Automated Visual Inspection for Bottle Caps Using Fuzzy Logic

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Abstract **– Automated Visual Inspection System (AVIS) has the capability to investigate large numbers of manufactured goods quickly and accurately. In addition, this system operates with a high level of reliability and consistency in their tasks. This study proposed an AVIS for detecting cap situations by using fuzzy logic classifiers. The objectives of this research are to develop an applicable image processing algorithm, together with a feature extraction technique, and to detect the cap for plastic bottles which is based on the average of distances. Three types of classification were compared for detecting the bottle caps. They are Mamdani, Sugeno, and production rule. The system was evaluated in a real time environment. The results are 97.91%, 97.5%, 96.66% accuracy for Mamdani, Sugeno, and production rule respectively.**

Keywords **– Automated Visual Inspection System (AVIS), Machine vision, Fuzzy logic, Bottle caps.**

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1. Introduction

Automated Visual Inspection System (AVIS) automates the process of inspection. According to the product images, AVIS is designed to make appropriate decisions in the quality control process automatically and to classify the results by using image processing and Artificial Intelligence (AI) techniques [1], [2].

Quality control is considered as an essential process in manufacturing sector [3]. It is commonly used in industrial robots [4]. AVIS is developed to inspect the products in manufacturing process to replace human inspectors due to the fact that manual inspection is time consuming, tedious, and low efficiency. AVIS is applied in various inspection applications such as electronic boards [5], [6], surface defect [3], [7], metal [1], [8], ceramic tile [9], and solar cell [10].

According to the previous researches [11], there is no industrial vision system capable of handling all tasks in every application field. It means that an appropriate machine vision system should be designed for a particular application and different applications have their requirements that should be produced [11]. In the packaging industry, plastic bottle packaging is one of the common applicable packaging styles. AVIS presents a wide range of applications providing rapid inspection systems that replace human vision in this industry.

In any industries for the higher profits, product sales must increase including the bottling industry. A poor quality product in the market affects low consumer confidence which consequently decreases sales and tarnishes the reputation among competitors who have higher quality products. Therefore, from the manufacturer to the consumer, it is necessary to provide secure systems in packaging for easy defects detection on packaged products in order to ascertain product reliability [12].

This paper is organized as follows. In section 2, some related works are reviewed. Section 3 provides the methodology and framework in details. Section 4 describes the experimental results and comparison of the proposed classification systems. Finally, this paper is summarized in the last section.

2. Related works

According to previous researches, there are many investigations which are focusing on bottle caps inspection. Some existing methods are discussed in this section.

In order to overcome the detection of error and low level adaptability issues, main breakthroughs in empty bottle inspection systems have been proposed. Those breakthroughs have two different approaches. The first breakthroughs identify the place of bottle mouth, bottle bottom and walls. The second breakthroughs involve defect detection [13].

Intelligent automated vision system was developed to inspect Glass bottle wall's defects by using Fuzzy Support Vector Machine (FSVM) classification and edge detector [14]. Another study has been done to investigate the lid of bottles by mathematical morphology and FSVM Neural Network (FSVMNN) classifier [15].

Automated real-time vision system using computer-network was developed to perform quality inspection based on color concentration and water level [16]. Color concentration used the histogram and quadratic distance. Then, coordinate vertical and horizontal reference levels were applied for the level inspection.

In the real environment, such as in the beverage industry, it is emphasized that container closure should be checked for defects in order to improve the inspection systems. Hence, a machine vision was developed with the capability of inspecting the dark container cap by measuring the hardware configurations [17].

In another study, a machine vision system was enhanced for fast detection of defects on the bottle caps surface [18]. The circular region was emphasized as the region of interests (ROI) from the surface of a bottle cap. The circular region projection histogram (CRPH) was used as the feature of the matching process.

Moreover, an AVIS for detection of cap was developed by using Back Propagation Neural Network and Sobel edge detector [19]. As mentioned in the previous studies, there are different types of classification systems in the bottling industry, such as Neural Networks (NN), Fuzzy logic and Support Vector Machine (SVM). SVM is usually suggested for a large set of data classification with unknown dependence [20].

Although NN has high ability for learning, the control rules are difficult to comprehend and time consuming for learning [21]. In addition, pattern extraction from imprecise data can be too complex for a simple system [22]. Fuzzy logic; a logic which uses a fuzzy set instead of normal and certain sets, can simulate human thinking with a high fault tolerance [15]. Therefore, the objective of this paper is to develop an algorithm by using a fuzzy logic classification in a real time environment to detect a misplaced cap.

3. Methodology

The proposed inspection system is a combination of hardware and software frameworks [23]. The hardware framework includes the setup of the experimental devices, such as a webcam, illumination sources (LEDs), and conveyor belt. The software framework includes Artificial Intelligence (AI) and image processing techniques.

3.1. Hardware framework

One of the major challenges in this study is the illumination source and the reflection problem during image capture. The structure of the modified system is shown in Figure 1. According to structure, the camera position is in the front of the moving bottles. In addition, there is a small LED lamp which is adjusted for illuminating the cap. Moreover, the black box is used for preventing noise and acquiring the image inside. The conveyor belt is operated to simulate a real time environment of moving the bottles at a desired speed.

Figure 1. Hardware framework

The exact configuration, the adjustment of distances for the LED and the camera; and the setup parameters for hardware installation are shown in Table 1.

Table 1. Experimental setup for cap inspection

Light source	White LED with 10 cm diameter
Background	Black
Camera	Logitech C190 Webcam 1080p
Distance of camera	15 cm from cap of bottle
Distance of LED	20 cm from top of bottle

3.2. Software Framework

The diagram for the proposed AVIS is shown in Figure 2. All steps to generate cap inspection system together with a demonstration of the relation between the modules are given in sequential. The diagram shows that there are five main stages: image acquisition, image enhancement, segmentation, feature extraction and classification.

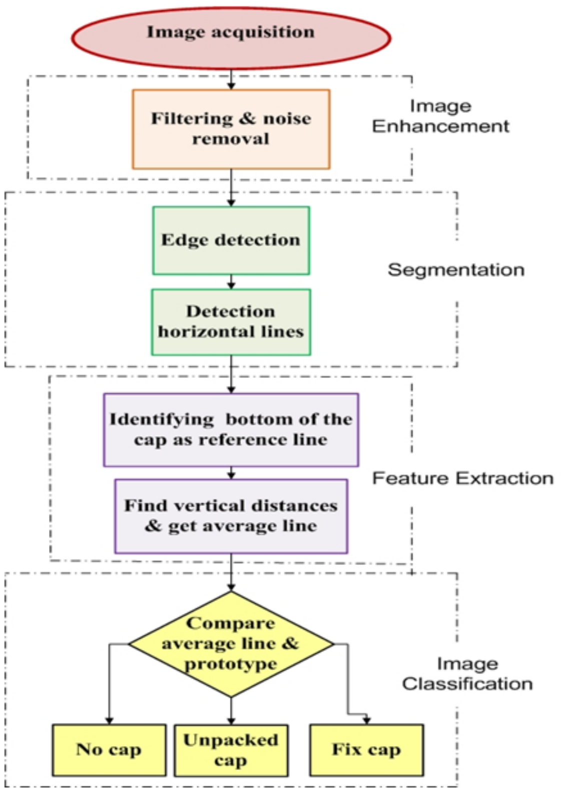


Figure 2. Proposed AVI for cap inspection

3.2.1. Image acquisition

In addition to the hardware setup, an image acquisition algorithm was prepared to capture the image of moving bottle and to provide the best image from the viewpoint of light and position. In this experiment, a webcam with a maximum resolution of 10 Megapixels is used to capture the images. The webcam is capable of grabbing 30 frames per second, with a high speed USB connected to the PC. The color spaces of Red, Green and Blue (RGB) are chosen and the capturing process starts by a trigger. The algorithm enters a loop for capturing the image. The camera takes the image continuously and then checks them to find the acceptable image. Each acquired image changes into a binary image by thresholding.

Furthermore, the small portion of the image is cropped and its inner white pixels counted. This technique determines if the object is inside of the picture and whether it is in an appropriate position for further processing. After that, the acceptable images are verified for not being continuous. In this case, the suitable image is confirmed and used for the experiment. Then, acting by a timer, the algorithm starts to perform the capturing process till the end of the process.

3.2.2. Image enhancement

After resizing the captured image, it should be enhanced to decrease unwanted noise. Image enhancement refers to the features related to the improvement process of an image for a specific application. In enhancement stage, for checking addition of gray scale transformation, a median filter is needed. One of the applicable methods that has the ability to improve data and remove noise is the median filter [24]. One of the advantages of the median filter with noise filtering is that it can also keep the edges and boundaries of the shape in an image. Besides, it computes easily. The algorithm starts by sorting neighboring pixels according to size on the window in order to find the middle gray level value as the value of the central pixels in the window. Generally, the window size is 3*3 [25].

3.2.3. Segmentation

This step demonstrates the highest efficiency. Since the system should also be able to identify horizontal lines, the segmentation technique is very necessary as it leads to this aim.

Thresholding

For the cap inspection, the thresholding method was applied. Thresholding technique segments the image into two colors, black and white, which are indicated as 0 and 1 in the image respectively. Different light condition causes significant variances in image colors and this has an effect on different binary images. Therefore, the image is captured with artificial light (LED) inside of a black box to achieve similar illumination conditions [26]. In this study, fix thresholding value was defined.

Edge detection

After thresholding, the edges are indicated. Thus, there is a need for an appropriate edge detector for the cap lines. So the Prewitt edge detection was applied.

Morphology operand

Mathematical Morphology (MM) is a theory and technique for the analysis and processing of geometrical structures. In this research, morphological opening is utilized to remove noise in order to reach the edges and lines more easily. Opening morphology removes small objects from a binary image. In fact, all connected components (noise) that have fewer than N pixels will be removed.

Horizontal line detection

Hough Transform (HT) was used to find the line of the edges in the image. According to the pixels on the edges, HT finds the connected line on the edges based on a determined limitation.

3.2.4. Feature extraction

This stage indicates a powerful feature for detection the three cap conditions. Based on proposed feature extraction techniques, distance values should be calculated [27]. For extracting distance values, it is necessary to obtain horizontal lines inside of cap part in an image. In all of the images after segmentation, there is a stable line on the neck of the bottle which is considered as a reference line. In fact, there are two lines: the top of the cap and the reference line at the bottom of the bottle cap. By using Hough Transform line detection, lines with more than 10 connected pixels are accepted as a line. All lines are in the region of the reference line (bottom of the cap) and top of the cap. The lines are then sorted from the upper line to the lower line in image. Thus, the two important lines for this method are found (the upper most and the lowest). For each point of the upper line, the difference between the y points is computed. In fact, the distance between the lowest y and the each point of upper line are calculated. Then, the average of these distances is determined. This value comprises the features for our comparison in the classification module. Another important parameter in this AVIS is finding the appropriate tolerance range of the average values, which should be formerly defined as a static value for result comparisons.

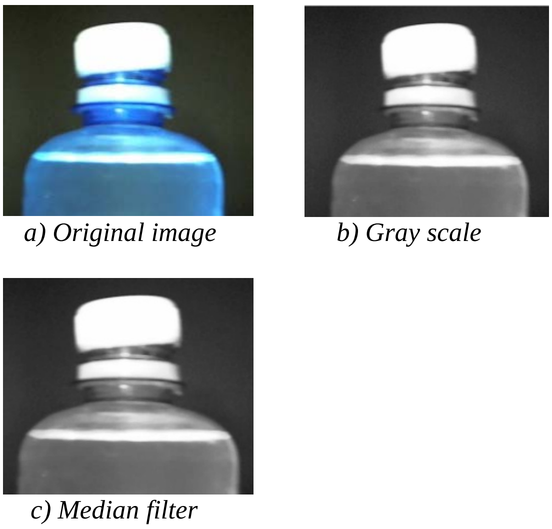
3.2.5. Image classification

In this step, the AVI system should classify the bottles into three cap situations: no cap, misplaced cap, and fixed cap. Fuzzy Logic classification methods are employed to achieve the results. The AVIS accepts the situation of fixed cap only. In this classification system, the average value from the previous step is applied as a feature for the fuzzy rule-based classifier. The Rule-based is useful for the problems in which the number of classes is fixed. In addition, the fuzzy rule-based is a powerful and feasible classifier. In this study, three types of rule-based systems are applied: production rule, Mamdani, and Sugeno. Therefore, these classification systems are employed and to be compared.

4. Results and discussion

This section is organized to demonstrate the results of the proposed detection method for bottle caps. The performance of the proposed AVIS is shown to estimate system efficiency. The outcome of applying this method in real time is analysed. Moreover, the results with different fuzzy classifications are compared. The output of the algorithm for misplaced cap situation is presented step by step as shown in the following figures.

Figure 3. shows the result of gray scale and median filter when a cap is misplaced.



a) Original image *b) Gray scale*

c) Median filter

Figure 3. The result of gray scale and median filter for a misplaced cap

The results of segmentation when a cap is misplaced are shown in Figure 4.

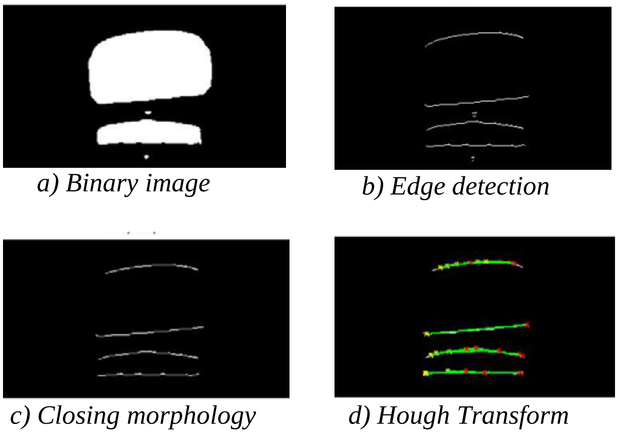


Figure 4. The result of segmentation when a cap is misplaced

Furthermore, feature extraction method is applied for a misplaced cap as shown in Figure 5.

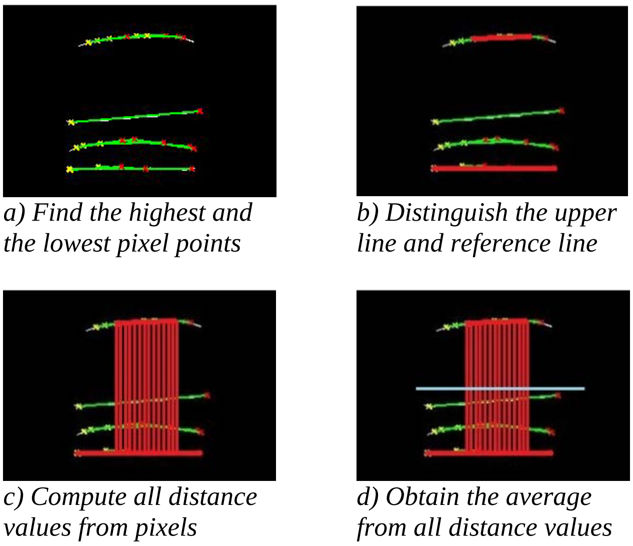


Figure 5. Feature extraction method for a misplaced cap

In order to compute the performance of proposed AVIS in a real time system, the accuracy for detecting three cap situations was evaluated. Three types of classification which are Mamdani, Sugeno, and production rule are applied. For each classification testing, 240 bottles were used in a real time experiment. The bottles are different in the case of cap position. The performance evaluation of cap detection for different classification methods is shown in Table 2.

Table 2. Performance evaluation of cap detection for each classification methods

Type of classification	Mamdani	Sugeno	Production rule
Accuracy (%)	97.91	97.5	96.66

Comparison of accuracy for cap detection by different classification methods with the parameter of NCC (Number of Correct Classification) is shown in Figure 6.

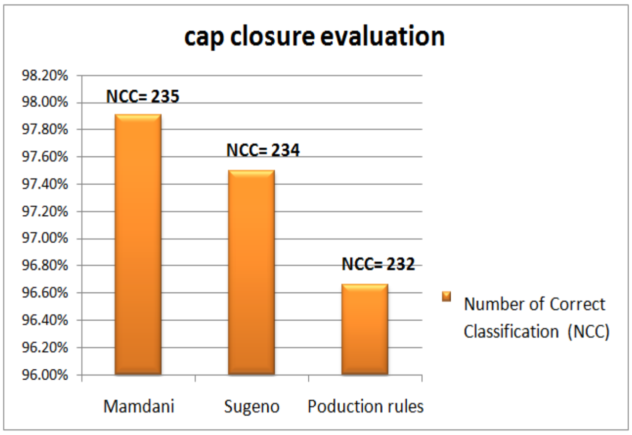


Figure 6. Comparison of accuracy for cap detection by different classifications

5. Conclusion

In this research, an Automated Visual Inspection System (AVIS) is developed in order to check cap of bottles. According to the experimental results, it can be concluded that the overall intelligent real time AVIS, by applying the proposed feature extraction algorithm, has the significance to be used in the quality control processes of the bottling industry. In addition, its low rate of error demonstrates the validation of the feature extraction algorithm and classification system, together with the feasibility of applying this study in industrial quality control inspection tasks.

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