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Quantification of dirt in drinking water bottles using OpenCV

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***Abstract*— The paper presents a contour function-based algorithm to identify, detect and quantify the dirt that is present in drinking bottles due to prolonged usage despite regular cleaning by brushes. The images are taken using a smartphone-based camera before and after cleaning with a commercially available household brush. The image processing techniques can identify the areas of dirt effectively. This information can help designers to make suitable changes in the cleaning brush or to use appropriate cleaning liquid to eliminate this dirt. The dirt can have a detrimental effect on human health when water is consumed from such bottles. Also, the dirt is not noticeable in normal usage and hence advanced image processing techniques are used to identify the same. The algorithm can be converted into a device as a part of future work.**

***Keywords*— OpenCV, Image Processing**

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I. INTRODUCTION

Image processing and computer vision are playing an extensive important role in industry to benefit the development of a product and to ensure high quality of the same. The problem identified in this paper was a result of observation by the authors related to the dirt that had accumulated at some regions in a commercially available drinking water bottle, such bottles increase risk of bacterial growth on it and cause diseases like gastroenteritis and food poisoning. This dirt goes unnoticed even after cleaning and was present as shown in Figures 1,2 and 3,4.

Water being an essential quantity for sustenance of life on this planet, clean and accessible water for everyone is needed. To help achieve this goal, the existing products need to be possibly modified or improved or treated to increase their durability and assure clean water to our people. In this paper, we have attempted to use image processing techniques like OpenCV which will be able to not only detect the dirt areas but also quantify the same before and after cleaning. This information will add value to the designer so that he can make suitable changes in his design to accommodate the cleaning action and thereby improve the quality of water which will also reduce contamination. The main contribution of this paper is to identify the regions of dirt that go unnoticed even post cleaning rigorously with suitable commercially available cleaning brush as seen in Figure 2.

BEFORE CLEANING OF BOTTLE

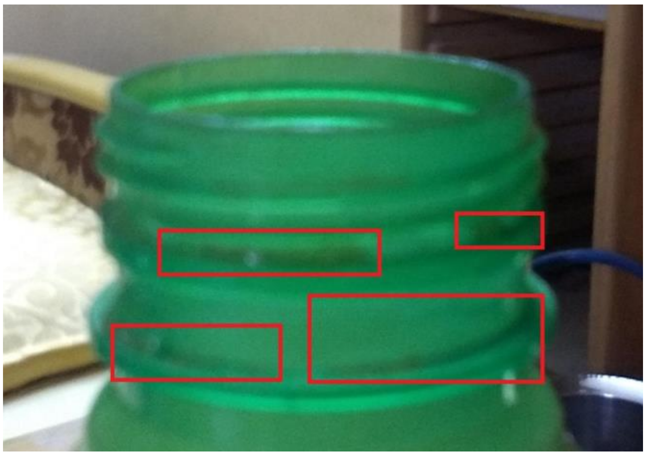

Fig. 1. Side part of bottle with regions of dirt marked in red

Fig. 2.: Bottom part of bottle with regions of dirt marked in red

AFTER CLEANING OF BOTTLE

Fig. 3. Side part of bottle left uncleaned and unnoticed

Fig. 4.: Bottom part of bottle after cleaning with brush

The cleaning brush as seen in Figure 5 comes with various forms. Typically, the most common one is that of second type which has a sponge at the end which is used to clean the bottom of the drinking bottle. As seen in Figure 3 and 4, the regions of dirt have been significantly cleaned after normal usage and rinsing using the brush in Figure 5. Figure 4 is the region at the top of the bottle which typically goes unnoticed during cleaning and gathers dirt which results in harmful bacteria, viruses, and pathogens to be intake during water consumption through drinking water bottles.

II. IMAGE PROCESSING ALGORITHM

In this section, it is explained in detail the process that is carried out for image processing on the images shown in Figure 7(a) and 8(a). The images are masked in-order to process the same and develop the output as seen in Figure 7(b) and 8(b). The images captured in the Figures are by a smartphone device MOTO G5 PLUS

Below are steps to arrive at the result in OpenCV [2]:

Fig. 6. Cleaning brushes typically available on Amazon and commercially in market. [1]

A. HSV Color Space:

- The H Component indicates the color information is intact even under illumination changes.
- The S component is also very similar in both images.
- The V Component captures the amount of light falling on it thus it changes due to illumination changes.

B. LAB Color Space

In LAB color space, the L channel is independent of color information and encodes brightness only. The other two channels encode color.

C. CLAHE Filter

CLAHE is a variant of Adaptive histogram equalization (AHE) which takes care of over-amplification of the contrast. CLAHE operates on small regions in the image, called tiles, rather than the entire image. The neighboring tiles are then combined using bilinear interpolation to remove the artificial boundaries.

CLAHE filter is then created by defining contrasting threshold and number of tiles in row and column

III. DETAILS OF ALGORITHM

In order to reduce glare and shadows caused during capturing of data image, we first need to perform preprocessing.

A. Preprocessing

Converting input image into HSV color model and filtering the image using appropriate upper and lower thresholds
The above result is then used as mask for **cv.inpaint** function which restores the selected region by the mask using neighboring pixels in the area, storing the result as result1. Now we convert result1 into LAB color space and use **cv.split** to split it into its 3 single channels or planes

Using which we create and apply Clahe filter of appropriate parameters on the first intensity channel or plane and merge this equalized intensity plane with other two planes. Finally, we convert the image from LAB to RGB color space

B. Processing

To observe the desired dirt regions, we simply used thresholding using cv2.inRange function on the preprocessed image with appropriate thresholds

Save and show the final output using cv2.imwrite and cv2.imshow, exiting the runtime using cv2.waitkey and cv2.destroyAllwindows. Print the number of black pixels after counting using **np.sum**(output ==0). Using for loop we perform the algorithm for both before and after data image

IV. RESULTS AND DISCUSSION

The section presents the results and discussion of the algorithms and its implementation on the images. Figure 8 (a) shows the features of the image of the bottom region of the bottle which clearly indicates that the dirt and the embossing of the manufacturer look very similar. Additional pre-processing is required to classify these features and hence find regions of interest which clearly depict the dirt on the bottle surface.

The effect of normal cleaning is seen in Figure 8(a) which indicates that the cleaning brush after prolonged usage will not be able to reach the outer areas of the bottle. This is also evident since the sponge material in the brush has permanently deformed and hence some design changes are required to prolong the usability of the brush.

The black pixels as seen in Figures 7 and 8 are indicating the dirt in the images of the bottom of the bottle. The formula for % dirt is calculated as below:

% dirt = [Black pixels (original) – Black pixels (clean)] / Black pixels (original)

Based on the above formula and Figures 7 and 8 as seen above, the result is as given below:

% dirt (before cleaning) = 50.01 % of total area

% dirt (after cleaning) = 12.95 % of total area

Reduction in dirt due to cleaning = 37.06 %

Fig. 7. Original image of bottom (b) Post processing

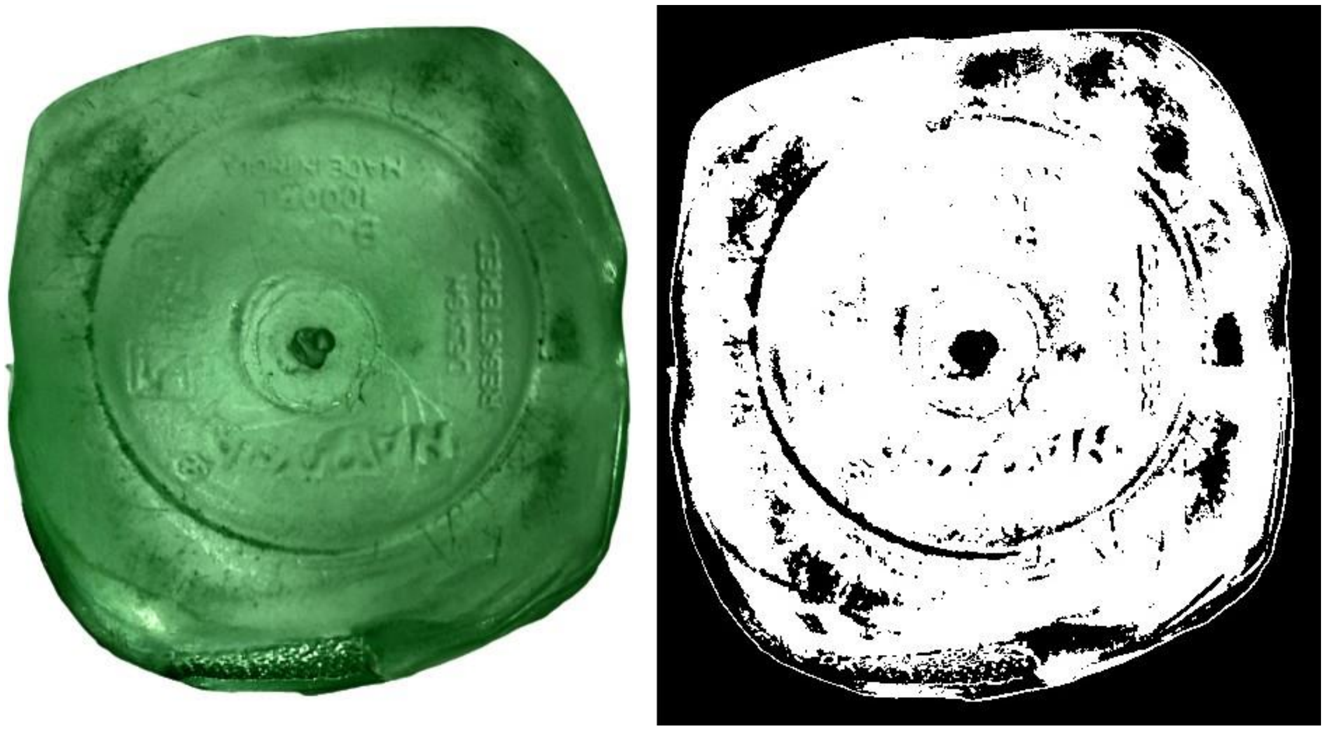

Fig. 8. Cleaned image of bottom (b) Post processing

V. RESULTS AND DISCUSSION

As seen in the results, Figure 7 clearly indicates the areas where dirt is present and can isolate the same. As observed, we can conclude that the central portion of the bottom region remains clean and most of the dirt that adheres to the surfaces remains at the edges of the bottom surface. Also, tendency for dirt accumulation is more at the various features that are available on the bottle surfaces like the rim and the corners. These are areas that need to be cleaned or reached by brushes so that dirt accumulation is eliminated.

The following areas will be considered for future work

1) Identification of change in design of cleaning brush to reach the areas where dirt has accumulated

2) Inclusion of cleaning liquid spray in brush

3) Top area of brush to be modified to reach the interior of the cap of the bottle

4) To make the bottle self-cleaning so that customers can use it for a long period of time.

Algorithms to classify the features like shadows on the bottle surfaces which will help in more accurately quantifying the dirt areas.

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