Detection of Circulatory Diseases Through Fingernails Using Artificial Neural Network

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***Abstract*—This study focuses on detection of circulatory diseases such as Coronary Occlusion, Congestive Heart Failure, and Congenital Heart Disease by analyzing fingernails. It used an image processing system which includes image segmentation, color threshold, and shape analysis. The fingernail database used are classified using Artificial Neural Network (ANN). The proposed detection system diagnosed 6 patients having the said diseases (3 Congenital Heart Failure, 2 Congenital Heart Disease, and 1 Coronary Occlusion). It was matched with all the findings and diagnosis of all the attending specialists. With this, it was 100% successful in detecting circulatory diseases.**

***Index Terms*—Artificial Neural Network; Circulatory Disease; Fingernails; Image Processing.**

I. INTRODUCTION

Ideally, a healthy and normal nail is smooth, uniform in color and free of spots and discoloration. Abnormalities in the fingernail can be a strong indication of chronic diseases most especially circulatory disorders [1]. The blood circulation of a person is clearly observable in the appearance of the nails, either if blood flow is reasonably strong or compromised because of various factors. Signs and symptoms of most circulatory disorders first affect the appearance of fingernails before the rest of the body. However, in terms of visual analysis, the resolution of the human eye is limited to classify a few pixels only while computers have the capability to detect every pixel accurately and precisely. Therefore, analyzing the nail color, texture and shape with the help of computers are proved to be superior compared to human eyes. One way of analyzing an image with the help of computer-based capabilities is through image processing [2, 3, 4, 5, 6, 7, 8]. In imaging science, image processing is used for two main purposes: To develop the pictorial information for human analysis and to process the scene data for independent machine observation. The latter is a process of interpreting the image data for storage, transmission and representation for computer processing. One way of executing this process is by the use of Image Processing Toolbox in MATLAB programming software [9]. It provides an inclusive set of reference-standard algorithms, functions, and applications for image processing, analysis, visualization, and algorithm development. Here, one can perform image segmentation, image analysis, image enhancement, and image registration which can be applicable in studying and analyzing fingernail appearance.

A review of the National Heart, Lung, and Blood Institute's Dynamic Registry has shown that circulatory problems are the reason for "11 million doctor visits each year, and more hospitalizations than all forms of cancer combined [10]." Congenital Heart Diseases (CHD) are "structural abnormalities of the heart at birth" and has an "age-standardized rate of 1.2 deaths per 100,000 people [11, 12]." People who suffer from CHD often have nail clubbing and bluish tint on fingernails, more known as cyanosis because of the disruption of blood flow [13, 14].

Meanwhile, Congestive Heart Failure (CHF) is a chronic condition wherein the heart cannot pump sufficient blood because the heart muscle is much weaker than normal [15]. The less supply of blood may cause the nails to be opaque and show a dark band at the tip (Terry's nails) [16]. Approximately 550,000 new cases of are diagnosed in the U.S. annually [17]. CHF is the most common diagnosis in hospital patients age 65 years and older [18].

In addition, Coronary Heart Occlusion happens when there are blockages in the coronary arteries which supply the heart muscle with blood containing oxygen. In a collaborative study conducted by WebMD and Medscape in 2016, around 500,000 people die of Coronary Occlusion in the United States year [19]. People who suffer Coronary Heart Occlusion/Disease have a purplish-red and triangle/oval-shaped fingernail [20].

Awareness in determining how a healthy nail looks is necessary to maintain proper health care. It is also essential to learn how to distinguish the difference of a healthy nail and a nail that is affected by different diseases, especially circulatory diseases since it is considered as the number one cause of death all around the world. This is to provide early detection, cure and prevention. However, one can only observe the fingernails through his naked eyes, which are characterized by limited capabilities in terms of color analysis.

In the recent years, medical science has improved drastically which gave way to the development of innumerable ways of diagnosing different types of diseases in the human body. Most of the modern diagnostic techniques often require expensive equipment and highly-trained specialists. One good health indicator is through the visual observation of the changes in the physical appearance of the body, including the fingernails. Most of the diseases that are found to affect the circulatory system can cause a quick change in the appearance of the nails. Ideally, healthy nails are pinkish in color and free of ridges or discoloration. Abnormalities in the appearance of fingernails correspond to an aberration in the overall health condition. But subtle variations in its color cannot be clearly identified even by trained eyes. The resolution of the human eye vision is very limited and small changes in neighboring pixel values cannot

be precisely identified.

With this in mind, a device was developed that is intended to simply allow individuals to detect likely health complications in the circulatory system without having to depend on analysis from large lab devices. It made use of image processing with an input image that is compared to a knowledge database to determine if a person has a certain kind of circulatory disorder.

The overall goal of this study is to develop a device that is capable of diagnosing three types of circulatory disorders namely Congenital Heart Disease, Congestive Heart Failure and Coronary Occlusion by analyzing the color and shape of the fingernails through image processing. Specifically, the objectives of the study are: 1. To create a Graphical User Interface that will serve as a link between the camera and the program so that it will process the input image; 2. To use a MATLAB toolbox that will process and analyze the input image for image segmentation, color threshold and shape analysis; 3. To develop a program based on Artificial Neural Network that will identify if a person has a circulatory disease; 4. To assess the functionality of the device by comparing the results generated by the device to the diagnosis of the doctors.

This low-cost disease-detecting device is mainly beneficial to small healthcare units and medical operations in remote areas. It can provide a non-invasive procedure for early diagnosis and can give fast yet accurate results without the use of facility-bound laboratory instruments.

II. Artificial Neural Network

Feed-forward Artificial Neural Network (Figure 2), a type of ANN (Figure 1) was used to classify the circulatory disease based on the values acquired from image segmentation, color threshold, and shape analysis. It has three layers of neurons: input; output; and hidden. The number of nodes in a network is determined based on application requirement. It determines links between the elements. It is commonly trained and attuned so that the given specific input can have its targeted output. For the given situation below, the network is attuned, based on the comparison of the output and the target, until the network output matches the target.

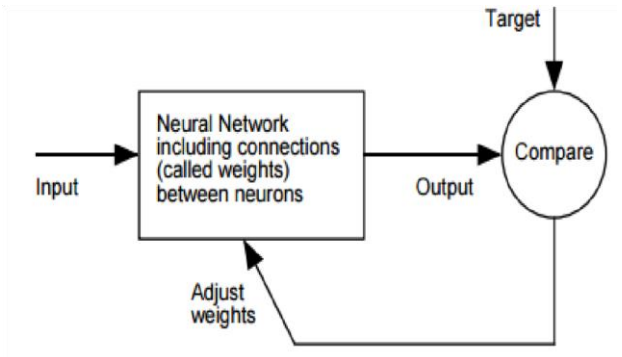


Figure 1: Neural network

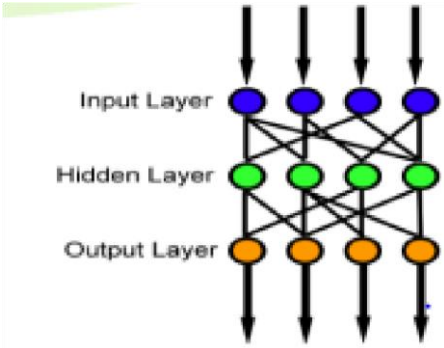


Figure 2: Feed-forward artificial neural network

III. Methodology

As shown in the system flowchart of Figure 3, the input will be the actual image of the fingernail. It will undergo image segmentation, color and shape analysis which are the important processes that will be employed using MATLAB and are needed for the detection of circulatory disease. These parameters obtained will be compared to the data base stored in the program, which will then lead to the generation of the output which is the disease diagnosis.

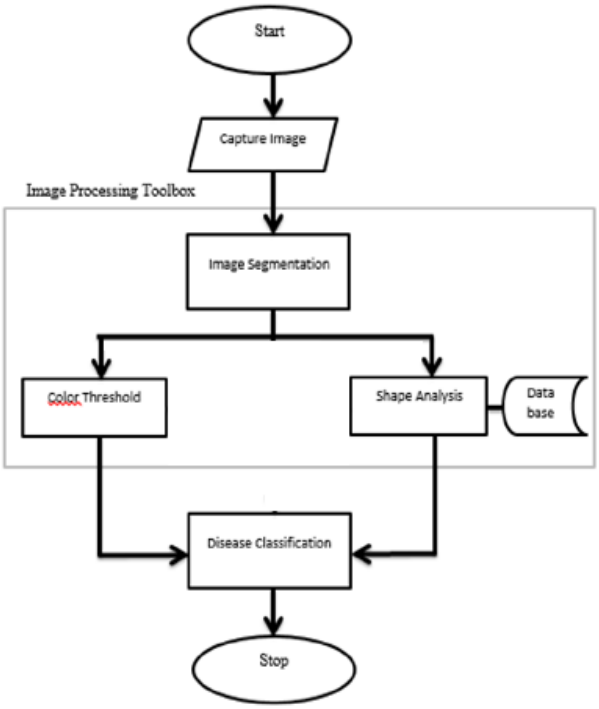


Figure 3: Flowchart of the disease classification

The construction of the device will require a tablet where the software (the MATLAB program and Graphical User Interface implemented using C# for Visual Studio) will be installed, a high-definition web cam for the input of the device and a USB LED light for proper lighting. The functionality testing is also essential for assessing the operation of the system. The output of the device will be the RGB values of the fingernail as well as the shape for disease classification.

Each of the fingers of the patient is to be placed into the inlet of the chassis until the camera takes a photo of it. The image will be forwarded to the MATLAB program for it to

undergo image segmentation, color threshold, and shape analysis. The parameters acquired such as color and shape will be compared to the values that are stored in the database. If it matches any of the values for the three types of circulatory diseases, the Graphical User Interface or GUI will display the corresponding disease diagnosis but if not, it will show ‘’Unidentified’’ as a result.

Visual Studio is the programming software used to design the Graphical User Interface (GUI) of the proposed system. The flowchart of the Visual-Studio-based GUI is shown in Figure 4. The GUI will control the image capturing and after it shows the classification of the disease a dialogue box will appear indicating that the entirety of the program is already executed.

After the application starts up, a window will appear indicating that the image of the fingernail can be captured already. A preview of the captured images will appear, while it is being analyzed by the MATLAB function that is pre-installed in the application. Once the entirety of the MATLAB program has been executed to analyze the input image, the classification of the disease will appear if it is Congestive Heart Failure, Coronary Heart Occlusion or Congenital Heart Disease.

But if it does not match any of the values from the stored database, it will deliver a result “Unidentified”. The program is designed for the benefit of the user in such a way that it will give the corresponding diagnosis for each of the fingernail captured.

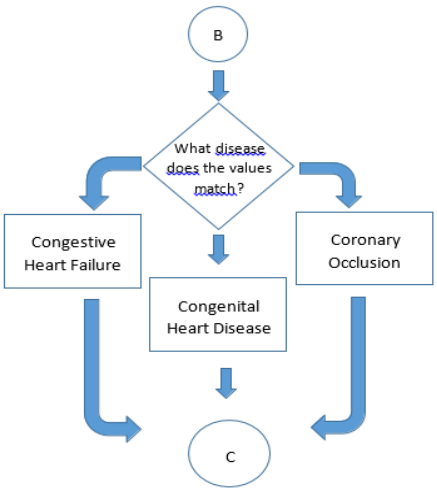
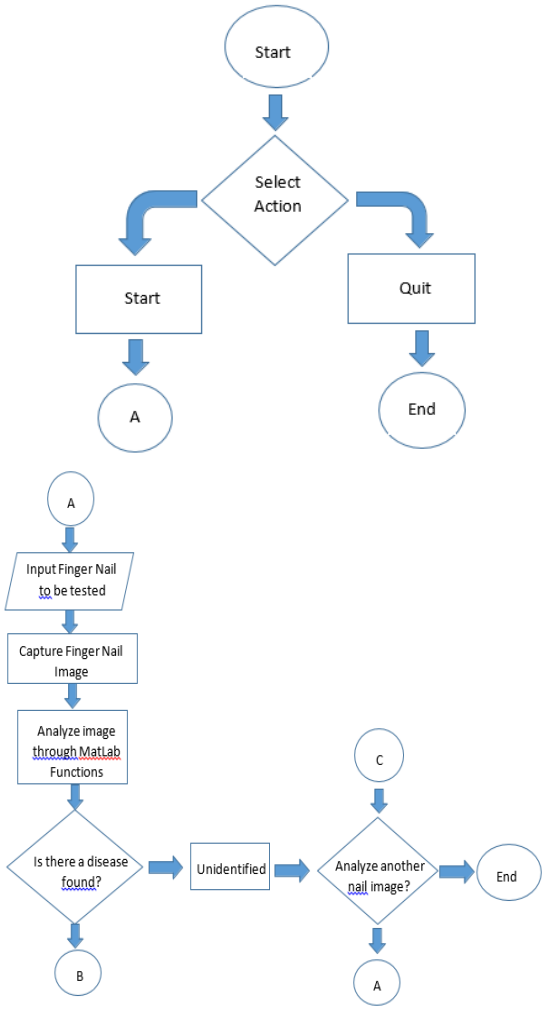


Figure 4: Flowchart of the Visual Studio-based GUI

Figure 5 shows the workflow of Artificial Neural Network Classifier where in the input data image will undergo training and adjusting of values to generate a certain value of parameters. Then, it will be classified by the Artificial Neural Network Fitting algorithm and the processed image will be compared to the classified result in order to match the input data with the targeted result which is the circulatory disease detection.



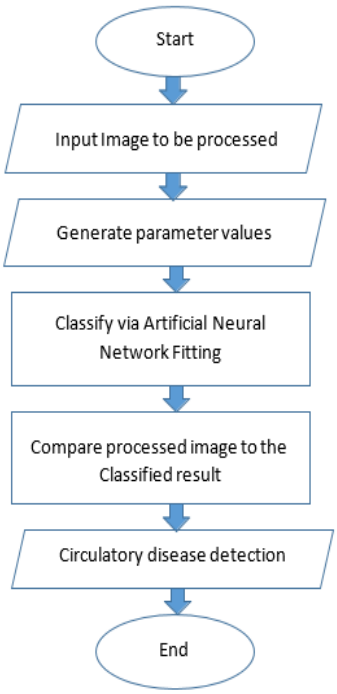


Figure 5: Flowchart of the ANN classifier

Figure 6 shows that the captured image will be the input for the system which will undergo image segmentation. After the image goes through segmentation, it will be processed for color threshold for detection of circulatory disease.

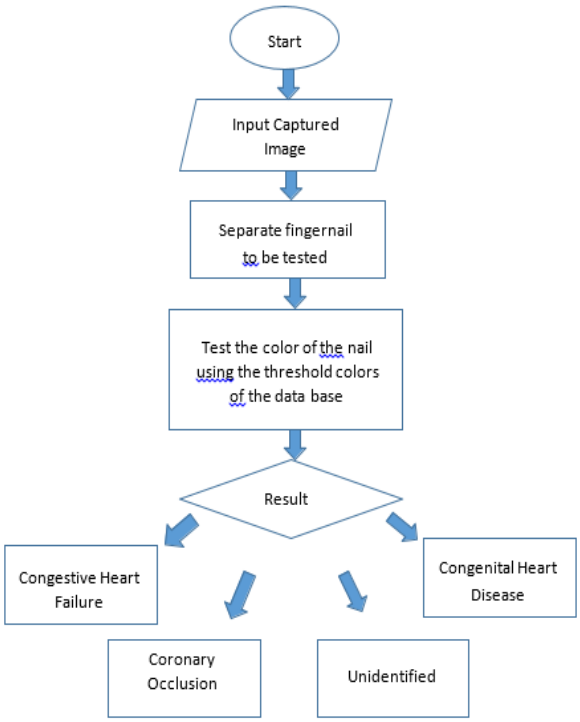


Figure 6: Color detection flowchart

Figure 7 shows that the captured image will be the input for the system which will undergo image segmentation. After the image goes through segmentation, it will be processed for edge detection to extract the actual fingernail from the rest of the image to determine its roundness.

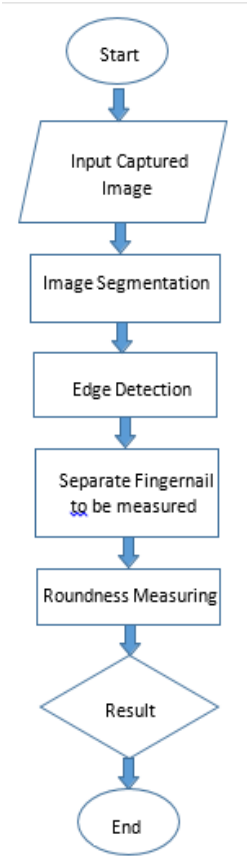


Figure 7: Roundness measuring flowchart

Figures 8 and 9 show the extraction of the fingernail image from the rest of the image through image segmentation and the RGB values extraction of the segmented image through color threshold, respectively. Meanwhile, Figure 10 illustrates the fingernail shape analysis.

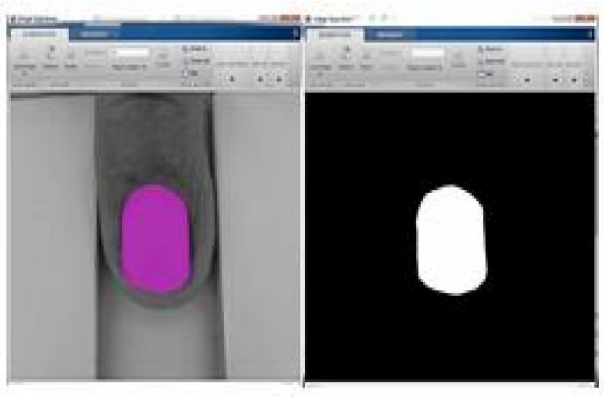


Figure 8: Image segmentation

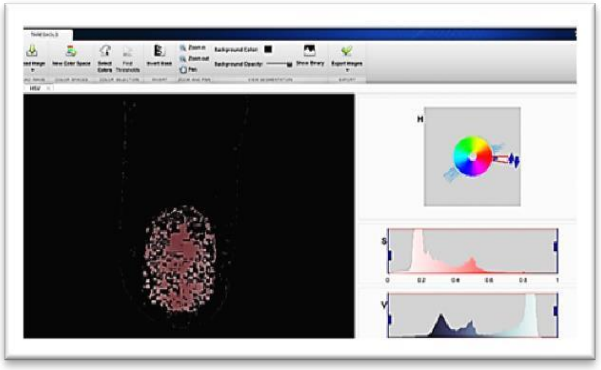


Figure 9: Color threshold

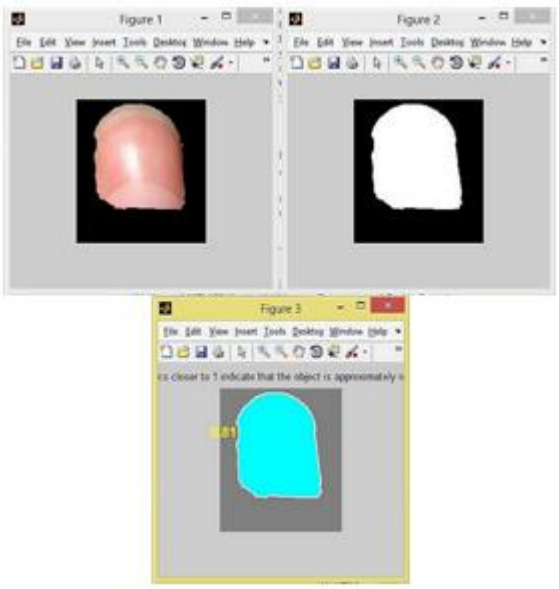


Figure 10: Fingernail shape analysis

IV. DATA GATHERING

Figures 11 to 15 shows the procedures in using the proposed device. Each of the fingers of the patients in Hospital A (at standard temperature of 25 degrees Celsius) was inserted in the inlet of the proposed detection system for the nail image acquisition. The fingernails must not be

polished or painted. The images were taken using the high-definition webcam controlled by the Graphical User Interface. The images then underwent image segmentation, color, and shape analysis using the program that was created in Image Processing Toolbox of MATLAB.

74 fingernail images from 10 patients with Congestive Heart Failure, 49 fingernail images from 6 patients with Congenital Heart Disease and 35 fingernail images from 4 patients with Coronary Occlusion were gathered from the said hospital. After all the images were taken, their values were compiled and they were used as the database of the device.

Figure 11: Inserting the finger into the inlet of the proposed detection system

Figure 12: GUI of the proposed detection system

Figure 13: Captured fingernail images using the proposed detection system

Figure 14: Classify disease after images were taken

Figure 15: Classification of circulatory disease

V. RESULTS AND DISCUSSION

Figure 16 shows that the 74 fingernail samples with congestive heart failure has a red value that measures between 120 to 130 and has an average of 123.126. For green value, it falls between 100 and 110 and has an average of 103.432, and lastly, blue value measures approximately 85 to 95 that has an average value of 90.256.

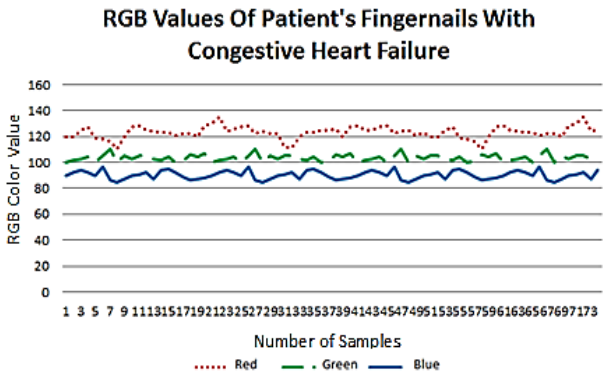


Figure 16: RGB values of fingernails from patients with congestive heart failure

Figure 17 shows that the 49 nail samples with congenital heart disease has a red value that measures between 110 and 120 and has an average value of 114.204. For green value, it falls between 70 and 80 and has an average value of 72.408 and lastly, blue value measures approximately 60 to 70 that has an average value of 68.162.

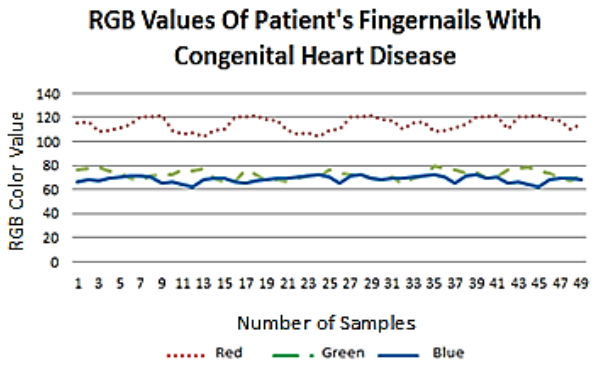


Figure 17: RGB values of fingernails from patients with congenital heart disease

Figure 18 shows that the 35 nail samples with coronary occlusion has a red value that measures between 100 and 110 that has an average value of 103.428. For green value, it falls between 70 and 80 that has an average value of 69.8 and lastly, blue value measures approximately 40 to 55 and has an average value of 49.314.

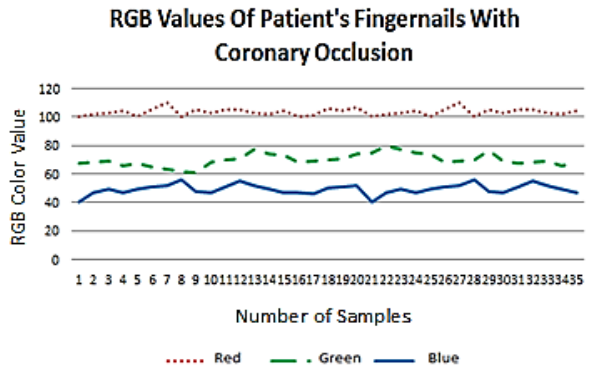


Figure 18: RGB values of fingernails from patients with coronary occlusion

Table 1 shows the roundness of the fingernails to determine its shape. A value closer to 1 signifies that the shape is round. A normal fingernail has a roundness of approximately 0.7.

Table 1
Roundness of Nail

Roundness	Fingernail
0.75-0.78	Normal Shape
1	Round/Nail Clubbing

Figures 19, 20, and 21 show that the roundness of fingernails of the patients with Congestive Heart Failure, Congenital Heart Disease, and Coronary Occlusion have an average of 0.782, 0.900, and 0.778, respectively. From these values, it can be said that patients with CHD have a nearly rounded fingernail compared to the other 2 diseases.

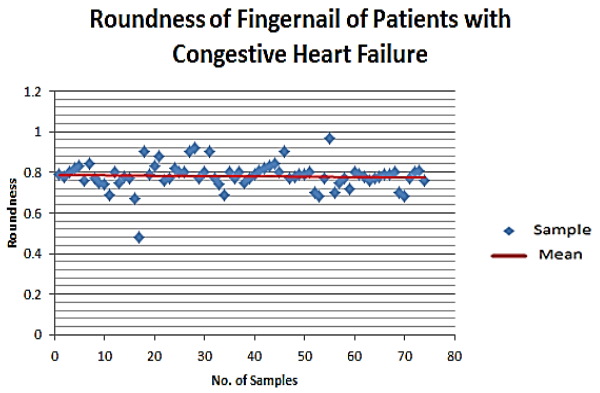


Figure 19: Roundness of fingernails from patients with congestive heart failure

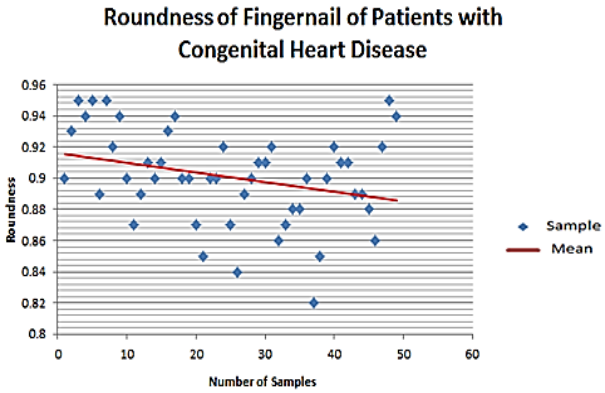


Figure 20: Roundness of fingernails from patients with congenital heart disease

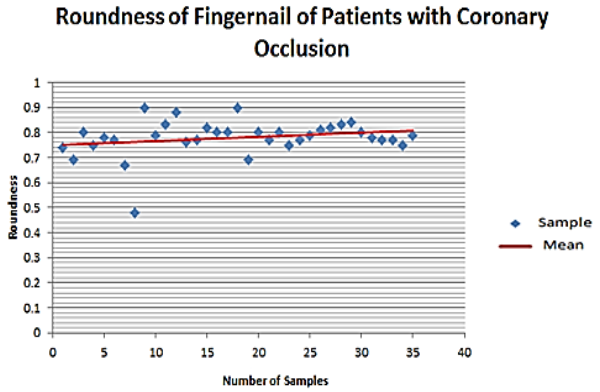


Figure 21: Roundness of fingernails from patients with coronary occlusion

Table 2 shows the summary of results of training the database using the ANN feature of MATLAB. Each type of fingernail undergoes training and setting 100 hidden neurons.

The number of iterations of database training for little, ring, middle, index, and thumb fingernails are 5, 4, 4, 6, and 5, respectively and stop at 0, 0, 1, 6, and 0 second/s of iteration/epoch, respectively. Epoch is the presentation of the set of training (input and/or target) vectors to a network and the calculation of new weights and biases. Table 2 shows the value of mean squared error, gradient, overall regression coefficient, and best validation performance for the five fingernails which undergone database training.

Table 2
Summary of Database Result Training Using ANN

Finger-nails	Mean Squared Errors	Gradient	Overall Regression Coefficient	Best Validation Performance
Little	1.15E-21	1.12E-11	0.97177	7.29E-08
Ring	3.45E-21	4.13E-11	0.99173	6.21E-06
Middle	6.40E-24	9.45E-13	0.9719	1.75E-07
Index	6.34E-26	1.15E-13	0.96389	3.73E-07
Thumb	2.61E-24	2.26E-13	0.99027	6.21E-09

Table 3 shows the data that a total of 23 samples were tested in Department 1 of Hospital A. Out of these 23 samples, 6 samples were classified with the diseases that falls under the scope of the study. Meanwhile, Table 4 shows that a total of 11 samples were tested in Department 2 of the same institution. By looking at the results generated from the said hospital, the proposed detection system was 100% successful in detecting three types of circulatory diseases. This proves that the device is applicable as a reliable supporting device for medical institutions.

For Table 3, shortened acronyms CHF, CHD, CO, Cardi, Hypo, Ather, Carda, Cardc, Diabe, Brain, Liver, Septi, Kidne, and Breas stand for diseases namely: Congestive Heart Failure, Congenital Heart Disease, Coronary Occlusion, Cardiomyopathy, Hypotension, Atheroma, Cardiac Arrhythmia, Cardiac Arrest, Diabetes Mellitus, Brain Aneurism, Acute Liver Failure, Failure Septi Shock, Acute Kidney Injury, and Breast Cancer, respectively.

For Table 4, shortened acronyms Asth, Acut, Mus, Flu, Den, Gast, Imp, Pityr, and Arth refers to Asthma, Acute Upper Respiratory Infection, Muskoskeletal, Flu, Dengue, Gastroenteritis, Impetigo, Pityriasis Rosea, and Arthritis, respectively.

Table 3
Data Gathered from Department 1 of Hospital A

Proposed Detection System							
Sample	Fingernails	CHF	CO	CHD	UI	Diagnosis	Results
1	10	10	0	0	0	CHF	1
2	5	5	0	0	0	CHF	1
3	8	8	0	0	0	CHF	1
4	7	0	0	7	0	CHD	1
5	8	0	0	8	0	CHD	1
6	10	0	10	0	0	CO	1
7	10	0	0	0	10	Cardiomyo pathy	1
8	10	0	1	0	9	Hypon	1
9	10	0	0	1	9	Atheroma	1
10	10	0	0	0	10	Cardaac Arrhythmia	1
11	5	0	0	0	5	Cardaac Arrhythmia	1
12	8	0	0	0	8	Cardaac Arrhythmia	1
13	5	0	0	0	5	Cardcac Arrest	1
14	5	0	0	0	5	Cardcac Arrest	1
15	10	0	0	0	10	Diabetes Mellitus	1
16	10	0	0	0	10	Diabetes Mellitus	1
17	5	0	0	0	5	Brain Aneurism	1
18	10	0	0	0	10	Liverure	1
19	5	0	0	0	5	Septi	1
20	10	0	0	0	10	Kidnery	1
21	8	0	0	0	8	Kidney	1
22	10	0	0	2	8	Breaster	1
23	10	0	0	0	10	Diabetes Mellitus	1

Table.4:
Data Gathered from Department 2 of Hospital A

Proposed Detection System							
Sample	Fingernails	CHF	CO	CHD	UI	Diagnosis	Results
1	10	0	0	0	10	Asthma	1
2	10	0	0	0	10	Acute Upper Respiratory Infection	1
3	10	0	0	0	10	Mus	1
4	10	0	0	0	10	Flu	1
5	10	0	0	0	10	Dengue	1
6	10	0	0	0	10	Gastroenteritis	1
7	10	0	0	0	10	Imp	1
8	10	0	0	0	10	Imp	1
9	10	0	0	0	10	Pityrsea	1
10	5	0	0	0	5	Arths	1
11	8	0	0	0	8	Arth	1

VI. CONCLUSION

Based on the findings on the result of the study, the following are the conclusions: The Graphical User Interface served as the link between the camera and the program so that it can process the input image. The program that can process and analyze the input image for image segmentation, color threshold, and shape analysis was created through the Image Processing Toolbox of MATLAB programming software. The program based on Artificial Neural Network that can identify if a person has a circulatory disease was successfully executed using image processing techniques. The functionality of the program was well implemented through

Artificial Neural Network classifier. As verified by the medical specialist from Hospital A, the device was 100% successful in detecting the three Circulatory Diseases (Coronary Occlusion, Congenital Heart Disease, and Congestive Heart Failure).

Future work includes additional types of circulatory disorders and other non-circulatory disorders and additional database for the three circulatory diseases mentioned which will increase the device's use and function. Moreover, HSV and natural YUV will be employed in the color extraction of fingernails.

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