2019 7th International Conference on Robot Intelligence Technology and Applications (RiTA)
November 1 - 3, 2019, Daejeon, Korea

Vision-based Liquid Level Detection in Amber Glass Bottles using OpenCV

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Abstract— **All manufacturing processes, from raw material processing to electronics fabrication, require quality control to ensure consistency across all products of same specifications. It helps establish the reputation of a certain brand, gain customer loyalty, and maximize profit. In the bottle filling industry, it is important to ensure that the amount of product in each bottle is consistent with the packaging label. Less than that, the company may lose customers and face legal consequences; more and the company loses profit by giving more than what was marketed. This study makes use of a vision-based technique in detecting the liquid level in amber glass bottles. The proposed system has applied Python and OpenCV for the pre-processing and image processing. Moreover, the study was successful in detecting and classifying filled bottles into three categories: under-fill, within target and over-fill.**

Keywords— Canny edge detection, image processing, level detection, OpenCV

I. Introduction

The conventional way to ensure that fill levels are correct and consistent involve routine inspection by trained staff. Not only is this method labor-intensive and costly, it is also highly subjective as each person's perspective may vary in spite of having undergone the same training. To solve this, several manufacturing sectors have started using computers and artificial intelligence to aid in quality control, instead of having humans constantly checking for problems and flaws in production lines. Cameras and video recorders, coupled with image processing, have been used to monitor defects, inconsistencies, and the like. Aside from eliminating human bias and reducing the required labor, using a machine vision system also speeds up the process and reduces human contact, thereby reducing chances of contamination.

Systems which use image processing techniques for fill level monitoring have been developed and marketed for use in the industry. However, such systems are expensive and are mostly purchased by large manufacturing companies only. Researchers have proposed the use of different algorithms, aiming to find a simple but reliable way to detect cases of overfill and under-fill. Some have proposed the use of an edge detection technique, such as Laplacian of the Gaussian (LoG) [1], Canny [2] and infinite symmetric exponential filter (ISEF) [4], then taking the average distance between the liquid level and the cap's bottom edge [5]. A message is then triggered indicating if and whether the bottle is overfilled, under-filled, or within the acceptable range.

Previous studies on liquid level detection with smart vision have used clear bottles which are relatively easy to work with, but certain products require the use of amber bottles as they contain photosensitive ingredients. Such products can be found in the pharmaceutical industry where quality control is extra critical. Certain pharmaceuticals must be consumed as prescribed lest health complications may occur. In this study, an algorithm for liquid level monitoring was proposed and tested with amber bottles. Execution of the algorithm was done using *Python* and the *OpenCV* library.

II. Canny-Edge Detection

The Canny-edge detection specified three issues that an edge detector must address: error rate, localization and response. With the error rate, the edge detector should respond not only to edges and should find all of them, therefore, no edges should be missed out. The localization is the distance between the edge pixels as determined by the edge detector where the actual edge should be as small as possible. For the response, the edge detector should not identify multiple edge pixels where only a single edge exits.

Assuming a step edge subject to white Gaussian noise, the edge detector was assumed to be a convolution filter f which would smoothen the noise and locate the edge. The value of the signal-to-noise ratio (SNR) is the output signal-to-noise ratio and should be as large as possible. The localization value represents the reciprocal of the distance of the located edge from the true edge and should be as large as possible, which means that the distance would be as small as possible.

Canny attempts to find the filter, f, that maximizes the product SNR*localization subject to the multiple response constraint, and while the result is too complex to be solved analytically, an efficient approximation turns out to be the first derivative of a Gaussian function.

The Canny edge detection follow these steps: (1) read the image, I, to be processed, (2) create a one-dimensional Gaussian mask, G, to convolve with I, (3) create a 1-dimensional mask for the first derivative of the Gaussian in the x and y directions (Gx and Gy), (4) convolve I with G along the rows to give the x component image, Ix, and down the columns to give the y component image, Iy, (5) convolve Ix with Gx to give Ix', the x component of the I convolved with the derivative of the Gaussian and convolve Iy with Gy to give Iy', and lastly, (6) compute the magnitude of the edge response by combining the x and y components.

III. Methodology

An amber glass Boston round bottle filled with tap water was used to take three images corresponding to an over-filled (see Fig. 1), within target (see Fig. 2), and an under-filled bottle (see Fig. 3). These images were captured using a 4128 x 3096 CMOS camera of a smartphone. Images are aligned with respect to the lined aluminum cap's tuck-under and were cropped to form 4" x 4" images. There was no need to measure the actual volume of the liquid in each scenario as the differences in the liquid levels are apparent.

Fig. 1 Original image of an over-filled bottle

Fig. 2 Original image of a bottle with a volume fill within target

Fig. 3 Original image of an under-filled bottle

Images were processed using Pithadiya et al.'s algorithm [5] integrated with additional image pre-processing techniques [6][7] in deciding the bottle filling level, which will be based on distances from the center of the region of interest (ROI). The algorithm is as follows:

- Capture the image from Figures 1, 2 and 3.
- Convert all these images to grayscale.
- Blur using a Gaussian filter with 7 x 7 kernel (see Fig. 4, 5 and 6).

Fig. 4 Blurred grayscale image of an over-filled bottle

Fig. 5 Blurred grayscale image of a bottle with volume fill within target

Fig. 6 Blurred grayscale image of an under-filled bottle

- Apply Canny edge detection at [55, 110] threshold and morphological closing (see Fig. 7, 8 and 9).

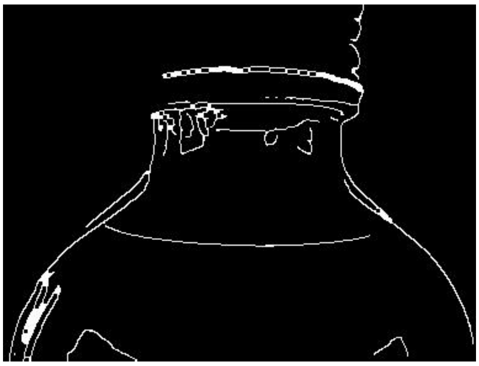

Fig. 7 Closed Canny edge-detected image of an over-filled bottle

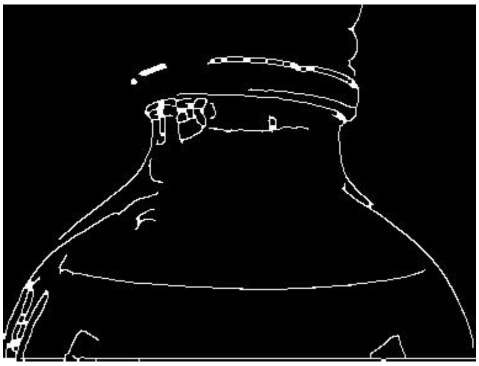

Fig. 8 Closed Canny edge-detected image of a bottle within target

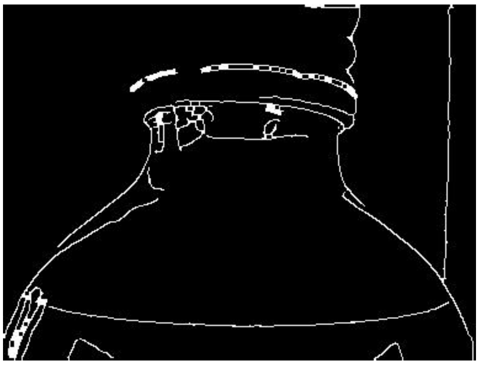

Fig. 9 Closed Canny edge-detected image of an under-filled bottle

- Find the ROI (see Fig. 10, 11 and 12).

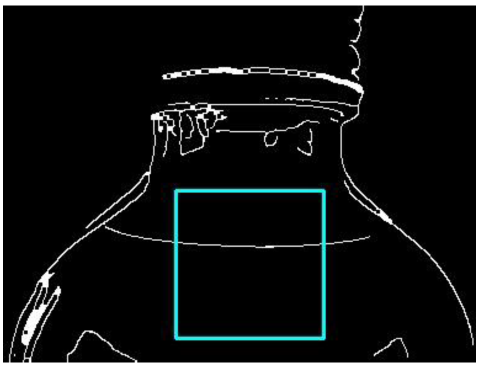

Fig. 10 Detected image of an over-filled bottle with ROI

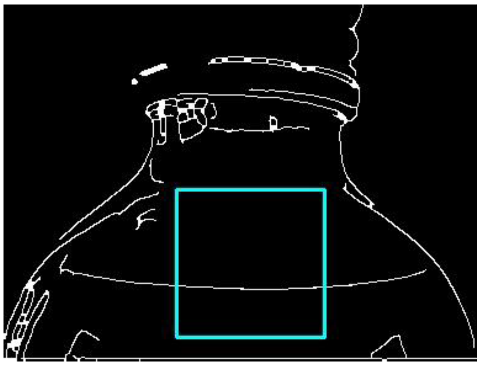

Fig. 11 Detected image of a bottle with volume fill within target with ROI

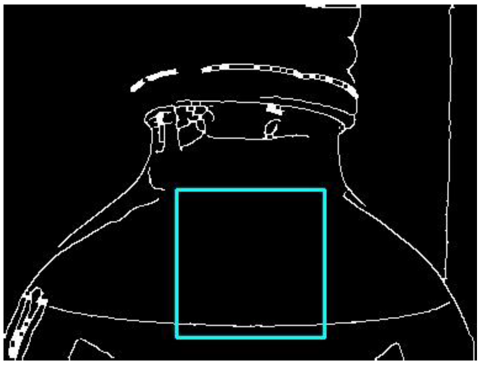

Fig. 12 Detected image of an under-filled bottle with ROI

- Set a horizontal reference line in the ROI.
- Find a pixel having a value 1 in box 2.
- Find the vertical distance between these two pixels.
- Do it for all pixels having value 1, in boxes 1 and 2.
- Take the average of all distance lines. If *ave* > the datum distance, the bottle is over-filled. If *ave* < the datum distance, the bottle is under-filled.

Slight modifications in the above procedure were made The steps after defining the ROI were replaced with the following:

- Define the acceptable values as the average distance from the liquid's surface to the top boundary of ROI.
- Find the coordinate points making up ROI edges. These points already represent the liquid's surface.
- Find the vertical distance between each point and the top edge of the ROI (see Fig. 13, 14, 15).

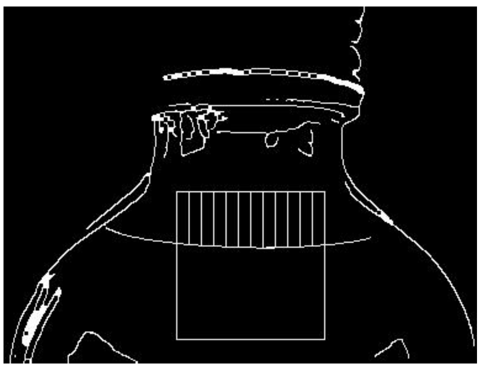

Fig. 13 Distance lines in ROI of an over-filled bottle

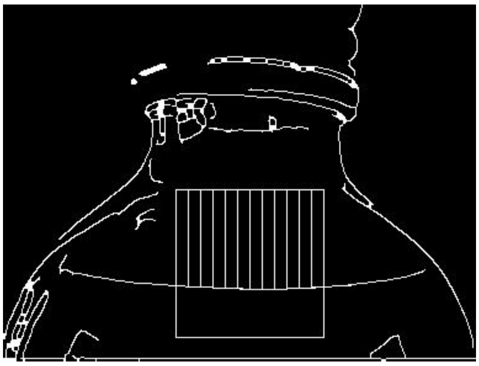

Fig. 14 Distance lines in ROI of a bottle with volume fill within target

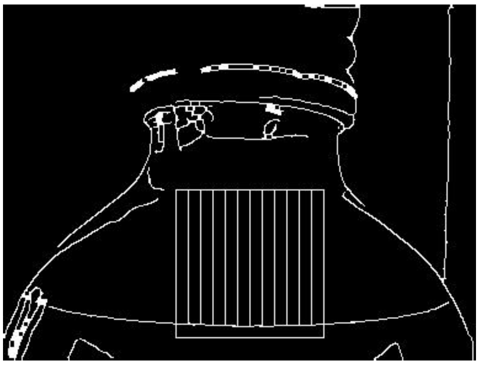

Fig. 15 Distance lines in ROI of an under-filled bottle

- Take the average of all distance lines. If *ave* > the maximum allowable distance, the bottle is under filled. If *ave* < the minimum allowable distance, the bottle is overfilled.

IV. Results and Discussion

Three photos corresponding to each possible scenario, over-filled, under-filled and within volume target, were taken and were used in testing the algorithm. In calibrating the proposed system, that is, to determine the acceptable distance range for this example, the average vertical distances for each photo was first determined and the measurements were listed in Table 1.

TABLE I. Average Vertical Distances

Level	Ave. Distance	Case
1	44.49	Over-filled
2	79.94	Under-filled
3	109.98	Within target

A range of 75 to 85 pixels was defined as the acceptable range basing from these measurements. This, of course, may be easily changed, depending on the actual volume needed, and the desired tolerance to errors.

After defining the acceptable range, each photo was introduced into a code that will display the photo along with a text indicating the case it belongs to (see Fig. 13, 14 and 15).

Fig. 16 Output image of an over-filled bottle

Fig. 17 Output image of a bottle with volume fill within target

Fig. 18 Output image of an under-filled bottle

V. Conclusion and Recommendations

The study was successful in detecting the over-fill and under-fill of liquid contents in amber bottles using the Canny edge detection. While the study was able to show that the algorithm can be used for liquid level detection, the system still needs to be developed more before it is used in manufacturing lines where products are constantly moving in a fast pace.

The researchers highly recommended that the detection system also checks and investigates for errors other than the fill level inconsistencies such as presence of bubbles and bottle cap misplacement.

Acknowledgement

The authors would like to express their sincerest gratitude to the Engineering Research and Development for

Technology (ERDT) of the Department of Science and Technology (DOST) for the conference subsidy support.

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