Figure 7 shows the shape analysis process for the defect bottle. The process was started with the conversion of red, green and blue (RGB) color image in Figure 7(a) into a grayscale image in Figure 7(b). The conversion process was applied to reduce the complexity during the analysis. RGB color images were unable to provide details information in order to identify the important edges or features of the object. Besides, the RGB image was easy to be exposed to the noise variations [25]. Thus, the conversion into the grayscale image was important in reducing complexity from 3 dimensional (3D) pixel value into 2 dimensional (2D) pixel value [26].



(a) (b) (c) (d)
Figure 7. Shape segmentation process

The grayscale image was then transformed into standard deviation image as shown in Figure 7(c). In this process, standard deviation algorithm was applied to segment the shape of the bottle by separating the bottle and the background image. The background noise at the edge of the bottle can be removed by increasing the value of LSD resulting the reduction of contrast gain of the image. Therefore, the shape of the bottle was outlined using the white line to separate between the shape of the bottle and the background image.

The standard deviation image was converted into a binary image as shown in Figure 7(d). The shape of the bottle was presented in white pixel (1) while the background image was in the black pixel (0). Finally, the feature extraction parameters were extracted to be used for the classification process where extent parameter was calculated based on the ratio of the bottle area and the bounding box area.

Four bottle parameters of height, width, area, and extent extracted from the good and defect shape images were tabulated in Table 1. As expected, both sample images have similar area of bounding box but different value of the bottle area. The area value for good bottle was higher compared to defect bottle which then influenced to the extent value.

Table 1. Parameters of bottle shape

Sample image	Area bounding box (pixel)	Area bottle (pixel)	Extent
Good1	1.29792e+07	3.52914e+06	0.2719
Good2	1.29792e+07	3.50918e+06	0.2704
Defect1	1.29792e+07	3.00041e+06	0.2312
Defect 2	1.29792e+07	3.24855e+06	0.2503

Figure 8 shows the rule-based classifier process to identify the defect shape of the bottle. The maximum and minimum of extent values were selected and used in the rule-based classifier algorithm. The range of the extent value was found to be between 0.2612 and 0.2761. From the rule-based classifier, if the extent value was greater than 0.2761 or lower than 0.2612, the shape of the bottle was classified as a defect condition. While if the extent value was in between 0.2612 and 0.2761, the shape of the bottle was classified as good condition.

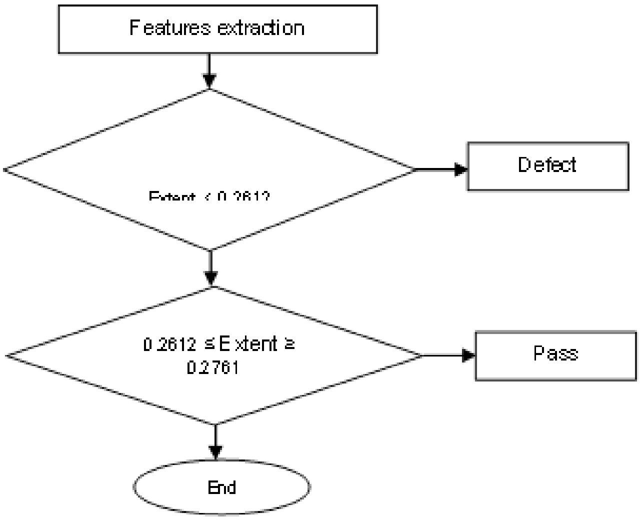


Figure 8. Rule-based classifier

The offline accuracy of good and defect bottle is illustrated in Figure 9. The experimental results show 100% accuracy for good and defect bottles based on 100 samples image. The performance of the analysis to classify the bottle shape defect is depends on the sample number of bottle image. Based on the percentage of the accuracy, it shows the proposed technique capable of detecting the shape defect effectively.

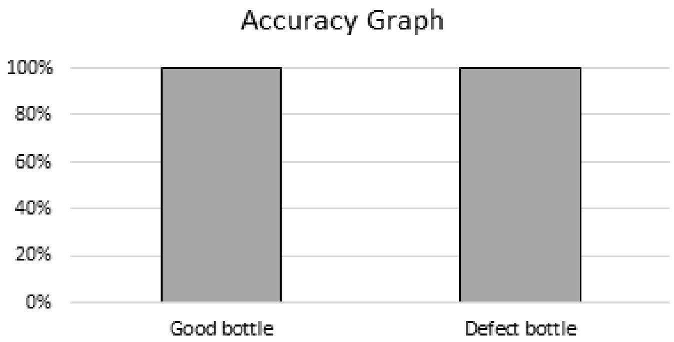


Figure 9. Accuracy graph

4. Conclusion

This paper presents the analysis of shape defect detection using LSD techniques. The first process is started with a pre-processing stage where the image is corrected and improved to eliminate the noise in the image. Then, LSD technique is used to segment the shape of the bottle. LSD technique shows the ability to segment the shape of the bottle very well by reducing contrast gain in the image. Next, parameters which are height, width, area, and extent parameters are extracted from the image. Extent parameter is used to calculate the ratio of the bottle area. Lastly, the rule-based classifier is applied to classify the defect of the shape bottle either good or defect. The performance of the technique was verified in terms of accuracy. From the experimental result, 100% accuracy was achieved to detect the shape defect of the bottle for 100 samples image. This indicates that the LSD technique could be an effective method to detect shape defect in manufacturing process.

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