TUBERCULIN SKIN TEST CHECKER USING DIGITAL IMAGE PROCESSING

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ABSTRACT

The wheal, produced by tuberculin skin tests, was identified by nurses through marking its edges. Four marks were made and measured – the greatest length of each mark to another mark was considered the size of the wheal. An attempt to imitate the procedure was done by designing a system that can measure the marked sides of the wheal. The implemented system used an algorithm that located the four marks in an image. These four marks were measured using the Euclidean distance to determine the distance between each other. Among the 6 edges of the four marks, the one with the greatest length was considered the size of the wheal. Using a scale with a defined size, the pixel value of the greatest length was converted in millimeters. The results showed that the system's measurement was always less than the measurement of the nurse. With an accuracy of 91.53% for the test data, the researchers were able to implement a system that can facilitate in reading the results of tuberculin skin test.

Keywords: *wheal, tuberculin skin test, Euclidean distance, scale*

INTRODUCTION

One way of detecting tuberculosis is through the use of tuberculin skin test, which is being used globally by health institutions for many years now. The test involves injecting a purified protein derivative to the patient's arm that will cause a small wheal to that area (see Figure 1). [1] After 48-72 hours, the wheal will be measured using a millimeter ruler which is the standard procedure of the test. The size of the wheal is one determinant whether the patient has a prior TB exposure or not.


Figure 1. Tuberculin skin test producing a wheal

Based on the patient's lifestyle, demographics, jobs, and other background information, doctors categorize their patients as high-risk, mid-risk, or low-risk. The result of the test is determined by the size of the wheal and the patient's category.[2] In order to have a positive result to the test, the patient's wheal should be at least 5mm for the high-risk patients, at least 10mm for the mid-risk patients, and at least 15mm for low-risk patients.

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The problem with this test is, more often than not, the wheal flattens and it is difficult to detect by just looking at it. According to the

medical practitioners of the Philippine Institute of Tuberculosis, the nurses need to touch the area where the wheal originally formed and gently touch the wheal to trace its sides.[3] They use a ballpoint pen to mark four sides of the wheal and measure each two sides, horizontally (A and B) and vertically (C and D) (see Figure 2).
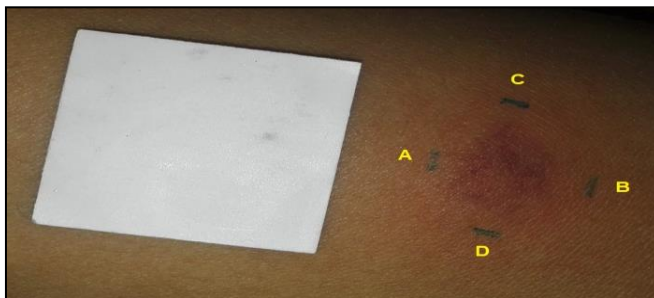
Figure 2. The wheal after its four sides were marked.

Only two measurements were done and the lengthier side was considered the size of the wheal. If the wheal's size is greater than the cut-off value, the patient is positive to the test. It is considered negative, when it is less than the cut-off value. The nurse only measured horizontally and vertically, but it was not impossible that if the sides were measured diagonally, it would be greater than both the results of horizontal and vertical measurements. This could lead to a false-negative result if the diagonal measurement was greater than the cut-off value when the horizontal and vertical measurements were less than the cut-off value.

This research focused on addressing the problem of subjectivity in measuring the result of the test by identifying all the possible measurements of each sides in order to provide a more accurate reading of the test. Through the use of digital image processing, the researcher aimed to design and implement a system that will facilitate in measuring the size of the wheal.

RELATED LITERATURE

Pouchot and his companions quantified the reliability of the test. Ninety-six (96) patients took the test and two (2) health care personnel read the test, one after the other.[4] Through statistics, the results showed that 5% of the time, the second measurement would be 2.7mm less than or 3.0 mm more than the first reading. They concluded that if the results were near at the cut-off value, the reading of the test was more likely to result into a reclassification of the test. Another factor that may be true, according to this study, is the reader's knowledge of the cut-off value, which can provide an unconscious bias in reading the results.

An algorithm that can automatically measure skin wheals was done by Prinza, Viglb, and Wöhrlb.[5] The aim of the study was to remove the subjectivity in reading the results of the skin test. The data from the skin wheals in this study were from skin prick tests. After outlining the wheal, a digitized image was made using a scanner. Due to the wheal's outline, the area that must be calculated can be easily identified. Inside the wheal, pixel counting algorithm was done and converted to mm^2 to have the actual size. The algorithm had a standard deviation of 6.9% compared to 6.59% when the test was conducted manually. This study by Prinza, Viglb, and Wöhrlb was very similar to this research since it also focused on the measurement of skin wheals. There are variables that differentiate this study. The test was for skin prick test and the algorithm that was used is pixel counting and was performed by the use of a scanner. The proposed study was for Tuberculin Skin Test. To measure the wheal, the proposed algorithm was used. Also, the study used a camera and a scale.

Another study by Rege, Memane, Phatak, and Agarwal suggests that to be able to properly identify an object's shape and color, there should be some pre-defined perimeters.[7] After using edge detection to highlight the points of interest, the object was rotated counterclockwise depending on the angle of the inclination. A bounding box was made outside of the subject. The leftmost, rightmost, topmost, and bottommost pixels of the subject were pointed out and these points were connected to produce the bounding box.

METHODOLOGY

For the system to be designed and implemented, the researcher used a set of training data that contains six (6) images. These images were used as the basis of the system's capability to measure the wheal. The images were taken from the staff and employees of Philippine Institute of Tuberculosis when they conducted their annual staff surveillance. The head nurses performed the test by injecting purified protein derivative one by one to the employee's non-dominant arm.

The wheal was evident after the injection. After 48 hours, the head nurse checked on the wheal but it was not palpable so she gently touched the area where it was injected and sensed the stiff part. Using a ballpoint pen, she marked four (4) sides of the wheal – the left and right, and top and bottom sides. She then began to measure these sides using a millimeter ruler (see Figure 3). After recording the result of the measurement, the researchers put a 1x1 white scale near the wheal then started to take a picture about two and a half (2 ½) inches away from the patient's arm. These images gathered from 6 employees were used as a basis in making the system.

Figure 3. Actual measuring of the wheal

The hardware that was used in developing the system has Ubuntu 15.04 operating system, Intel i5-430M @ 2.27GHz, 4GB RAM, and NVIDIA GeForce 310M. The cellphone used in taking the picture was Huawei Honor 4C with a 12-megapixel camera. The software used was OpenCV 3.1.0 using Python programming language version 2.7.

Crop the Image

The original image had a lot of potential noises but only the scale and the wheal were needed to be present in the image so the image was cropped leaving only the important parts.

Convert the Image to Grayscale

By using the average method in determining the average value of the three pixels and assigning this value to that pixel, it converted the colored image to grayscale by using the function cv2.COLOR_BGR2GRAY.

Apply Gaussian Blur

Blurring method simply blurred the image to a certain extent based on the size of the kernel used (in this case, 7x7). The function cv2.GaussianBlur blurred a grayscale image based on the size of the kernel.
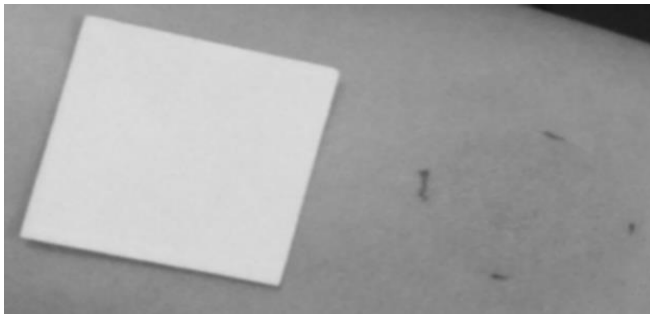

Figure 4. Result of grayscale and 7x7 Gaussian blur

Apply Canny Edge Detection

Canny edge detection was efficient because it had a lower error rate compared to existing edge detection algorithms.[8] The function

cv2.Canny was used in this image with a minimum and maximum value of 50 and 100, respectively.

Apply Morphological Dilation and Erosion

Dilation was used for "bridging gaps" in an image with broken holes through the use of a structuring element, while erosion removed the original pixel that was at the origin or the center of the structuring element (see Figure 6). The function cv2.dilate and cv2.erode with a structuring element of 3x3 was used.
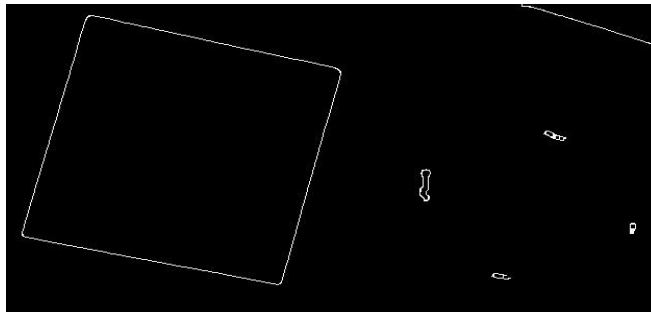

Figure 6. Result of Canny edge detection, and dilation then erosion.

Locate the Scale by Using Contour Finding

The scale used had one inch on all of its sides and this was present in the image together with the marks of the wheal. It was used as a reference object for identifying the actual size of objects in the image depending on the size of the scale and the numbers of pixels the side of the scale had.

The contours located in the image depended on the size of the edges in the image. To locate the scale, a large threshold value of 500 was used (see Figure 7). The decision on wether the contour will be accepted or not was based on its size and if it surpasses the threshold value or not.
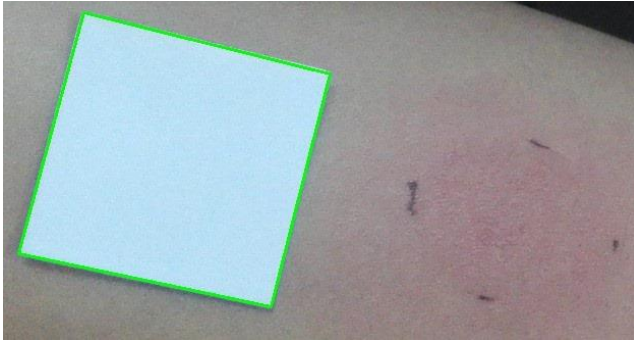
Figure 7. Locating only the scale through contour finding

Identify the Edges of the Scale

After locating the scale, the system determined the edges of the scale by using the function cv2.approxPolyDP which returned the edges of the contour. These values had the *x* and *y* coordinate of the four edges of the contour. After using the function perspective.order_points() from imutils package, these values were arranged in order from topleft, topright, bottomright, and bottomleft.

To calculate for the distances between each edges, Euclidean distance was used by using the function dist.euclidean. This function returned the distance between two points in pixel value. The system produced 4 pixel values by measuring the distances between each 4 edges. Since the scale had four sides, the side with the minimum distance represented the size of the scale or equivalent to one inch.

Find the Marks and Its Distances

After locating the contours of the marks using a significantly lower threshold compared to the scale's (because the areas of each mark is smaller than the scale), a bounding box was made around the contour to make an object boundary. The mark, as seen in the original image, varied in size and it was assumed that the center of the mark represented a single mark. By making a bounding box around the mark, the center of the mark was located and was done by computing the average of the pixel addresses on the edges of the bounding box. The center was another pixel that had *x* and *y* coordinate which represented a single mark.

This process was done three more times to locate the center of the four marks of the wheal. After locating the pixel addresses of the centers of the marks, the distances between each mark was computed by using Euclidean distance.

The system computed for the Euclidean distance of each mark and based on the procedure of tuberculin skin test, the greatest length represented the size of the wheal. The system compared the distances between each mark and the greatest distance was considered the size of the wheal.

Calculate the Actual Size Based on the Scale

The distances between each mark was in pixel value and to convert it in millimeters, the value of the scale that the computer earlier used as the basis for computing the actual size of the distance by dividing the distance between each mark to the value of the scale. The value was in inches and to convert it to millimeter, this value was multiplied by 25.4 (see Figure 8).
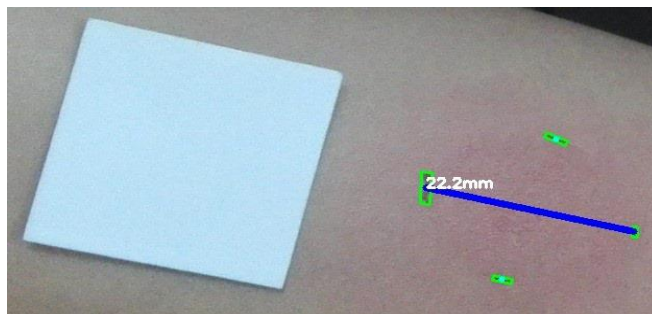
Figure 8. The maximum distance between each edges

RESULTS AND DISCUSSION

After implementing the system's algorithm to a set of training data that has 6 images, another set of images were gathered and were used as a test data which also contained 6 images, wherein the

system's accuracy were tested on actual data. Just like in training data, Gaussian blur's kernel size, Canny

edge detection's threshold value, dilation and erosion's number of iterations, and contour's threshold value were also manipulated until the scale and the marks of the wheal were detected by the system.

As shown in Table 1, the accuracy of the system's algorithm was 91.53% after it was implemented to a set of test data having six images. Also, it can be concluded that the system's measurement of the wheal was always smaller than of the nurse's measurements. Actually, the average difference from the measurement of the nurse and the measurement of the system is 2.03.

Test data	Wheal's size based from the nurse (mm)	Wheal's calculated size by the system (mm)	Difference (mm)	Accuracy (%)
1	20	19.39	0.61	96.95
2	24	21.45	2.55	89.38
3	26	25.17	0.83	96.81
4	27	23.35	3.65	86.48
5	32	31.95	0.05	99.84
6	22	17.54	4.46	79.73
			Average difference **2.03**	Total accuracy **91.53**

Table 1. The accuracy of the system based on the set of test data

SUMMARY AND CONCLUSION

This study aimed to develop and implement a system that can calculate the size of the wheal based on a given image using digital image processing techniques and algorithms. The problem with the current system or procedure that nurses and medical practitioners used was that after marking four marks of the edges of the wheal, they only measured the horizontal and vertical edges. After comparing the sizes of those two, the greater size was considered the size of the wheal and decided whether the patient was positive or negative to the test based on that. However, measuring these edges diagonally can produce another 4 measurements that could be greater than the value of the measurements of horizontal and vertical edges, which in turn should be the actual size of the wheal.

The researcher developed an algorithm using image processing functions and algorithm with an accuracy of 91.53% when using the system for a set of test data. The system's measurement was smaller than the nurse's measurement with an average of 2.03 difference.

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