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EMPTY AND FILLED BOTTLE INSPECTION SYSTEM

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Abstract

Automated Visual Inspection System (AVIS) have a strong ability for quality control in manufacturing industries by inspecting products automatically instead of manual inspections. This paper gives methods for bottle inspection in manufacturing industries. The paper describes mechanism for the defect detection, top and bottom detection, cap placement and fill level inspection. For empty bottle inspection the image is processed by contrast enhancement and then circular Hough transform is used. The location and radius of top and bottom of bottle is analyzed. After filling the bottle with liquid and placing the cap, edge detection method is used which is followed by horizontal line detection to identify whether fill level and cap closure is appropriate or not. Presented bottle inspection system works with 100% accuracy in proper illumination condition.

***Keywords*:**

Bottle Shape Inspection, Circular Hough Transform, Liquid Fill Level Detection, Cap Closure Identification, Boundary Extraction

1. INTRODUCTION

Machine vision system provides computer desirable understanding of objects from single image or array of images. Application of machine vision systems in industries improves productivity as well as the quality of the product manufactured. Visual inspection by humans has many flaws. It is quite tedious and time consuming. Automated Visual Inspection (AVI) is handy tool in PCB manufacturing, textile production, food and beverages packaging, in metal industry and many others for recognition of defects encountered during making. Bottles are major packaging methods in major industries, like beverages, milk, medicine and other chemical products. Automated bottle inspection includes, recognition between glass bottle and pet bottles, defects in shape of pet bottles, inspection for over-fill, under-fill or appropriate fill of liquid, cap placement, verification of label, detection of quality and defect in products etc. For various parameters, requirements are different hence, diverse techniques are essential. In this paper, a work on defect detection, inspecting top and bottom detection of bottle, fill level and cap placement of filled bottle is reported.

2. PREVIOUS WORK

In reference [1] for bottle top and bottom inspection, first image is processed by applying denoising, contrast enhancement and edge detection. For bottle top and bottom inspection, least square method followed by chain code tracing for the circumference and randomized Hough transform for location of the center is used. Reference [2] use Sobel operator for edge detection. Cap condition and fill level inspection is done by defining two region of interest to determine the distance between the reference line and fill level line. The study of Hough transform where the method includes standard Hough transform (SHT), Gerig and Klien Hough transform (GKHT), modified fast Hough transform (MFHT), 2-1 Hough transform, Gerig Hough transform with gradient (GHTG) etc are presented in [4]. SHT requires large storage requirement for images of different sizes, while GHTG performs better than 2-1HT in the sense of robustness.

3. BOTTLE INSPECTION

In bottle inspection system there are four stages as indicated in Fig.1. First empty bottle is checked for shape and top as well as bottom alignment. If it is found proper then liquid is filled and fill level is checked. Finally, cap placement is verified before final dispatch.

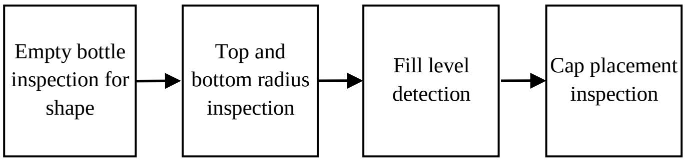
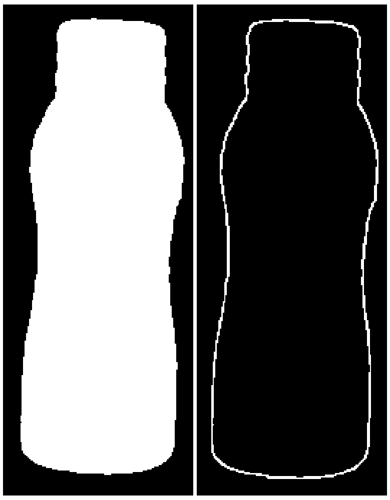


Fig.1. Stages for bottle inspection system

3.1 EMPTY BOTTLE SHAPE INSPECTION

In industries there is a possibility of deformation of shape during transportation of bottle from one section to another. So after the fabrication of bottle and before filling it with liquid, it is necessary to inspect the shape.

(a) (b)

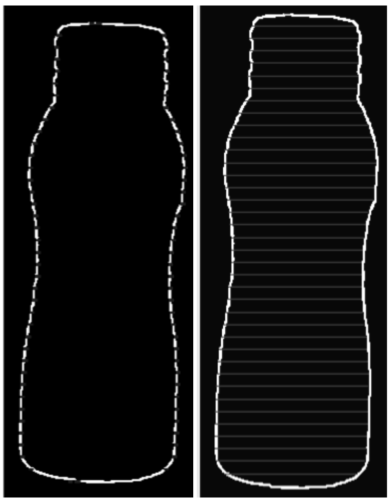


(c) (d)

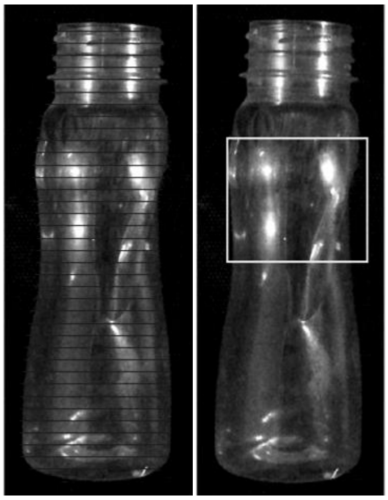
Fig.2. (a) Original image (b) Binary image (c) Image after noise removal (d) Boundary extracted image

As shown in Fig.2(a) original image of bottle is captured with dark (preferably black) background. Using thresholding binary image is generated such that the bottle can be highlighted which is our foreground (white) and the background is black. Morphological opening process is used in order to remove the small protrusions around the bottle and the result of this procedure is shown in Fig.2(c). After getting the seamless image, boundary of the bottle is extracted using boundary extraction process as shown in Fig.2(d).

The boundary extracted image is scanned and the horizontal distance between the boundary points is found as indicated in Fig.3(a). For selecting boundary points, vertical interval of 25 pixels is considered which results in a matrix of horizontal distances. Bottles with such horizontal lines are shown in Fig.3(b) and Fig.3(c) for reference and defective bottle respectively. Such matrix is calculated for each bottle and its absolute difference from the reference bottle matrix is computed. If any deformity is present then large difference is found in computation. Detected defective area is shown in Fig.4(d). These same steps can be used to detect the deformity at the base of the bottle also.



(a) (b)



(c) (d)

Fig.3. (a) Points of interest on boundary of reference bottle (b) Distances between points of interest (c) Defected bottle (d) Actual defective area detected

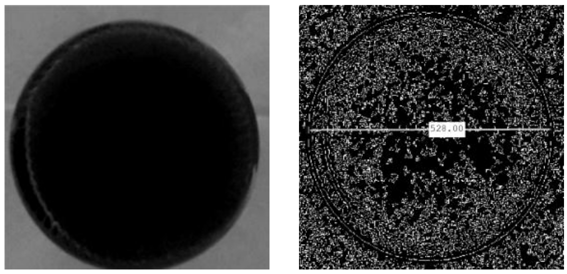
3.2 TOP AND BOTTOM INSPECTION

If the shape of the bottle is proper, the radius of the top and bottom have to be examined using edge detection and circular Hough transform. By using Canny or Sobel operator edges of the object is detected as shown in Fig.4. First step in process is to apply Gaussian filter to smooth the image. Intensity gradient of each pixel is computed using Eq.(1) and direction of the gradient is given by Eq.(2).

$$|G| = \sqrt{Gx^2 + Gy^2} \tag{1}$$

$$\theta = \text{arc } \tan \frac{Gy}{Gx} \tag{2}$$

To get rid of spurious response to edge detection non-maximal suppression is applied which results in thin edges. There are still some edge pixels at this point caused by noise and color variation. To remove them and to determine potential edges double thresholding is applied. After that all the other edges that are weak and not connected to strong edges are suppressed.



(a) Original image (b) Canny edge Detection

Fig.4. (a) Original bottom of bottle (b) Applying canny edge detection

Circle detection method is used to find the centre and radius of circle. In this paper circular Hough transform technique (CHT) is applied for finding circles in images. This approach has been adopted because of its robustness in the presence of noise, occlusion and varying illumination. The parametric equation of the circle can be written as Eq.(3).

$$(x-a)^2+(y-b)^2=r^2 \quad (3)$$

here, (a, i) are center of circle and r is its radius. (x_i, y_i) are arbitrary edge points transformed into right circular cone in the (a, b, r) parameter space. Point of intersection of cones is a single point in (a, b, r) if image points lie on circle.

The classical Hough transform requires a 3-D array for storing votes for multiple radii, which results in large storage requirements and long processing times. The phase coding solves this problem by using a single 2-D accumulator array for all the radii. The basic steps involved in the computation are:

Accumulator array computation

The pixels with high gradient are considered as candidate pixel, which are allowed to cast 'votes' in the accumulator array. The pixels vote in pattern around them form a full circle of fixed radius as shown in Fig.5.

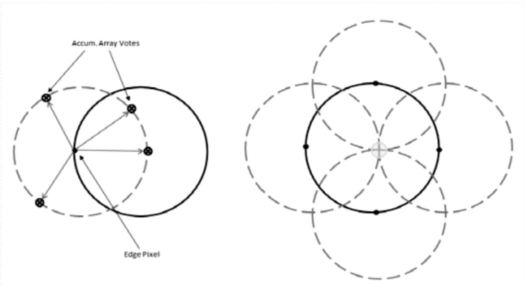


Fig.5. Classical CHT voting pattern [6]

Center Estimation

The votes of candidate pixels belonging to the circle tend to accumulate at the accumulator array bin corresponding to the circle's center. Therefore, the circle centres are estimated by detecting the peaks in the accumulator array.

Radius Estimation

In phase coding method, it makes use of complex values in the accumulator array with the radius information encoded in the phase of the array entries. The votes cast by the edge pixels contain information not only about the possible center locations but also about the radius of the circle associated with the center location. The radius can be estimated by simply decoding the phase information from the estimated center location in the accumulator array.

3.3 FILL LEVEL AND CAP PLACEMENT

After top and bottom inspection of empty bottle the liquid is filled and cap is placed on the bottle. Then the bottle enters the fill level and cap inspection system.

The captured image is first converted to gray scale image to reduce the computational complexity. The main aim is to detect horizontal lines so edge detection algorithm like Sobel or Canny can be applied. To acquire sharp edges Canny edge detection algorithm is used where it convolves the image with the horizontal mask as shown in Fig.6. After extraction of horizontal lines, morphological opening is applied to remove noise reaching to the edges and lines more noticeably.

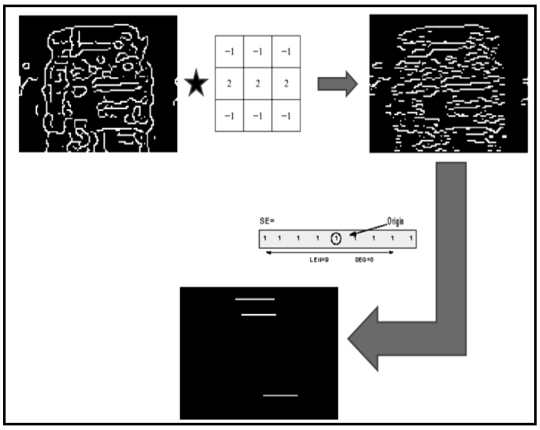


Fig.6. Steps to retain horizontal lines

4. EXPERIMENTAL SETUP

In the experimental setup 3 cameras are used as shown in Fig.7. Camera 1 and Camera 3 are used to capture the images of top and bottom respectively. They are positioned above and below the bottle such that focus of camera 1 and camera 3 lie on the same axis. Camera 2 is placed exactly in front of bottle such that it captures the cap and the fill level of the bottle. The images captured by the cameras are given as input to the inspection system which processes the image and generates the required output. Setup details for bottle are shown in Table.1.

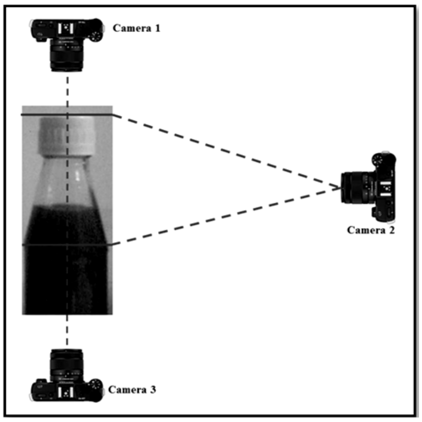


Fig.7. Camera positions in experimental setup

Table.1. Video details

Frame rate	30 fps
Size of each frame (in pixels)	480 x 640
Total number of frames for each bottle	750-800
Optimum frames	Between 375-400
Distance of camera from bottle	Approx. 30-35 cm
Background for shape inspection	Black
Background for fill level, cap placement inspection	White

In this experimental setup, bottles are moving on conveyer belt and depending on speed of belt; number of frames for each bottle are variable. It is necessary to detect optimum frame for processing bottle inspection such that bottle is at the centre of the frame. To serve the purpose, vertical line detection is applied and if the vertical edge of the bottle lies in the specified range, the frame is extracted and further processing is done.

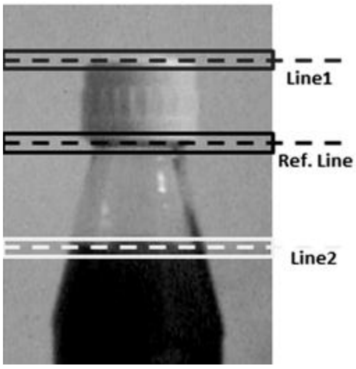
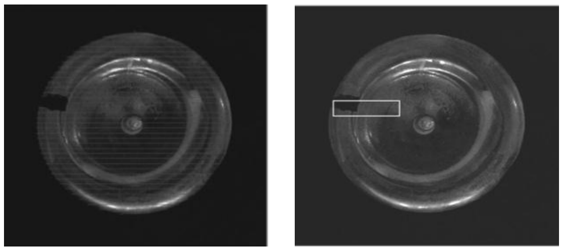


Fig.8. Bottle image with reference line, Line1 for cap placement and Line2 for fill level

All the distances in vertical direction will be measured from the reference line as shown in Fig.8. The neck of the bottle is taken as the reference. As shown in Fig.8, horizontal line detected at the top of the cap is taken as Line1. To detect the placement of the cap the distance between Line1 and reference line is measured. Proper cap placement is identified if the distance between these lines is equal to the height of the cap. If the distance between the reference line and Line1 is not equal to the cap height or no horizontal line is detected in red region then cap is not placed properly.

Fig.9. Proper fill level and cap placement

For standard fill level distance between reference and fill level (Line2) is specified. If the distance between reference line and Line2 is equal to the standard distance then fill level is proper. If line is not detected in the range shown by the yellow box then fill level is not proper. As shown in Fig.9 actual bottle is tested and proper fill level and cap placement is detected. Bottle with defective bottom is tested as per mechanism discussed in section III and result for defect detected is shown in Fig.10.

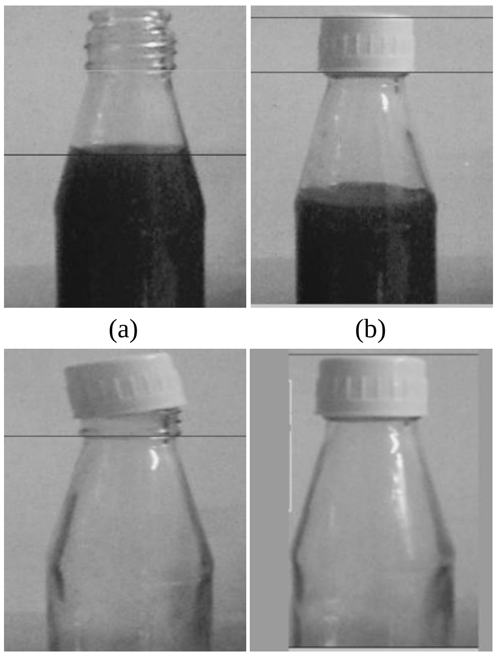


(a) (b)

Fig.10. (a) Defected bottle (b) Defect detected where the horizontal distance was less

After verifying bottle for shape deformity and defect at top or bottom, radius of bottle bottom is measured and alignment of top and bottom is checked. The Fig.11 indicates top and bottom circles of bottle and their centre as well as radius is computed. The Fig.12 shows various cases of inspection for glass bottle like cap not placed but fill level is proper, cap placed properly but fill level is not proper, cap not placed properly as well as fill level is not proper. If fill level is not proper or bottle is not filled, both cases are showing error. Similar results for plastic bottle are shown in Fig.13 and Fig.14 respectively.

Fig.11. Top and bottle radius inspection (glass bottle)

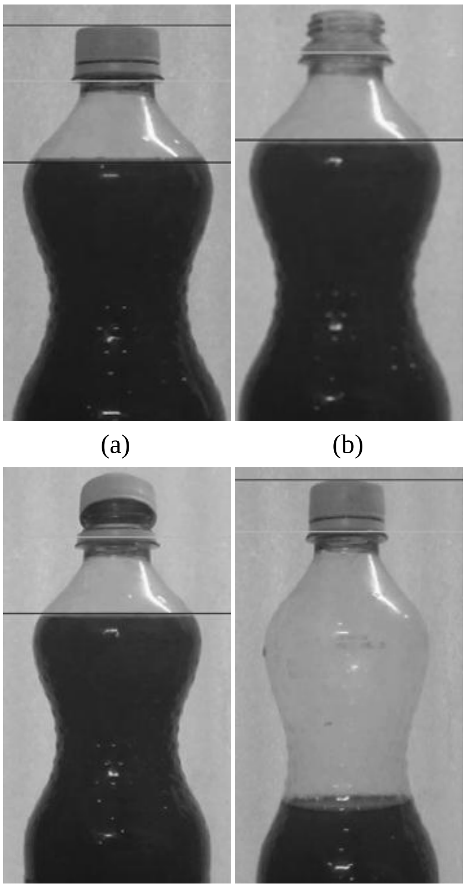


(a) (b)

(c) (d)

Fig.12. (a) Cap not placed, fill level proper (b) Cap placed properly, Fill level is not proper (c) Cap not placed properly, Fill level is not proper (d) Cap placed properly, fill level is not proper

Fig.13. Top and bottle inspection (plastic bottle)



(a) (b) (c) (d)

Fig.14. (a) Cap placed properly, fill level proper (b) Cap not placed, Fill level is proper (c) Cap not placed properly, Fill level is proper (d) Cap placed properly, fill level is not proper

With experimental setup described various bottles are tested in diverse lighting condition. If light is improper then edges are not detected as per requirement and false detection takes place. Analysis for shape inspection, top and bottom inspection as well as fill level and cap placement are shown in Table.2. If light is proper and frame captured is having appropriate illumination and contrast then system works with 100% accuracy.

Table.2. Result analysis

	No. of bottle tested	**No. of correct detections**	**Accuracy**
Bottle shape inspection	15	13	86%
Bottle bottom and top inspection	50	47	94%
Fill level and cap placement detection with diverse illumination	75	66	88%
Fill level and cap placement detection with proper illumination	75	75	100%

5. CONCLUSION

Bottle manufacturing and packaging industries are the key areas which require inspection through machine vision. In this paper, for shape inspection boundary extraction is used. For bottle top and bottom inspection edge detection and CHT are used. For cap closure and fill level inspection horizontal line detection is applied. Experimental results are discussed in detail for both the algorithm.

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