Feature Extraction Algorithm for Fill Level and Cap Inspection in Bottling Machine

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***Abstract*—Automated Visual Inspection Systems (AVIS) have a strong ability to improve bottle manufacturing quality control by means of inspecting products automatically instead of through manual inspections. AVIS automatically tends to make a suitable decision in process and results classification according to the images of the products via image processing and Artificial Intelligence techniques. Since bottling is one of the most common packaging styles in the food and medical industries, in this paper we will concentrate on the visual inspection of bottles. Checking the quality of the cap closure and over-filling/under-filling checks for the level of the liquid in the bottle have been investigated to reach an optimized bottle product. Therefore, in this research general hardware and modules for these systems are investigated. Besides, new techniques of bottle inspection are reviewed along with presenting previous work of other researchers. Subsequently we will propose a feature extraction algorithm to inspect cap closure and level of the liquid in the bottle together, in the same system. According to the new proposed method, our system classifies three situations for cap condition and three situations for the condition of the level of the liquid. As a result the system has investigated 9 situations. The algorithm of the system will accept its system when the liquid level is in the correct position and the cap is in the normal condition. Other situations will be rejected. The proper algorithm which is proposed here using bottle visual inspection techniques leads our system to reach an optimized liquid level with a high quality of the cap closure.**

***Keywords*— Feature extraction, bottle inspection, cap closure, level of content detection.**

I. INTRODUCTION

Computer vision systems generally refer to the systems which extract desired features from digital images. Increasing the scene comprehension from input images is the main objective of these systems [1]. Application of the vision systems in industries in order to automate manufacturing process is considered as Machine Vision [2]. Also it is defined as Automated Visual Inspection (AVI) when attempts are made to inspect, control products and recognize the defects by using only product images (quality control) [3]. In fact, humans as inspectors are slower and their efficiency is affected by their states of exhaustion, illness or other human shortcomings. In some applications they need training to attain proper skills. Moreover, there are sometimes special environments which are dangerous and not conducive for human operation [2]. On the other hand, especially in the manufacturing environment, it is necessary to improve quality control and productivity in order to maintain an advantage over their competitors. Intelligent visual inspection systems (IVIS) are related to different subjects such as pattern recognition, image processing, machine learning, image analysis, signal processing and software and hardware behind artificial vision systems as well as Artificial Intelligent (AI) techniques. Therefore, extensive research has been done on AVIS to propose high levels of visual inspection through merging of these areas [4].

In this paper we will concentrate on the bottle industry (bottling machine) which is one of the major and applicable packaging methods in the packaging industries. Beverage and food industries, milk industries, medicine industries and other chemical product industries are the foremost samples of this work. In this area, accurate filling, inspecting cap closure, sorting recycling plastic bottle, recognition between glass bottle and pet bottles, inspection for over-fill or under-fill, verification of label quality and detection of defect products are some significant parameters which seem to be necessary to be inspected. Industrial vision systems are not able to handle all tasks in every field of application [2]. It means that each system due to its specific requirements and its limitations needs particular techniques that should be taken into account. Thus, for any application, particular requirements need to be defined reaching to an optimized system subject to its parameters. Therefore principle issues for any application should be discussed separately.

The basic components for all bottle visual inspection as for any other AVIS are revealed in Fig. 1. The first step of designing a visual inspection system is the image acquisition which is concerned about hardware equipment to increase quality of the initial image for further processing [5]. As we know, camera features (number, kind and position of camera), colour of background and speed of the conveyor belt have important consequences on the image quality. Additionally the position and brightness of the light are significant factors in the inspection system design (e.g. in reflectance especially when bottle is transparent) [9]. After image capturing, there is the necessary use of computational techniques to filter, analyze, restore, compress and reconstruct the images to remove various types of noise in the image and enhance its

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quality. Also, to simplify the digital image, pixels need to be partitioned and labelled. Lines or curves inside of the image should be identified properly. In fact relevant information from the image is required to be extracted to reduce the data sets. Based on the feature vector from the previous step, the identity of the object will be verified in order to decide in which class the inspected object belongs. The classes should be distinct and exclusive. Supervised classification can be used in this step. General classification algorithms have both training and testing parts for bottling machines. Neural networks, Fuzzy, SVM and Neural-fuzzy are some of the applicable classifiers.

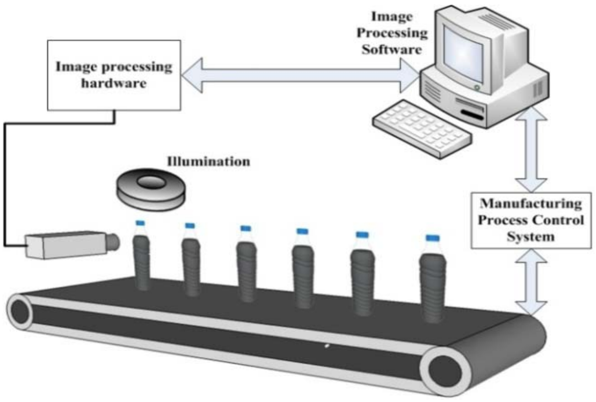


Fig. 1 General component for a typical bottling AVIS

In this paper, we have investigated basic principles of bottle visual inspection. Moreover, we have presented different methods and techniques for bottling machines and most recent algorithms have been stated. In this research, we have focused on investigating two quality inspections in bottles: cap closure and level of content detection. We have proposed AVIS which inspects these two parameters together. Besides, we have presented a Feature Extraction algorithm for detection of cap condition and level of content and it has been explained completely through figures.

II. Previous Work

In 2007, a low-end webcam within distance of 15 cm from cap of bottle is used for detection of cap closure. Also a dark background of bottle was selected and speed of the conveyor was 106 rpm. The accuracy of image acquisition has been reached to 94.264 % for a moving bottle. In order to enhance the image quality, they chose a proper threshold value to increase image contrast. The Sobel's algorithm was applied as an edge detection technique. Moreover a back propagation neural network system was applied to determine three bottle cap situations: without-cap and misplaced-cap situations will be rejected and a normal situation will gain acceptance [5].

In order to inspect level of content in a fusion bottle, HIK Vision DS-2CD812PF is used as IP Camera, Intranet, Computer and Alarm [6]. Also the Sobel's algorithm as the edge detection is applied and it is improved into two direction vertical and horizontal edges. It is said that image bineryzation has been applied to find out the threshold value and after that the filtering method is performed. To find horizontal lines, horizontal projection has been used. Author's technique has 99% accuracy when light is changing and 100% when infusion bottles are tilted.

The performance of Canny, Log and ISEF edge detection methods have been compared to measure levels of liquid in bottles. It is assumed that these methods are much more accurate compared to traditional methods [7], since another powerful technique in the image segmentation is thresholding. Two-dimensional Otsu algorithms proposed which indicate that one dimensional has more speed and resistance frontage of noise but do have some disadvantages that should be taken into account such as its need to use lots of space and having low accuracy when it is not enough [8].

In the case of bottle classification, there are different kinds of methods which are applicable in the bottle inspection technique. Chink defects in glass are detected bottles in order to recycle bottles by using low-level and high-level neural networks as in [10]. Moreover they have continued their work by Fuzzy Support Vector Machine (FSVM) and reached up to 98% accuracy [11]. Reference [12] in investigating lids of glass bottles have applied FSVM and later have classified their system by FSVMNN (Fuzzy Support Vector Machine Neural Networks) [13]. Their classifier is accurate up to 97%. Reference [14] in a case of improving training in neural network as a classifier, have proposed districted neural network which it is more powerful in pattern recognition. Reference [15] has used shapes and morphological operations to distinguish between different plastic bottles. In fact the morphological method has been applied for the feature extraction and obtaining of histograms. Besides they have considered neural network as a classifier. Their method reduces feature data sets properly.

In the specific case of the bottling machine a classification system is developed which is able to identify bottles from their colour and synthesis [16]. They applied a CCD camera along with a quadratic classifier for colour recognition. Another developed system for sorting plastic bottle composition was investigated as in [17]. They have presented automatic ROIS for extraction of features from plastic bottles in order to classify bottles into pet and non pet. The results show 80% accuracy.

III. Proposed Method

As we have explained before, in the bottle visual inspection systems, detection of the liquid level and cap closure have been inspected separately. In this paper, we will propose an Automatic Visual Inspection System (AVIS) which is capable of investigating both detection of liquid level and cap closure together in the bottling machine, something which has not been done yet. First we present the general modules and image processing methods which are essential in our systems. Then we will state our Feature Extraction (FE) technique. The figures are captured from plastic bottles.

A. *Proposed Modules*

In this part, essential modules for making this system have been explained step by step. There are seven modules, for which the relations between them are shown in a diagram (Fig. 2). In fact this diagram gives a general view of the proposed system.

1) Image acquisition condition: To reduce the light reflection problems in the bottles especially in glass bottles, we suppose LED as a lighting source. Also we assume our bottles are without any label. The background of the bottles will be light and the camera captures the image from one side of the bottles.

2) *Image enhancement (filtering):* In this step, for the removal of noise, filtering techniques are necessary.

3) Image segmentation: This step shows the most effectiveness in our study. Since this system should be able to identify horizontal lines as well, the edge detections such as Canny, Log and two dimensional Sobel will be applicable. We suggest applying the appropriate threshold for better edge detection.

4) Morphological technique: After using edge detection methods, morphological closing can be used to remove noise reaching to the edges and lines more noticeably.

5) *Feature extraction:* To detect the level of liquid content in the bottles and to investigate the cap condition, we will propose an appropriate algorithm in which two sub-algorithms introduced. Therefore, our system is separated into two main categories of cap checking and liquid level detection subject to their sub-algorithm. To extract the desired features, the first step in this algorithm is to find the region of interests. It means that the regions of the image which are relevant to get the desired information in the case of cap and level of liquid have to be selected. According to the Fig. 2, for the cap closure detection and the liquid level measurement, the algorithm should find two regions for each of the detections. Based on the main algorithm, one of the regions is determined by the reference line which is a line at the bottom of the bottle cap. Another important parameter in our algorithm is the prototype line which should be a defining former as a static value for result comparisons. The algorithm has been completely explained in the following part along with figures which demonstrate all regions and lines properly.

6) *Image classification:* In this step, the average line from the previous step should be compared with the prototype line. The prototype line is a determined line which is a constant criterion value for measuring expected liquid level and cap closure. The value of the prototype line will be considered separately subject to the case. Classification of liquid level and cap closure will be prepared separately. Different Neural Network techniques (NN) such as Back Propagation (BP) can be applied properly in this work. The output of our algorithm will be 3 cap conditions as the final result which are: no cap, unpacked cap and fixed cap. An acceptable condition is a sealed cap. Besides this, for the liquid level investigation, we will determine that the liquid level of the bottle is under-filled, over-filled or filled to the desired liquid level. The just-desired level is the acceptable condition in this case. Consequently this system has 9 different situations which are obtained by 3 conditions of liquid level multiplied by 3 conditions of cap investigations. If the cap is fixed and the liquid level is in the correct range of the bottle, the algorithm accepts its output, otherwise the output is rejected. Therefore, there are 8 rejection conditions. The diagram for the proposed AVIS is demonstrated in the Fig. 2. All steps to generate such system are shown step by step.

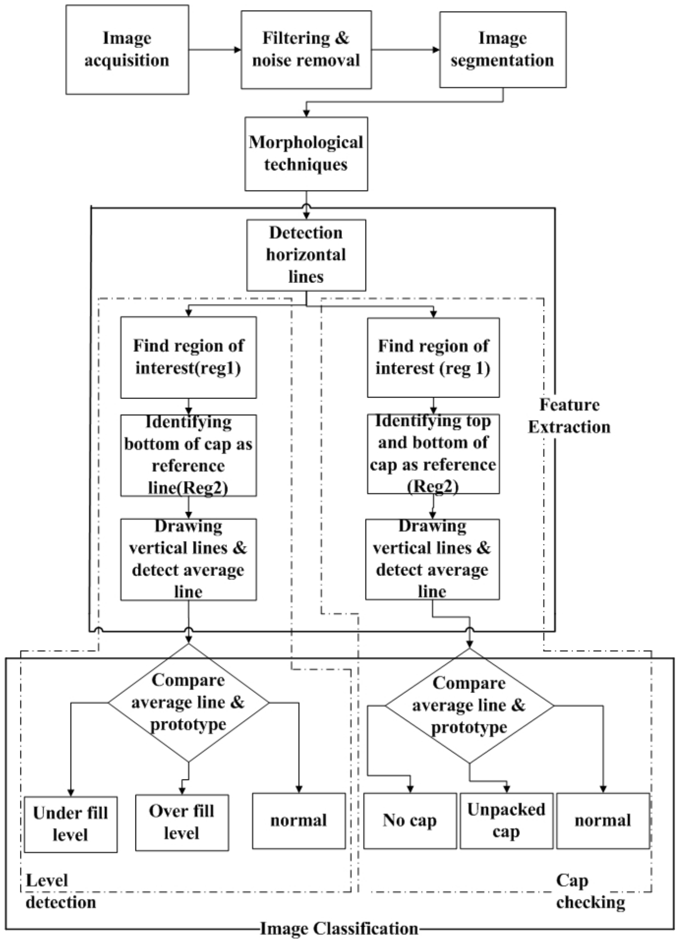


Fig. 2 Diagram for detect cap closure and level of content

B. *Technique*

As has been mentioned above, the proposed system in the Fig. 2 has the potential to detect cap closure and the level of the liquid content together by an appropriate algorithm, which has not been done yet. Table1 and Table2 show the main algorithm procedure for both liquid level detection and cap situation clearly. The main algorithm is included in two parts: part A and B. Part A belongs to the inspection of cap condition and part B is for level of content detection.

Level detection: to measure level of liquid contents we need to find two regions of interest (ROIs). We call the first one Reg1 (yellow box). This region starts from the bottom of the cap downward to the determined distance from the reference line. The reference line is a fixed horizontal line in the bottom of the cap (blue line in Fig. 3, 5, 6 and 7). Another region of interest (Reg2) that is essential in our system is determined from horizontal line detection (illustrated in Fig. 2).Then vertical lines from the image pixels in Reg2 which are positioned inside of the Reg. 1 should be considered to be illustrated. Next, the obtained lines of the previous step should be averaged in the whole domain when reaching towards the final result (Fig. 3, 5, 6 and 7).

TABLE 1
ALGORITHM FOR LEVEL OF CONTENT DETECTION

```
Algorithm 1
  1. Capturing  image
  2. Apply smoothing filter
  3. Using  edge detection
  4. Apply binarization technique on previous step
  5. Finding horizontal lines
  6. Distinct the horizontal line at the bottom of the cap
     as a Reference line ( R[i,j] )
  7. Draw a line as parallel as Reference line and level
     of content ( L[i.j]) as a Reg1

         For each i and j  on the L
           Define Prototype Line as  P[ i,
       Distance_Pixel ( L(i,j] AND R( i,j) ) / 2 ]
         End For

  8. Define area between reference line and longest
     horizontal line on top (H[i,j] )in top of the image
     as a Reg2.
       For each i AND j on the H
         Define Average Line as  A[ i, Distance_Pixel
       ( H(i,j] AND R( i,j) ) / 2 ]
       End For
  9. For Each i And j in A[i,j] and P[i,j]
       Dis_Value  =  Distance  (A[i,j]   ,  P[i,j])+
       Dis_Value
      End For

  10. IF ( Dis_Value > Threshold_Value )
                The level of liquid is over fill (Fig.6)
      ELSE IF ( Dis_Value < Threshold_Value)
                The bottle is under filled(Fig.5)
      ELSE
        the level of liquid is in appropriate situation
        (Fig. 3)
```

Cap condition: the algorithm of the detection location of the cap is the same as the liquid level detection. Fig. 3 (b), 5, 6 and 7 show the following explanations. In this type of inspection Reg1 starts from the reference line to the top of the cap. The Reg2 will be determined by means of the edge detection algorithm (Table 2) and vertical lines should be illustrated and an average obtained from them.

TABLE 2
ALGORITHM FOR DETECTION OF CAP CLOSURE CONDITION

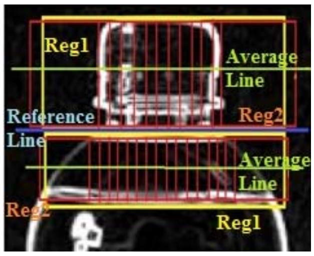
```
Algorithm 2
  1. Capturing  image
  2. Apply smoothing filter
  3. Using  edge detection
  4. Apply binarization technique on previous step
  5. Finding horizontal lines
  6. Distinct the horizontal line at the bottom of the
     cap as a Reference line ( R[i,j] )
  7. Draw a line as parallel as Reference line and the
     cap (L [i.j]) as a Reg1.

         For each i and j  on the L
           Define Prototype Line as  P[ i,
       Distance_Pixel ( L(i,j] AND R( i,j) ) / 2 ].
         End For

  8. Define area between reference line and longest
     horizontal line on top ( H[i,j] )in top of image as
     a Reg2
       For each i AND j on the H
         Define Average Line as  A[ i,
       Distance_Pixel ( H(i,j] AND R( i,j) ) / 2 ]
       End For
  9. For Each i And j in A[i,j] and P[i,j]
       Dis_Value  =  Distance  (A[i,j]   ,  P[i,j])+
       Dis_Value
      End For
  10. IF ( Dis_Value > Threshold_Value )
                The bottle is without cap(Fig.5)
      ELSE IF ( Dis_Value < Threshold_Value)
                The cap of bottle is not fixed(Fig.6)
      ELSE
        the cap is in appropriate situation (Fig. 3)
```

To detect rejected conditions as well as the accepted one, we require an enhancing image in order to obtain clear horizontal lines and an abstract image from the background. Fig. 3 (a) is the original image and Fig. 3 (b) is the enhanced image which displays only accepted conditions while the level is in the correct position and the cap is fixed. In the Fig. 3 (b) regions of interests (Reg1 and Reg2) according to the algorithm (Fig. 2) are drawn. Next, average lines are calculated to be compared with prototypes lines.

(a) Original image



(b) Enhanced image with horizontal and vertical lines

Fig. 3 Accept situation, cap and level are normal

There are eight reject situations for cap and level. All of them are demonstrated in Fig. 4 (a)-(h).

(a) No cap, liquid is over fill

(b) Unfixed cap, liquid is over fill

(c) No cap, normal level

(d) Unfixed cap, normal level

(e) Normal cap, over fill liquid

(f) Normal cap, under fill liquid

(g) Unfixed cap, under fill liquid

(h) No cap, under fill liquid

Fig.4 Eight reject situations

Regarding Fig. 4, even if any rejected condition of level detection or cap closure happens, our system should recognize it as a rejection condition. For example if the cap is in the fixed condition but the liquid level is under-filled (Fig. 4 (e)), the system rejects this bottle. The algorithm for identifying cap condition is shown in Table 1. To make clear the situation of the rejected conditions, the Fig. 5 has been illustrated.

Fig. 5 reveals an enhanced image of Fig. 4 (b). It is illustrated in the case of a no-cap condition but the level is in a good situation. In this case the average line from vertical lines in the cap area is less than the prototype line, so according to Table 1, this feature demonstrates a no-cap situation. However the average line for the level is in a proper range.

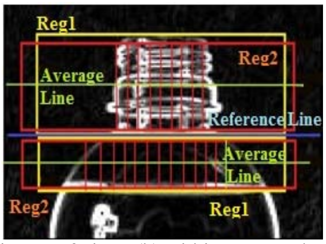


Fig. 5 Enhanced image of Fig. 4 (b) within Reg1 and Reg2 and average lines

In the Fig. 6, the cap is not fixed but the level is correct. Since Reg2 around the cap region is not rectangular, the average line will be at the top of the prototype line. So according to the Table 1, this situation demonstrates that the cap is not fixed.

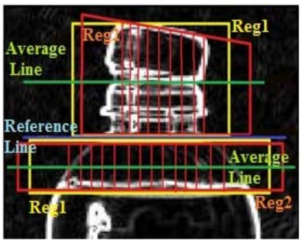


Fig. 6 Enhanced image of Fig. 4 (c) within Reg1 and Reg2 and average lines

According to the Fig. 7 for liquid level detection there is no average line. So this state will be considered as an under-filled condition which will be rejected.

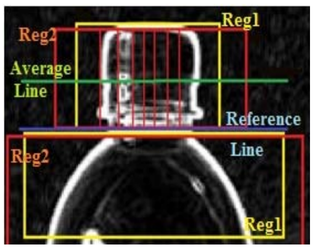


Fig. 7 Enhanced image of Fig. 4 (g) within Reg1 and Reg2 and average lines

C. *Hardware Setup*

As we explained before, the experimental setup has a vital role in all AVI systems in order to capture the best image. So in Table 3, we have cleared some experimental conditions like source lights, kind and number of cameras, distances between bottle and cameras and speed of moving bottle on the conveyor. Besides we have suggested using the C++ programming language.

TABLE 3
EXPERIMENT SETUP

Light source	One white LED
Background	Black
Speed of conveyor belt	10 m/Second
camera	One Webcam
Distance of camera from bottle	15-20 cm from cap of bottle
Kind of bottle	Plastic bottle without label
Programming language	C++

IV. DISCUSSION

An accurate level of the content and detection of the cap closure are two main challenges in the bottling packaging quality. So in this paper, we have proposed a new Feature Extraction (FE) technique to investigate these two parameters in one AVIS. The advantage of our system is to improve inspection by one algorithm which simplifies this system. For each of the features, there are 3 situations. So our techniques should be able to classify the results in 9 situations: no cap-liquid is over-filled, unfixed cap-liquid is over-filled, no cap-normal level, unfixed cap-normal level, normal cap-over-filled liquid, normal cap-under-filled liquid, unfixed cap-under-filled liquid, no cap, under-filled liquid and normal cap-normal level of content. However, the AVIS presented here seems to be potentially powerful to detect cap and level of content situations by the FE algorithm; we predicted the system will have difficulty while the level is too low or empty. It means that it may baffle two cases of the empty bottle with the full ones.

V. CONCLUSIONS

Since one of the most popular topics in industry is the automated visual inspection system and bottles are applicable in the food and medical industries, we have investigated general issues in the bottle inspection systems. Besides increasing the quality of the bottle packaging style we have concentrated on inspection of the cap closure and level of the liquid content in the bottle. We have proposed a system which will be able to inspect these two parameters together at the same time in an appropriate algorithm. The expected results from the system have been discussed in detail.

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