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BIOLOGICAL STAIN DETECTION USING OPENCV WITH THE AID OF ULTRAVIOLET A (UVA) LIGHT

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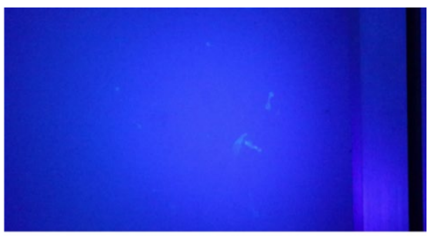
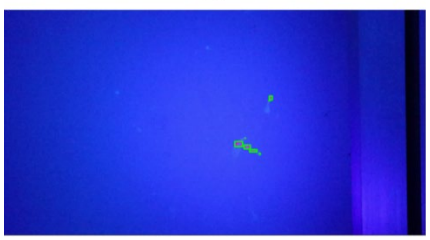
Graphical abstract



(a)



(b)

Abstract

The world are facing threats due to the spread of bacteria and viruses. Thus, a lot of researches are continuously exploring the topic of contaminants. One of the most significant ways to kill the contaminants are by sanitizing. Unfortunately, there is a lack of methods in detecting the contaminants for the sanitization to be performed efficiently. In this paper, we proposed the approach of detecting biological stains using the combination of HSV color segmentation, UVA light and also blue bandpass filter. Using color segmentation with the aid from UVA light, the fluorescent image of detected stains can be extracted. In addition, the blue bandpass filter can filter out the presence of background noises in order to increase the accuracy of the detection. A simple experiment was conducted in order to validate the developed algorithm.

Keywords: Biological stains, Blue bandpass filter, HSV, Segmentation, Threshold.

1.0 INTRODUCTION

High levels of germs and other diseases can thrive on touch surfaces because they are frequently touched by many different people. Because of this, pathogens that might cause infection may first be introduced to a new host via a tainted surface [1][2]. Despite the challenges, there is currently a lack of an adequate real-time monitoring system for biological contamination to evaluate contact surfaces. It is worth noting that present approaches for detecting biological contamination include both rapid but undefined adenosine triphosphate (ATP) assays and a slow cultivation technique [3].

However, a visual assessment of the surface is not equivalent to a microbiological swab or the ATP test for determining whether or not there is a lack of surface cleanliness. Therefore, it is impossible to make a prediction regarding the probability of microbial transmission from a contaminated surface [4] [5].

Biological stain detection usually require expensive equipment. For instance, Malegori et al. [6] and Schubert et al. [7] utilized hyperspectral camera in order to detect the unseen biological traces. Karchewski et al. [8] studies the performance of biological stain detection using Leeds Spectral Vision (LSV) system, in addition to Polilight-Flare Plus UV (365 nm) and the Mini-CrimeScope 400 CSS (485 nm). It is worth mentioning that these research [6], [8], [9] also uses bandpass filter in aiding the detection.

Image segmentation can be implemented as an alternative to detect biological stains that is caused by bacteria or other microorganisms. It is a useful tool for identifying and localizing regions of interest in images, so it can be used to identify and locate the stains in a sample. Image segmentation, in general, is the process of partitioning a digital image into multiple segments or regions. It is used to simplify or change the representation of an image by reducing the number of colors, shapes, or sizes in the image. It is also used to identify objects and boundaries in an image. The objective of image segmentation is to generate a representation of an image that is simple and altered in some way, so that it may be evaluated in a straightforward manner [10].

This paper implement color image segmentation for stain detection using HSV with the aid from UVA light and blue bandpass filter. UVA light is used to illuminate the presence of stains. Moving on, the image obtained is segmented using HSV based on color by manipulating the upper and lower values so that the objects and backgrounds are separated and can segment noisy color images, with the addition of blue bandpass filter. Based on the concept of computer vision in object detection, this method aims to visualize and analyze images acquired from cameras using digital image processing techniques [11].

The rest of the paper are organized as follows: Section 2 covers an introduction to color spaces and models. In Section 3, the process of converting RGB to HSV were discussed. The method in detecting stain were explained in Section 4. Section 5 displayed the results for the experimental validation, while the discussion are in Section 6. Lastly, this paper is concluded in Section 7.

2.0 COLOR SPACES AND MODELS

Color models and color space refer to systems for specifying colors in digital images. Color models are mathematical models used to describe color in terms of its components, such as hue, saturation, and lightness. Color space is an abstract way of representing the gamut of colors that are possible for a given color model. For example, sRGB (standard RGB) is a popular color space for the RGB (Red, Green, Blue) color model. In addition to RGB, some of the commons color spaces include CMYK, YCbCr, HSL and HSV. An RGB image can be transformed to any other color space using transformative methods [12]. Although RGB is the most common means of encoding images in color space, other color spaces may be more practical in certain scenarios. In this paper, HSV color space was used for stain detection since it is easier for the color space to recognize different shades of colors.

3.0 HSV

HSV (Hue, Saturation, Value) is a color model used in image processing and computer vision to represent a color image. It is used to detect different objects in an image and track their movement. HSV separates the image into its hue, saturation, and value components. This allows for more precise color detection and analysis than it is possible with other color models.

3.1 RGB to HSV Conversion

HSV perceived brightness of a color which aids in distinguishing between shades of the same hue. sRGB, on the other hand, requires exact and precise colors, such as those seen in digital photographs. In addition, it does not account for the perceived brightness of a color, which can make it difficult to differentiate between colors with comparable hues. The RGB to HSV conversion provided by [13] is shown in Equation (1) below.

$$C_{max} = \max(R, G, B)\,, C_{min} = min\,(R, G, B)$$
$$C = C_{max} - C_{min} \tag{1}$$

Equation (2), which is based on Equation (1), can be used to compute the values for each HSV element after the minimum and maximum values for each color have been determined.

$$H = \begin{cases} 60\left(\dfrac{G-B}{C}\right), if\ C_{max} = R \\ 120 + 60\left(\dfrac{B-R}{C}\right), if\ C_{max} = G \\ 240 + 60\left(\dfrac{R-G}{C}\right), if\ C_{max} = B \end{cases}$$
$$S = \begin{cases} 0, C_{max} = 0 \\ \dfrac{C}{C_{max}}, C_{max} \neq 0 \end{cases} \tag{2}$$
$$V = C_{max}$$

4.0 VISION SYSTEM ALGORITHM

4.1 Color Segmentation Using HSV

The segmentation process typically involves clustering pixels into similar groups based on some measure of similarities, such as color, texture, shape, or intensity. Once the clusters are established, a variety of techniques can be used to determine the boundaries of the regions and segment the image. These techniques can range from simple thresholding to more sophisticated machine learning algorithms. Color segmentation are widely practiced for object detection. The detection method in this paper are through color segmentation using HSV. Because the intensity is not dissociated from chromaticity, RGB color space does not generate appropriate segmentation results [14]. Nonetheless, RGB color space is suitable for presenting images instead of image processing. Some of the existing method, however, does not utilized all three planes of the HSV [15][16]. Nevertheless, all HSV planes are manipulated in this paper, in order to find the optimum threshold for image detection.

The first step is to change the image format from RGB to HSV. A GUI trackbar was developed in order to find the ideal range of HSV for the image. The hue, saturation, and value of each component have been separated so that they can be manipulated more easily. The optimal values for H, S, and V are found by dragging and adjusting the trackbar. At this stage, the threshold or the range values for all the pixels to be extracted have been finalized. The next segmentation process is called thresholding. Thresholding is the process of converting an image into a two-dimensional binary image (black and white) by setting a threshold value for each pixel in the image. Pixels with a value higher than the threshold are converted to white, and those with a value lower than the threshold are converted to black. This process helps to identify objects in the image and to separate them from the background. In this process, the resulting HSV image was masked out to separate the image from the background using a pixel feature value.

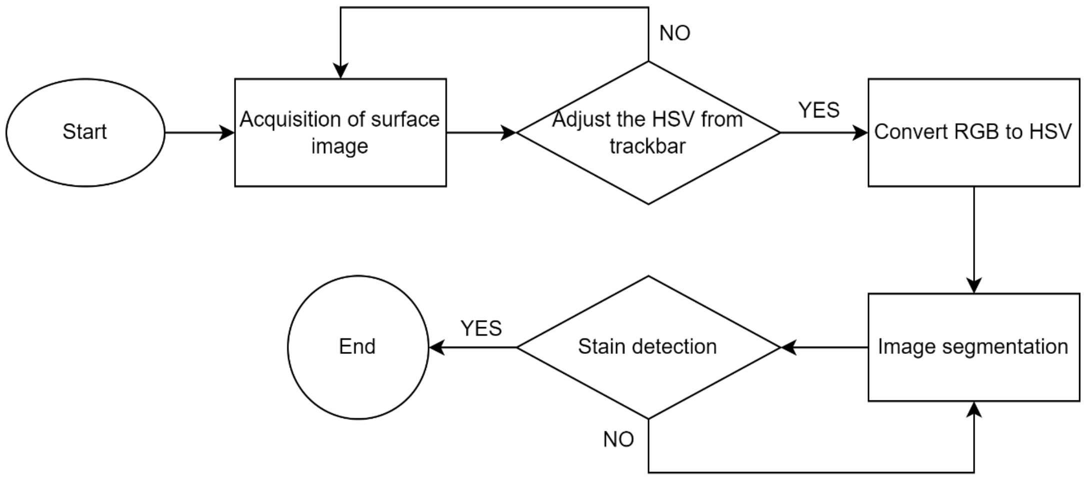


Figure 1. Flow chart of the experiment

4.2 Detection Using Bounding Box

The detection of the stains can also be highlighted by the application of contour and bounding box, in addition to image segmentation. The threshold of the fluorescent image was written as the contour in order to allow the bounding box to locate the contours of the stains. Hence, the stains are discernible in the image.

5.0 EXPERIMENTAL VALIDATION AND RESULTS

A simple experiment was conducted in order to validate the algorithm. The procedure for this research can be seen from the flowchart in Figure 1. The image acquired was taken in real-time. Firstly, the UVA light was shone on the surface in order to illuminate any fluorescent stains that present. UVA light has a wavelength of 365 - 400 nm, which is within the range of visible light. This range of light is able to penetrate biological stains, allowing it to be detected. UVA light is able to detect biological stains by the absorption of the light, which causes the biological stain to appear darker than its surroundings. The darker the stain appears, the more intense the stain is.

After that, the image was detected real-time using Canon EOS M200. Then, the next objective is to isolate the fluorescent stains from the background. In order to extract the fluorescent image, the H, S and V values need to be identified. The trackbar was developed to find the optimal range of HSV for the image. The HSV value can be adjusted according to the color of the fluorescence.

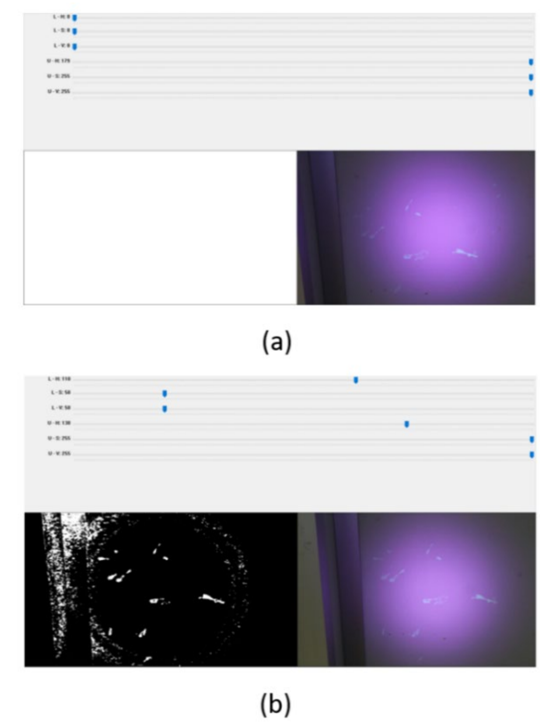
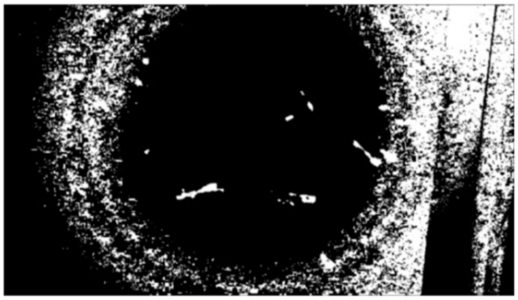


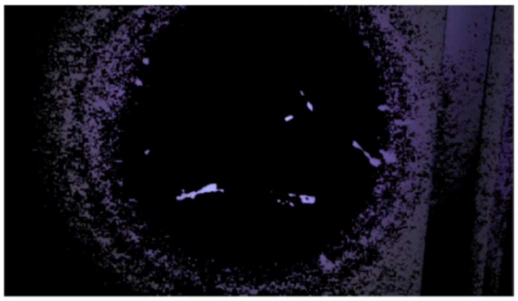
Figure 2. (a) Image before adjusting HSV value; (b) Image after adjusting HSV value

From Figure 2, the lower and upper value of HSV for the first experiment are 110, 50, 50 and 130, 255, 255 respectively. The obtained value is a fixed threshold and it does not need to be repeatedly adjusted for stain detection in the same condition.

The value acquired was then utilized for thresholding in order to extract the fluorescence as can be seen from Figure 3.

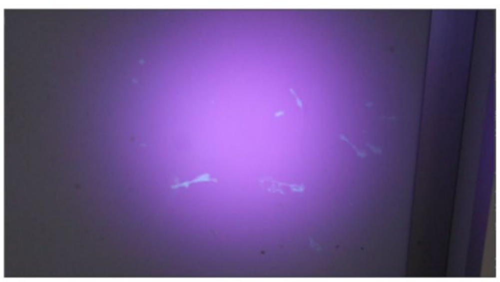


(a)

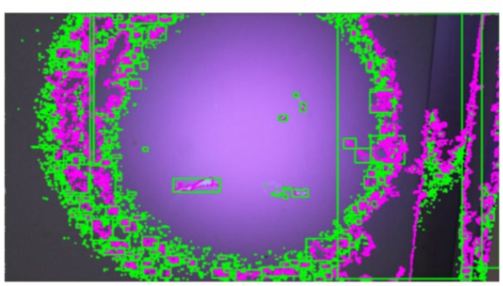


(b)

Figure 3. (a) Masked out image; (b) Extracted image



(a)

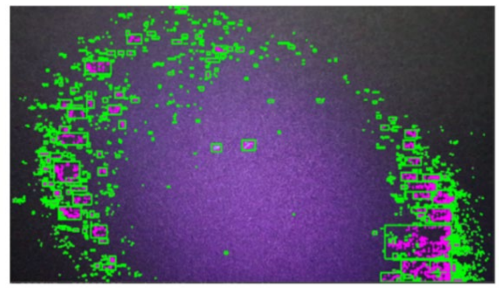


(b)

Figure 4. (a) Original image; (b) Image with detected stain on a white background

The detection results are displayed in Figure 4 and Figure 5. Unfortunately, the results obtained does not satisfy the objective of this project since it did not managed to detect the stains accurately. In addition to the biological traces, the image processing also detect the emitted light from UVA in the shape of a circle with some noises.

(a)



(b)

Figure 5. (a) Original image; (b) Image with detected stain on a black background

In order to reduce the background noise, a blue bandpass filter (see Figure 6) was used to filter out the stains. Generally, a blue bandpass filter is used to detect fluorescent images because it allows only blue light to pass through, which is the same wavelength that fluorescent dyes emit when they are illuminated. This allows fluorescent images to be captured while blocking out other colors. The filter also helps reduce glare and other artifacts that may be present in the image. Furthermore, a blue bandpass filter is required for the majority of machine vision UV fluorescence applications [17].

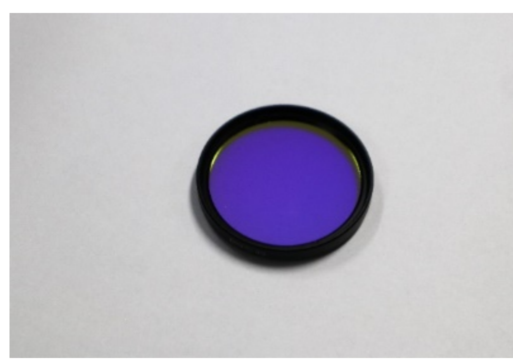
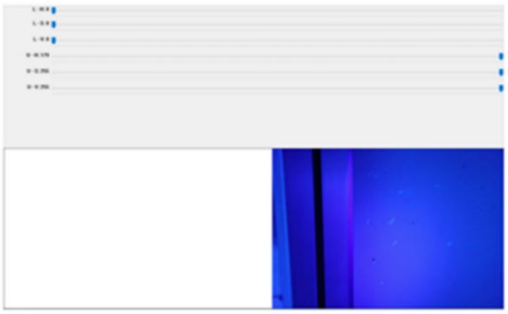
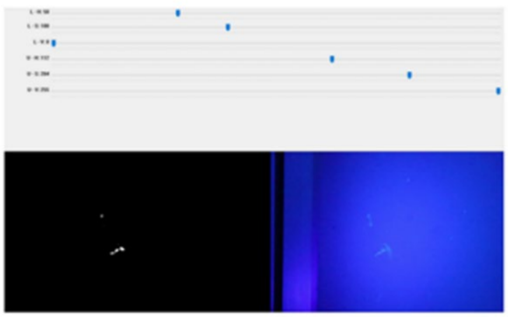


Figure 6. Blue bandpass filter

For the upcoming results, the image are in blue color because of the blue bandpass filter that is attached to the camera. Figure 7 displays the HSV value in which the lower limit are 50, 100, 0 and the upper limit are 112, 204, 255. Similar as previous, the values obtained is a fixed threshold and it does not need to be repeatedly adjusted for stain detection in the same condition.



(a)



(b)

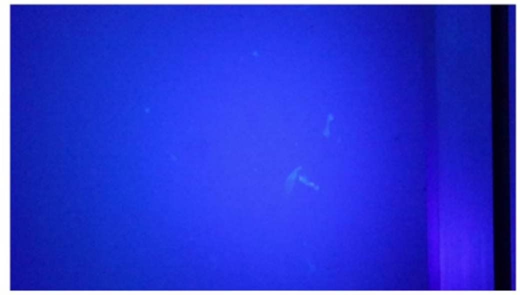
Figure 7. (a) Image before adjusting HSV value; (b) Image after adjusting HSV value

(a)

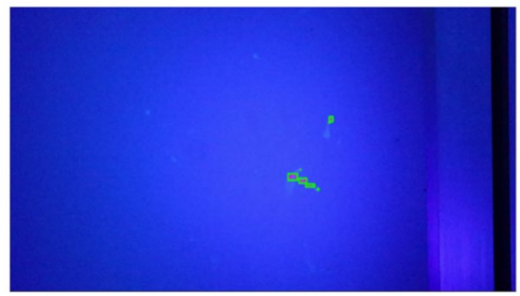
(b)

Figure 8. (a) Masked out image; (b) Extracted image

For thresholding stage in Figure 8(a), the fluorescence was separated from the background, and then the blue color was extracted as shown in Figure 8(b). As a final result, the stains were able to be detected more accurately as the blue filter managed to reduce the background noise as well as omitting the ring light from the UVA exposure. The results were displayed in Figure 9 and Figure 10.

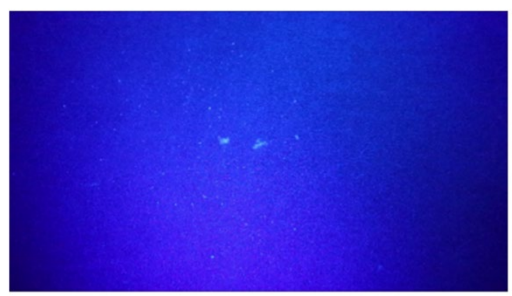


(a)

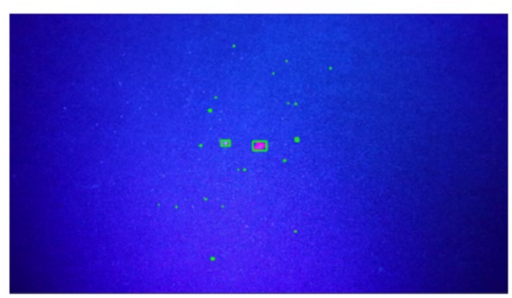


(b)

Figure 9. (a) Original image; (b) Image with detected stain on a white background



(a)



(b)

Figure 10. (a) Original image; (b) Image with detected stain on a black background

6.0 DISCUSSION

Blue bandpass filters and UVA light works well together for fluorescent imaging because it allows the blue light to pass through the filter, while blocking out other light wavelengths. This helps to reduce background noise and allows the UVA light to excite the sample, causing it to emit a fluorescent signal that can be detected by the camera. The usage of blue bandpass filter with UVA light is also useful for applications such as fluorescence microscopy.

Similar to previous studies, this research implement a constant threshold for color segmentation [18]. Since the values of the threshold are fixed, this algorithm still requires manual tuning of the HSV since the early value needs to be adjusted in order to accommodate the blue bandpass filter. The algorithm can be more adaptive by implementing a dynamic threshold [15][19][20] instead of a fixed threshold.

7.0 CONCLUSION

This paper discussed the implementation of image processing techniques using OpenCV application to detect biological stains on surface. With the aid from UVA light, the camera was able to capture the image of the surface to be analyzed in OpenCV. Using color image segmentation, the stain can be spotted by extracting the fluorescence color. A simple experiment was conducted in order to validate the stain detection algorithm. From the test, the camera that has been attached with blue bandpass filter managed to reduce the presence of noise. Thus, the combination of color segmentation, UVA light with blue bandpass filter in detecting stains can be seen as a promising method.

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