Prediction of Health Conditions with Dermatoglyphic Palm Pattern Prints

Benjamin Choy Kai Ghit, Li Fang, Song Liting, Kwek Jia Long

Abstract—There exists a close relation between the dermatoglyphic patterns of palms and the health condition of an individual, and hence a plausible prognosis. This builds upon the overall physical façade of the palm in giving a synoptic overview on an individual's state of health. The applications for palm prints in the area of biometric identification and security are myriad, and in recent years, its research and utilisation in health sciences has burgeoned. This paper aims to provide the research process, analysis and findings on the prognosis of some existing health conditions, such as schizophrenia, intellectual disability, and liver disease; based on the analyses of palm prints. The image processing and classification methods employed work on features like the palm patterns, lines, ridges, shape and colouration. For the purpose of this paper, work done is focused on the lines and colouration of palms. The applications and analyses could also serve as a rudimentary development guide for future enhancements.

Index Terms—Dermatoglyphic palm pattern prints, Health condition,Histogram equalization, Image recognition.

I. INTRODUCTION

Since the ancient times, palmistry, or the study of the palm (and its prints), has been used in various ways and different fields, such as fortune telling, predicting into the future, and characterization in criminology [1]. More interestingly, in recent years, prediction of illnesses in medical psychiatry has been discovered in modern-day palmistry, that various medical problems could be diagnosed based on different palm line formations [2]–[6]. To some, the reading of palm may be just a mere superstition and treated as more of a curiosity; while to others, it can be a very different outlook of looking into one's fortune, wealth and personal well being. This is commonly seen in the Western versus Eastern culture [7]. Palmistry has taken on different perspectives as the opinions from various parts of the world vary.

In the modern society, doctors rely on many kinds of tests to diagnose a patient's disease. They rely on the medical history of the patient and laboratory test results to trace the problem. The skin is an essential organ and changes on the skin often serve as early warnings of hidden, more serious illnesses [8]. Additionally, studies suggest that 1–4% of internal cancers will show some form of indications on the skin [9]. Similarly, the colour of the palm may show signs of underlying health problems. If the palm colour appears either darker or lighter than normal, this may indicate that the person is unhealthy. Traditional Chinese Medicine (TCM) palm diagnosis focuses on the study of pathological patterns and warning symptoms of diseases. Problems with different internal organs manifest symptoms on different regions of the palm. Analysis of palm colour may thus be an early diagnosis tool to identify and predict diseases earlier than other conventional techniques.

Even before birth, lines have alreadybegun to develop on the palms (palmar flexion creases), occurring as early as the 12^{th} week of gestation as a foetus and completely present at birth [10][11]. The lines aid in the stretching and squeezing of the hand (mainly grasping actions) accompany individuals in their entire lifetime [12]. As the lines are predefined at birth, the implications that curtail are pre-set in the body of an individual. It is no supernatural prediction when lines on the hands seem to appear in a common pattern. This sheer coincidence is the basis forming the symptoms for further prognosis of a medical condition.

This project tries to understand the practice of palm reading in the traditional manner, as well as putting into practice virtually through various approaches. The two chosen health conditions that this project will be focusing on would be schizophreniaand intellectual disability [3]–[5]. Several experiments with regard to research for this project were conducted with a palm print database collected by Hong Kong Polytechnic University, Hong Kong. Analysis of the chosen health conditions based on the available palm print database, translates to how they can be used in a real-world implementation. Given the results of the analysis, a proof of concept application will be developed to predict the possibility (based on an input palm print image) of suffering from either of the health conditions. An attempt was made to automate palm reading via image processing.

This project also focuses on the coloration of palms in determining the health status of an individual. Red palms (palmar erythema) indicate signs of liver damage, thyroid disorder or rheumatoid arthritis. Bluish hands may be due to a paucity of oxygenated blood or low body temperature. The lack of oxygen in will result in blue coloration of the skin, which manifest on the hands, feet and lips. Tripe palms, characterised by pronounced folds in the lines of the hand, is a symptom of cancer, especially so in lungs and stomach cancer. Sample images of the hands are as shown in Fig.1.

Fig.1. Example of palmar erythema, tripe palm and bluish hand (left to right)

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Benjamin Choy Kai Ghit, Department of Computer Engineering, Nanyang Technological University, Singapore, Singapore.

Dr. Li Fang, Lecturer, Division of Hardware and Embedded Systems, Nanyang Technological University, Singapore, Singapore.

Song Liting, Department of Computer Engineering, Nanyang Technological University, Singapore, Singapore.

Kwek Jia Long, Department of Computer Engineering, Nanyang Technological University, Singapore, Singapore.

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II. LITERATURE REVIEW

A. Schizophrenia

Schizophrenia is a major psychotic illness which brings disorder to an individual's mental health, causing them to have fragmented mental processes leading to a breakdown in thinking and poor emotional responses. Major symptoms of this mental illness include delusions, hallucinations, bizarre or disorganized thinking and behaviour. The illness affects both males and females equally, at any age with the onset usually during adolescence and young adulthood; 15 to 25 years of age among men and 25 to 35 years of age in women [13]–[15].

There is substantial evidence showing a constant similarity pattern of abnormal prints in the palm of schizophrenics [2]. The abnormal prints contain high densities of secondary creases lying on the lower palm, whereby it is described as the main feature of schizophrenic individuals. The contrast is as shown in Fig. 2 and Fig. 3.

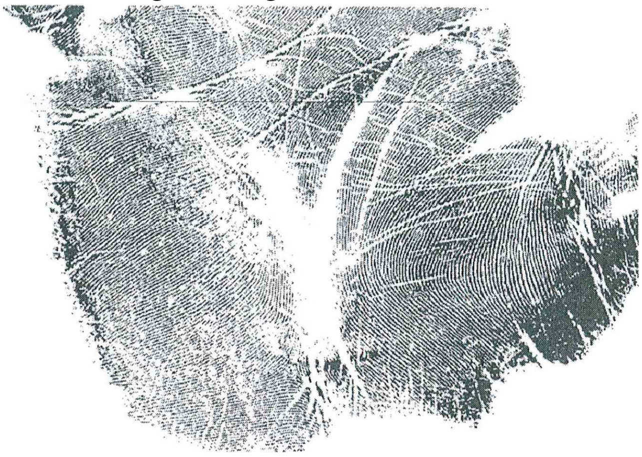

Fig. 2.Lower palm print of a normal individual [31]

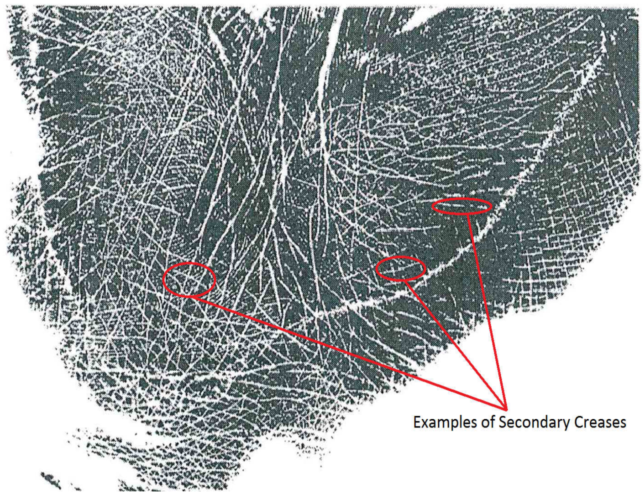

Fig.3.Lower palm print of a schizophrenic showing high densities of secondary creases [31]

For the experiment, diagnoses were conducted on 89 palm prints by 4 unbiased raters, all without the knowledge of the experiment. Their task was to identify palm prints with high densities of secondary creases, which concluded with all of the 4 raters unanimously isolating 7 palm prints. To affirm the relationship between high densities of secondary creases and schizophrenia, the result showed that all 7 previously chosen palm prints belonged to a group of 46 schizophrenic (ICD-9) individuals, while none from the 43 normal individuals were chosen. This 100% accuracy was significant in concluding that having high densities of secondary creases in the palm print might lead to schizophrenia, or vice versa.

B. Intellectual Disability

By intellectual disability,it is the mental condition characterized by below-average mental ability with the lack of social skills required for day-to-day living. Typical symptoms of the neurodevelopmental disorder would include (non-exhaustive):

- Delays in oral language development
- Difficulty in learning social rules
- Delays in development of adaptive behaviours

Intellectual Disability is often associated with the Intelligence Quotient (IQ) of an individual being less than 70. This however, is untrue as the current definition now includes two components:

1. Mental functioning
2. Functional skills within the environment

Thus, a person having low IQ does not necessarily imply that he/she is intellectually disabled. Intellectual Disability typically appears before adulthood, normally before the age of 22 and affects both males and females alike [16]–[18]. As proposed by Bali & Chaube in 1971, normal major palmar flexion creases were classified as in Fig. 4 [19].

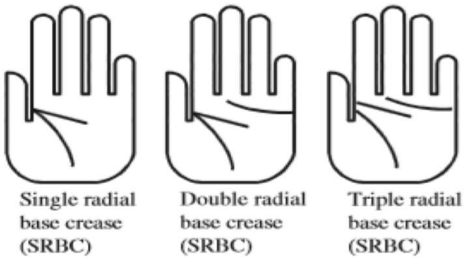

Fig. 4.Schematic drawing of normal patterns in major flexion creases [19]

As evidenced by Rosa et al., 2001,the palm prints of individuals classified as with health conditions, more specifically intellectual disability, do not match the prints as shown in Fig. 4 [4]. The research has also classified a set of palm prints with abnormal major palmar flexion creases as shown in Fig. 5.

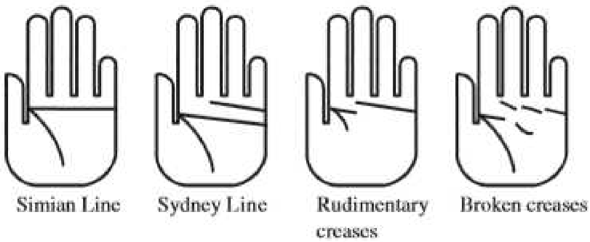

Fig. 5. Schematic drawing of abnormal patterns in major flexion creases [19]

In the distribution of abnormal palmar flexion in the study of 137 children, 62 are with intellectual disability, and 75 are healthy controls. The findings concluded that only 41.4% of the 62 children with intellectual disability had normal palmar flexion creases, which belongs to the normal classification, as compared to the healthy counterparts with 71.2% possessing the normal patterns. There are also other modern day tests

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and checks around the world on a newborn’s palm, to identify if there issingle or multiple palmar creasesasa single palmar crease might be a sign of intellectual disability [20][21].

C. Traditional Chinese Medicine Palm Diagnosis

According to TCM, just how healthy an individual is, it is all written in the hands, literally [22]. The overall observation of the façade of the palm would allow irregularities to be picked out by the physician, in terms of lumps colouration. The palm is also an area of concentration for peripheral nerves. The skin on the palm is more sensitive than any part of the body and it can better distinguish between hot and cold temperatures, soft and hard textures, dry and wet surfaces. Such ample peripheral nerve activities can have a significant impact on the formation of palm prints [23].

From the hand, one is able to gather a large amount of biological and non-biological electrical information. The composition, and hence the appearance, of palm prints is affected by capillary and microcirculation action. Differences in blood circulation conditions can result in visible changes in the palm. When the blood circulation is well, as that of a healthy individual, the palm shows a uniform colour because the skin is well nourished. On the other hand, poor blood circulation results in the withering of the palm or palm atrophy, and the palm will be seen as palewhitish in colour. Excessive carbon dioxide in microcirculation will cause the palm colour to turn bluish green due to deprivation of oxygen. Hence, the change in palm colour is important in palm print diagnosis. Moreover, many diseases can cause changes in microcirculation regulation even though the patient does not feel any pain or discomfort [23]. Analysis of palm prints may thus be an early diagnosis tool that can discover underlying health problems earlier than other conventional techniques.

In addition, the palm prints can be a diagnosis tool not only for congenital disorders, but also for acquired disorders. As shown in Fig. 6, by learning how to distinguish the fourteen lines and memorizing the positions associated with the internal organs on the palm, one can learn the fundamentals of palm print diagnosis.

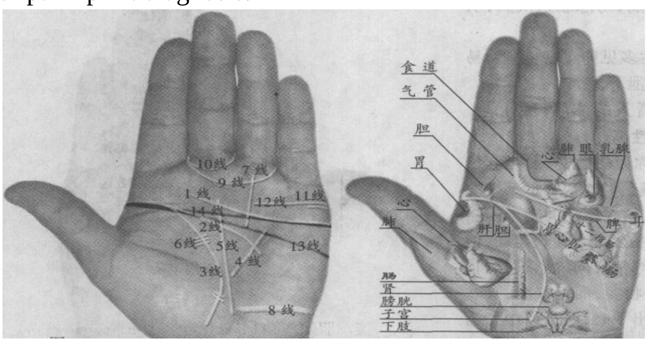

Fig. 6. Example of the palm lines and the associated positions of the internal organs on the palm [30]

During palm diagnosis, the first step is to observe whether any dark spots are present, then inspect the skin colour of at each area on the palm. This is followed by examination for any abnormal pattern that appears on the palm [24]. Symptoms of bronchial asthma are reflected on the palm such as the expansion of the liver area;and dark spots formed on lung, bronchial and kidney area, as shown in Fig. 7.

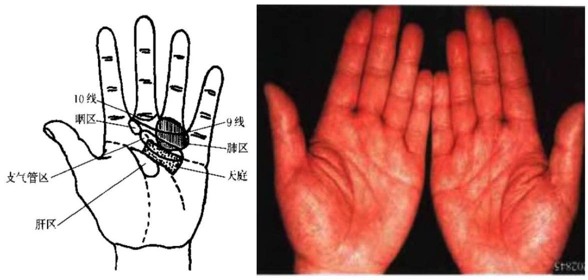

Fig. 7. Example of palms of a bronchial asthma individual [30]

For a healthy individual, the first and third main lines are usually deeper than that of the second line. The depths of the first, second and third main lines serve as the basis to gauge other lines. The formation of a pathological pattern or lines that appear to be deeper than the three main lines is known as Chen in Chinese [23]. In particular, if the fourth line appears to be Chen, it signals that the disease/condition has deteriorated. If there are shallow lines that ought to be deep, or deep lines that ought to be shallow, these indicate that the body is undergoing certain changes. Some of these changes and inconsistencies may not possess pathological origins; but nevertheless, they provide useful prognostic information.

The sympathetic nerve system and the parasympathetic nerve system coordinate and regulate each other. When the sympathetic nerve is in an excited state, it suppresses the parasympathetic nerves, and vice versa. These changes are reflected on the palm through the relative sizes of the regions of the palm associated with the two nervous systems, as shown in Fig. 8.

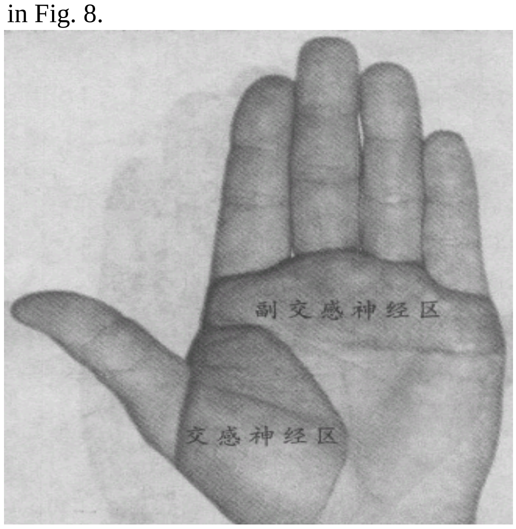

Fig. 8. Example of a palm exhibiting the regions of the two nervous systems [30]

The change in sizes as aforementioned can be used in the determination of an appropriate treatment for certain diseases. For instance for diabetic patient, if the blood sugar level has not been effectively regulated, the sympathetic area on the hand will gradually expand. If the sympathetic nervous system is often in the excited state, it will result in decreased salivation, gastric juice and sweat secretion, as well as increased blood pressure. This makes the body susceptible to stroke, heart and kidney diseases, hypertension, diabetes, etc. For the case of cancer in the malignant stages, the parasympathetic zone will expand while sympathetic zone will slowly shrink.

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III. METHODOLOGY

The flowchart diagram used in this paper as shown in Fig. 9 gives the work flow of identification via the Palm Print Prediction System, which is used the match the test palm print with the compressed database using trends and classifications. For the analysis of palm line, a line edge map is produced. The analysis on palm colouration and discolouration requires the palm image to be processed separately. This consists of 5 main phases, namely: image acquisition, image processing, feature extraction, healthy range computation, and comparison.

The input of palm print image is the grayscale image of an individual, which intensity ranges from 0 to 255, where 0 represents black and 255 represents white.If all the red, green, and blue (RGB) colour components use the same weight, it will result in the same grayscale level. This technique is applied by the human eye as it is more sensitive to green light as compared to red or blue light. In a palm print image, the region of interest (ROI) is extracted by feature extraction. Images are enhanced by histogram equalisation for comparison and classification. A scatter-plot is performed to determine the k-nearest neighbours and group them. The identification made is a plausible deduced prognosis.

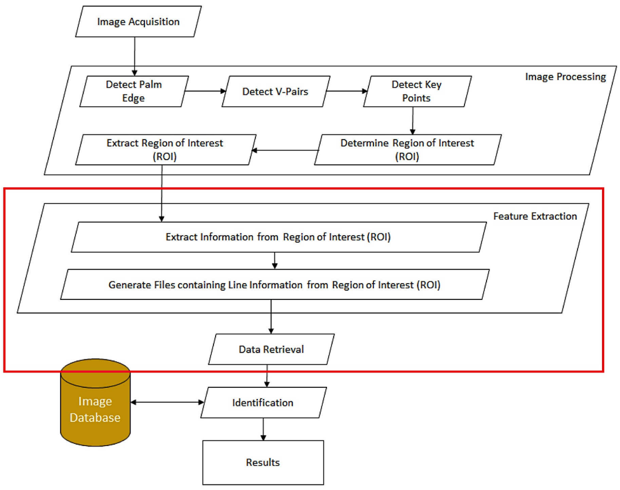

Fig. 9. Generic flowchart of the system

IV. PALM PRINT PREDICTION SYSTEM

A. Generation of Line Edge Map

The generation of the line edge map is based on the 8-bit TIFF format grayscale input image. This format allows the ROI to be accepted and processed by the system's line analysis function. The line edge map is akin to a replication of the palm print image in a computerised form through the formation of lines. This process generates the lines and the outputs the computer interpretable information as SPM format files.

The processed image prevents the lines from being affected by noise disturbances, which might decrease the accuracy when extracting the lines. The intermediate output files from the lines detection are:

1. hist_filtered.txt
2. thin_filtered.txt
3. binary.tif
4. edge.tif
5. thin.tif

After the processing, the intermediate files are converted to computer interpretable information. A collection of lines representing the palm print lines is produced from the tracing of contours. Dynamic Two-Strip (DYN2S) algorithm is performed to straighten the curves, reducing the space and time complexity of identification. This approximates the palm print lines of the input palm print image. The output SPM format file is seen as the line edge map of the image, consisting of:

1. dyn2S.rlt
2. dyn2S.rlt2
3. palm.pm
4. palm.spm
5. palmContour.txt
6. palmlong.pts
7. record.txt

The individual SPM format files for each ROI are stores in pre-defined folders. Thereafter images of the line edge map are displayed with numbers (in green) for identification, as shown in Fig. 10.

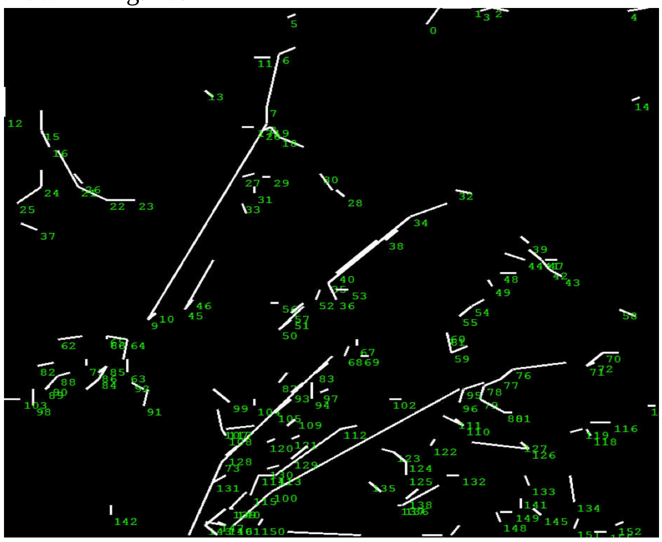

Fig. 10. Example of display of line edge map

B. Image Processing

By image processing, the ROI of palm print images were manually cropped using Adobe Photoshop. The justification behind processing and extracting the ROI is due to 2 problems. First, the original palm image usually consists of palm, fingers, wrist, and a large amount of background area. As in Fig. 11, redundant information such as background and the proximity between fingers vary, depending on how the image might have been captured. Next, it would be more efficient to do away with unwanted portions of the original palm image as it reduces the amount of computational cycles required in the subsequent stages.

Fig. 11. Example of an original palm image

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The main area of the ROI is focused on the centre of the entirepalm. When the image is added to the program, it is automatically resized to 160 x 160 pixels. A smaller resolution results in lesser pixels to be iterated through, and hence enabling easier manipulation and faster image processing. The ROI is as shown in Fig. 12.

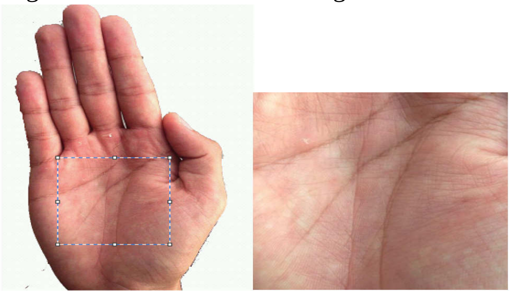

Fig. 12. The ROI extracted [30]

C. Feature Extraction

In this stage, the ROI is utilised to see which measurement is the best to differentiate the palms of different colours. The method uses k-means clustering to find the 3 most dominant colours on the palm – 3 specified clusters. The data points are partitioned into 'k' clusters where each cluster is associated with a centroid that is the calculatedmean of the points in the cluster. Each data point is then assigned to the cluster with the closest centroid. Before the use of k-means clustering to extract the colour, Python Image Library (PIL) resized the images to 160 X 160 pixels.

Using each pixel in the image as a point in 3-dimensional space to represent the colours: red, green and blue. Each pixel is iterated to calculate the distance to each of the cluster. Following the assignment of each point to the closest centroid, re-computation for the average of each cluster is performed. The re-computation is repeated until no further change in centroid is observed. Fig. 13 shows the black dots indicating the centres of each cluster and the coloured data points of the respective clusters.

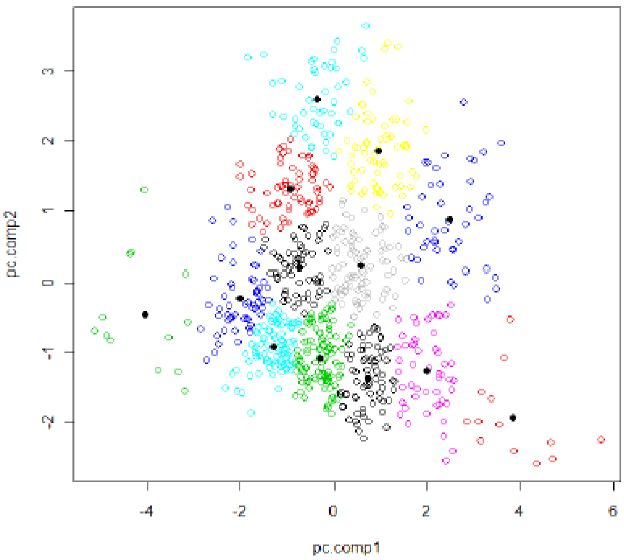

Fig. 13.The use of k-means clustering to determine the clusters and centroids [30]

By k-means clustering, it returns result of the 3 most dominant colours in the form of their RGB values. For example in Fig. 14, this input ROI returned 3 most dominant colours in RGB value: [206, 164, 151], [240, 200, 184], [177, 132, 120]. Although k-means clustering is easy to understand and implement but the difficulty is in performing analysis based on a single colour. Also, it does not have an optimal solution as the performance depends on initial centroids.

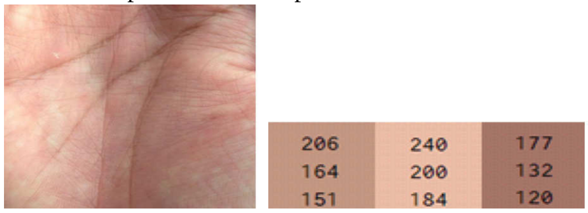

Fig. 14.The 3 most dominant colours found on the palm

Further enhancement is the application of grayscale to improve the pixels' intensity (as in line edge generation), as shown in Fig. 15. Image enhancement approaches are broadly divided into two categories which are the spatial domain methods and frequency domain methods. In this paper, spatial domain methods were applied by manipulation of the pixel values of an image. Spatial domain processes are denoted by the expression: $g(x, y) = T[f(x, y)]$, where the input image is $f(x, y)$ is and the processed image is $g(x, y)$, and T is the operator on f, defined over some neighbourhood of (x, y) [25].The second method is to convert RGB colour image to grayscale image by applying the formula: Luminance = 0.2126•R + 0.7152•G + 0.0722•B [26]. The luminance intensity computes the different weight of each colour component. The RGB values are applied to compute for the luminance or grayscale values. For easy retrieval, all grayscale values for each image are stored in a list. A single gray value result is stored in a variable for later comparison. Averagely, conversion to grayscale took about 30 milliseconds or less.

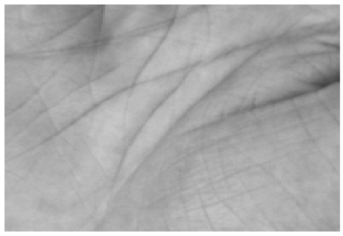

Fig. 15.Example of ROI in grayscale [30]

D. Histogram generation based on grayscale values

By using the grayscale values obtained, the histogram is generated to determine the threshold value. The use of a histogram offers a good graphical representation to analyse the frequency of appearance of the different grayscale levels of the overall image database.

After converting to grayscale images, the list of grayscale values of the image database is written into a text file. Matplotlib (Python 2D plotting library) is used to generate the histogram. Based on the grayscale levels,the mean and standard deviation were computed. Besides that, the value of the input ROI was retrieved for comparisontogether with the rest of the values and displayed on the histogram.

An ideal histogram covers all the possible grayscale values used. This histogram suggests that the overall images have good contrast as details of the ROIcould be observed easily. In Fig. 16, the histogram depicts a fraction of the complete range of grayscale levels in the image database. The blue bar indicates the palm print inputvalue. The values shown ranges from approximately 90 to 190 out of 256

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grayscale levels. ROI images with grayscale value less than 110 or more than 190 fall off the healthy range.

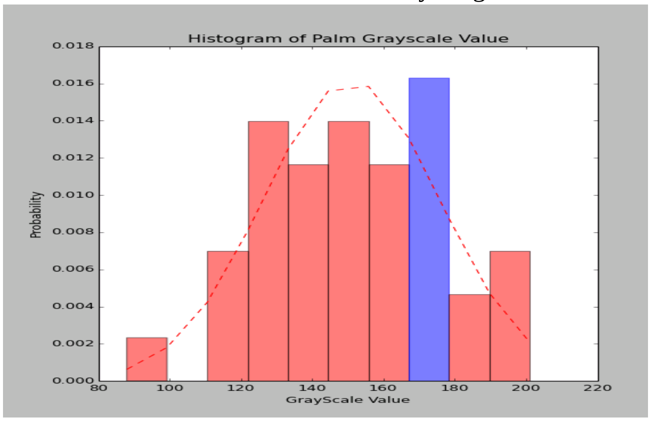

Fig. 16.Example of the grayscale histogram [30]

E. Histogram equalization

Some of the palm print images are taken at poor lighting condition which affect the intensity of an image. To counter this issue, the grayscale images were enhanced using histogram equalization. Histogram equalization aids in enhancing the contrast by spreading out most frequent intensity values. This method increases the overall contrast of images especially when an image'sbackground and foreground are of close contrast values. It improves the visibility of images that are under or overexposed.

Histogram equalization helps to flatten the grayscale levels(L) histogram of an image so that intensity values are equally spreaded out [27]. The images has n_k pixels with intensity r_k, for k = 0, 1, 2, 3, …, L - 1. Firstly, it obtains the grayscale images from the image database to produce the image histogram (h). The image histogram is defined as $h(r_k) = n_k$ [28]. Then using the histogram normalization formula: $p(r_k)= h(r_k) / (M \times N)$, where M x N is the number of pixels to the number of occurrence of each pixel colour r_k in the image. The mapping of pixel values is done by computing the cumulative distribution function (CDF) for each pixel colour, followed by normalizing it over 0 to 255.

Histogram equalization is applied to all grayscales images in the database and a copy of each image is saved in a separate folder. New grayscale values are stored a list. In Fig. 17 is an example of palm print before and after histogram equalization. The image features are more visible after equalization.

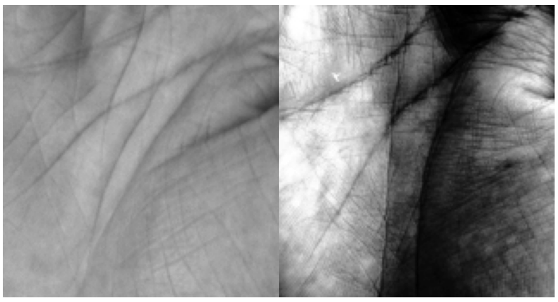

Fig. 17Example of palm print image before (left) and after (right) histogram equalization [30]

After performing histogram equalization,a new histogram is generated to determine the new threshold values. In Fig. 18 the histogram shows that the grayscale values ranging from 128 to 133, which are the new threshold values. ROI images with grayscale values less than 129 or more than 133 fall off the healthy range.

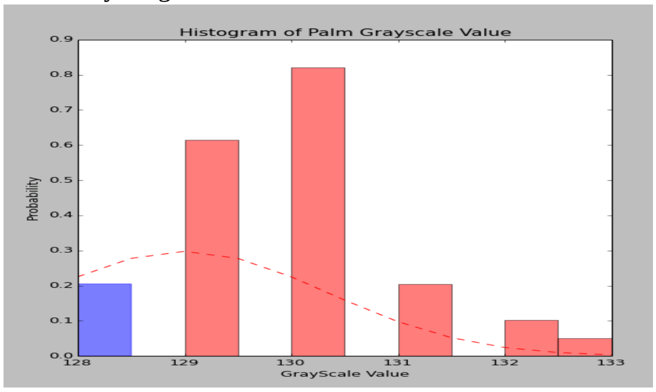

Fig. 18.Histogram portraying the new grayscale threshold values [30]

V. Results And Discussion

A. Lines analysis for schizophrenia

A simple analysis application was developed to aid in the analysis of the results with regards to schizophrenia.The objective of the application was to programmatically analyse and calculate the number of secondary creases in each of the 244 palms prints, whereabnormal prints feature high densities of secondary creases.

The generate analysis function, as shown in Fig. 19, ran through a collection of SPM format files to identify and mark the lines which are considered to be secondary creases based on the control length of 15 units, preset in each of the SPM format files. Based on the results, it was discovered that the average number of secondary creases is 42, in the set of 244 palm prints.

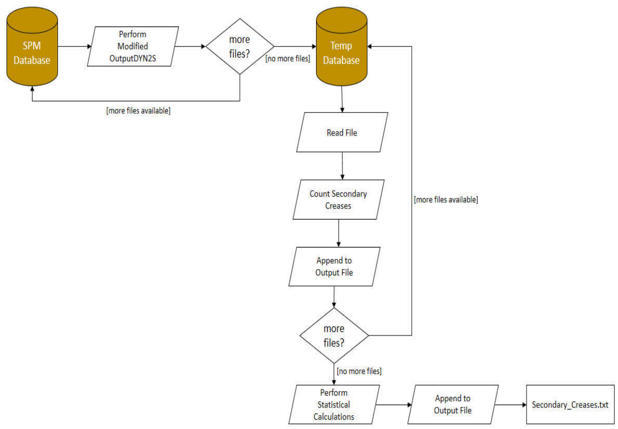

Fig. 19.Flowchart of generate analysis

The boxplot in Fig. 20 shows the result split into quartiles, where it is slightly skewed right with most of the observations on the lower end of the scale. The histogram plotted in Fig. 21indicates the secondary creases data and the threshold. Comparisons were made to detect any anomalies between data and find a threshold for the number of secondary creases to be considered under the abnormal category. The paucity of schizophrenic individuals' palm prints for comparison rendered the subtle distinguishment in the amount of of secondary creases.

Based on the data representation, a threshold of 70 secondary creases was derived. This would serve as a proof

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of concept application, with the assumption that palm prints with more than 70 secondary creases would be considered schizophrenic.

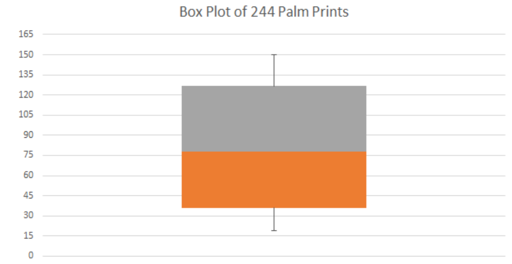

Fig. 20. Box plot of data from analytical application [31]

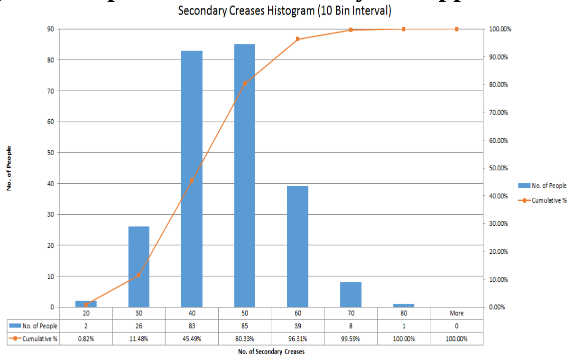

Fig. 21. Histogram indicationg secondary creases data from analytical application [31]

In addition, the read palm print for schizophrenic disorders function was also used for predition on a test subject. It required a BMP format or TIFF format image file type image to be selected by the user. An extra step is required for BMP format files to be converted into TIFF format with the correct and required TIFF image formatting. Thereafter, the image would be read and the SPM format file for the selected image would be generated. It was used to perform DisplayDYN2S() and OutputDYN2S() to generate the marked text file. The final step was the counting of the number of secondary creases (based on the output file), and finally making a prediction. The flow is as illustrated in Fig. 22.

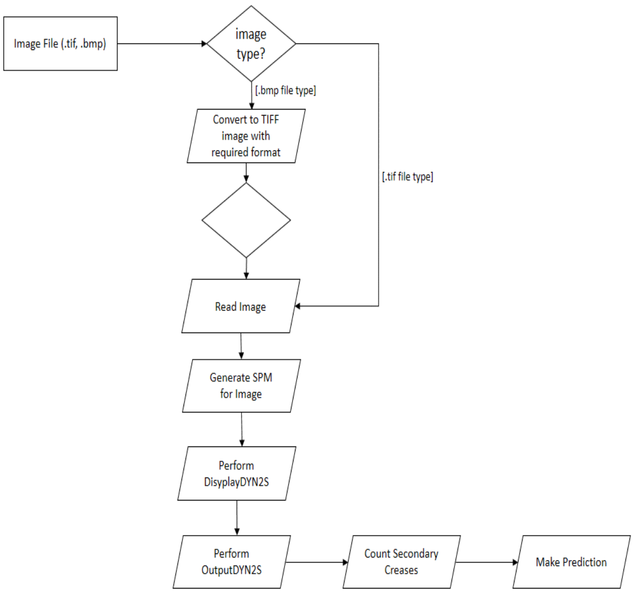

Fig. 22. Flowchart for the function of read palm print for schizophrenia

B. Lines analysis for intellectual disability

As there were no affirmed trends for identifying the major flexion creases on the palm, the analysis for this health condition was done manually by going through each and every TIFF format image of the 244 palm prints. The process included identifying and sorting each palm print into their respective normal or abnormal classification, based on their palm print type.The set of palm prints would be classified as shown in Table I.

Table I. Format for intellectual disability classification

Normal			Abnormal				Unidentifiable
Single Radial Base Crease	Double Radial Base Crease	Triple Radial Base Crease	Simian Line	Sydney Line	Rudimentary Line	Broken Creases	

The classifications of palm prints had a 96.71% similarity, with 235 palm prints classified under the same category. The averaged results can be seen in Fig. 23.

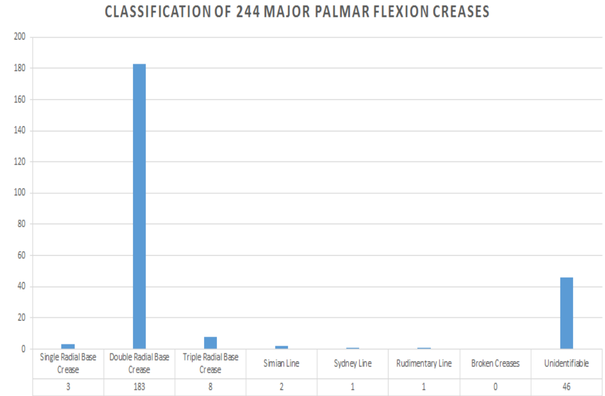

Fig. 23. Bar graph indicating the frequency of major palmar flexion creases in each class [31]

However, as seen from the results, there is an average of approximately 19.67%, or 48 palm prints that were deemed as unidentifiable, due to image expousre or does not fall within either the known normal or abnormal categories. Unidentifiable images are as shown in Fig. 24.

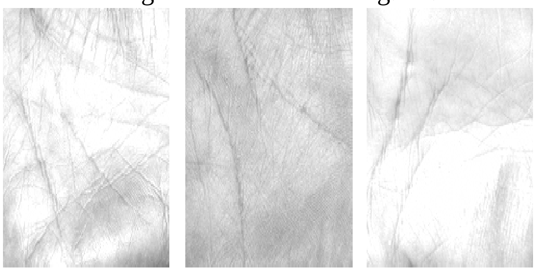

Fig. 24. Palm prints deemed as unidentifiable [31]

On the abnormal prints, the generate condition template files function (following the work flow shown in Fig. 25) will run through a collection of SPM format files deemed to be palm prints with abnormalities, or classified as simian lines, sydney lines, rudimentary creases or broken creases.For every SPM format file, the application will apply Hough Transform()and sort HTH ist () to it, resulting in the generation of 4 new files [29]. These files contain the information for the major palmar flexion creases of each palm print.

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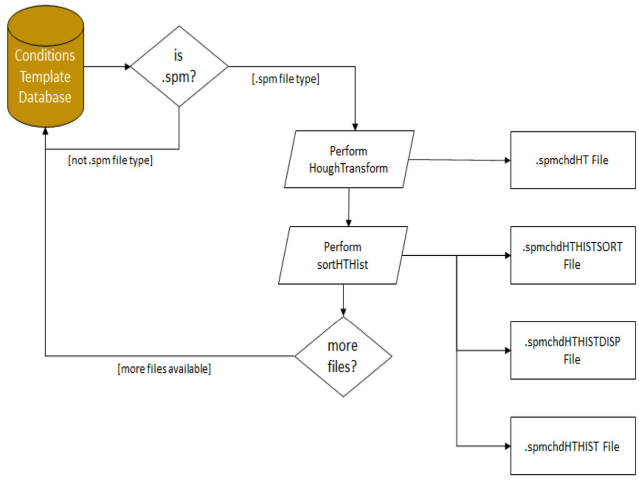

Fig. 25. Flowchart for the function of generate condition template files

Hough Transform () performs the Hough Transform technique for line detection, primarily the major palmar flexion creases. Hough Transform (HT) was not a feature that could be extract or referenced but was an additional implementation to detect the major palmar flexion creases. The main advantage of HT is its ability to be relatively unaffected by noise or gaps in lines. HT is a good technique for line detection of palm prints due to its capability of not only identifying lines on an image, but also arbitrary shapes line ellipses. This is especially useful for line detection in palm prints as the human's palm comes in both straight and curved lines.

A hierarchical matching scheme for detection of major palmar flexion creases have been developed prior, on the basis of motivation that the major palmar flexion creases are the most clearly observable feature in low-resolution palm print images. The database of palm print images used have a resolution of 96 dpi, which is close to the definition of low-resolution at 100 dpi.

The functions will first accept an input as an SPM format file and perform the HT technique on it. This was the first version of the implemented HT without optimization to remove or reduce the noise lines. Further modification was performed to amplify the results without the outliers. This can be seen in Fig. 26 where comparison is made between the resulting HTwith and without HT.For optimisation, the threshold value picked was 8, as it removed most of the outliers and maximised the major palmar flexion creases, as shown in Fig. 27.

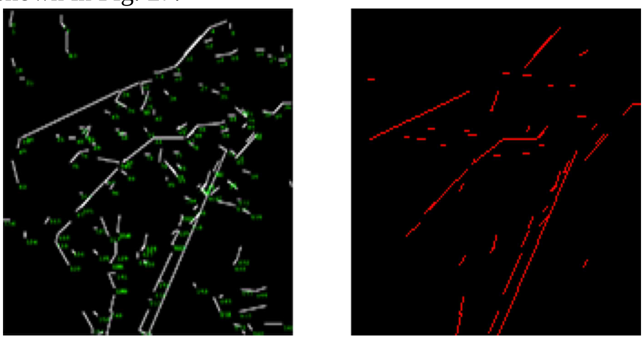

Fig. 26. Generated line edge map without HT (left), and with HT (right)

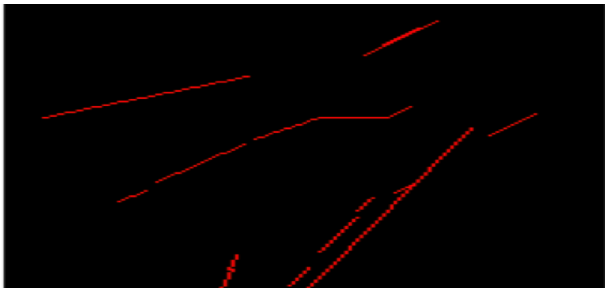

Fig. 27. Generated line edge map without HT and with optimised threshold value of 8

The classifications only identified 4 palm prints (1.23%) belonging to the abnormal category. The 4 palm prints were subcategorized as 2 simian line (50%), 1 sydney line (25%), 1 rudimentary creases (25%) and 0 Broken Creases (0%). Compared to normal, Fig. 28 shows simian line, Fig. 29 shows sydney line, and Fig. 30 shows rudimentary creases.

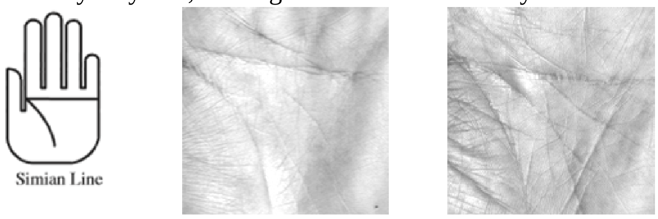

Fig. 28. Palm prints deemed with simian line

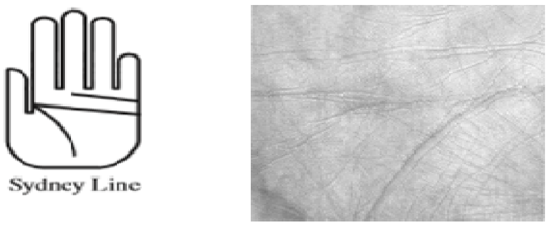

Fig. 29. Palm prints deemed with sydney line

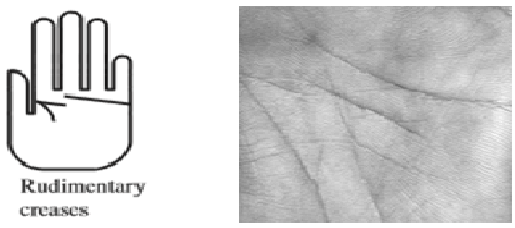

Fig. 30. Palm prints deemed with rudimentary creases

C. Colour analysis

For the analysis of palm prints' colouration, palm prints from 67 individuals were collected and categorised into various age groups. The subjects in each age group were tested healthy or unhealthy based on the system. All participants were from the race of Chinese. The current health statuses of the participants were recorded to act a reference for the prediction. The number of participants in each age group is a shown in Table II.

Table II. The number of participants in each age group

Age group	Number of participants
20-25 years old	41
26-30 years old	12
30-40 years old	2
40-50 years old	2
50-60 years old	9
70-80 years old	1

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The ROI images were converted to grayscale and the grayscale values were obtained. Histogram equalisation for normalisation was performed on the grayscale values and plotted as a histogram.The x-axis of the histogram demarks the normalised grayscale values of the images while the y-axis demarks the frequency of occurrence. From Fig. 31, the threshold ranges from 128 to 134. This formed the healthy range, while values outside of the range are classified as unhealthy.

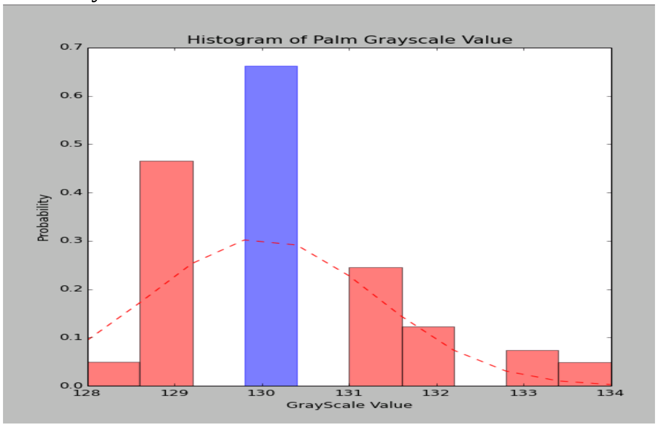

Fig. 31. Overall histogram result of the 67 individuals

For the age group of 20 to 25 years old, tested based on the threshold values established, 2 out of the 41 subjects were classified in the unhealthy range, as shown in Fig. 32. The number of participants in each normalised grayscale value is as shown in Table III.

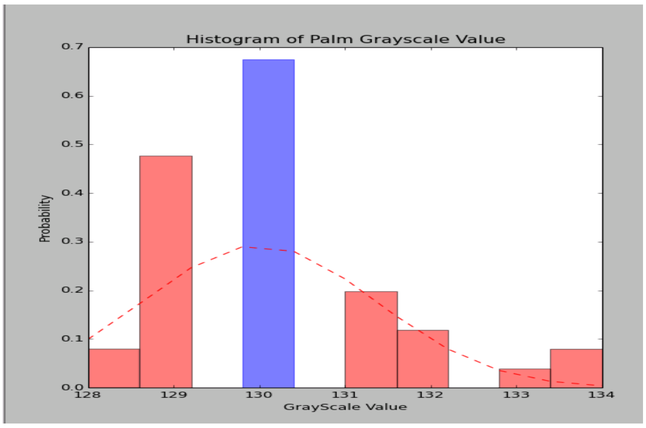

Fig. 32. Histogram results of palms (20 to 25 years old)

Table III. The number of participants in each normalised grayscale value (20 to 25 years old)

Normalised grayscale values	Number of participants
128	2
129	12
130	16
131	5
132	3
133	1
134	2

For the age group of 26 to 30 years old, tested based on the threshold values established, only 1 out of the 12 subjects was classified in the unhealthy range, as shown in Fig. 33. The number of participants in each normalised grayscale value is as shown in Table IV.

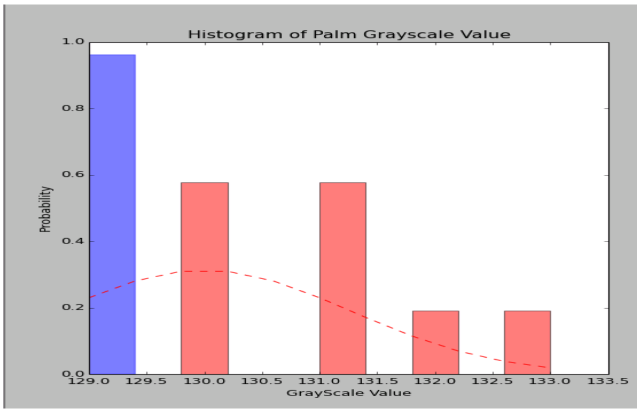

Fig. 33. Histogram results of palms (26 to 30 years old)

Table IV.The number of participants in each normalised grayscale value (26 to 30 years old)

Normalised grayscale values	Number of participants
129	4
130	3
131	3
132	3
133	1

There were fewer participants in the middle-aged group, thus the age groups within the range of 40 to 60 years old were combined and examined as one category. Based on the threshold values established, only 1 out of the 11 subjects was classified in the unhealthy range, as shown in Fig. 34. The number of participants in each normalised grayscale value is as shown in Table V.

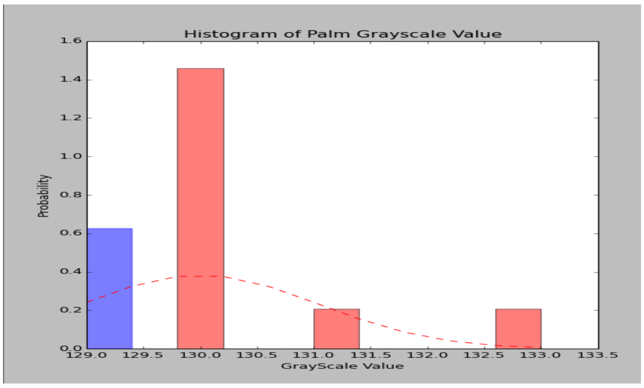

Fig. 34. Histogram results of palms (40 to 60 years old)

Table V.The number of participants in each normalised grayscale value (40 to 60 years old)

D. Unique Cases

Normalised grayscale values	Number of participants
129	2
130	7
131	1
133	1

From the observation of the palms, some of individuals may possess some health problems. According to the TCM palm diagnosis, an individual's palm appears to show some symptoms of having anaemia when anaemic veins are seen

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emerging on the palm, or the palm looks pale, or if the gen wei region appears to be pale (gen wei region as shown in Fig. 35). Fig. 36 shows the palm of a 20 years old individual that exhibits two of symptoms mentioned above, and hence it is highly possible that this person is suffering from anaemia.

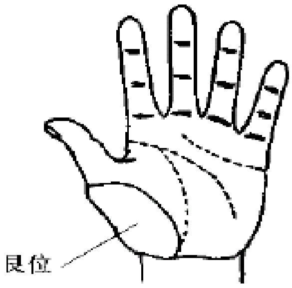

Fig. 35. The gen wei region on the palm

Fig. 36. Palm of an individual that might be anaemic or possessing symptoms of anaemia [30]

Fatty liver disease manifests symptoms such as red palms, or expansion of the liver regionon the palm, or having red and white spots on the palm (liver region as shown in Fig. 37). Fig. 38 shows a palm that exhibits the two of symptoms mentioned above and there exists a high possibility that this person might have fatty liver disease. Further analysis different region of the palm could provide more information on the specifics of the disease/condition.

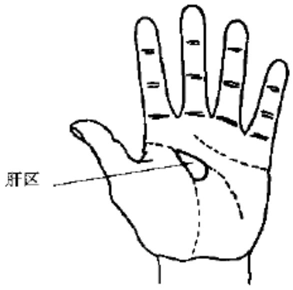

Fig. 37. The liver region on the palm

Fig. 38. Palm of an individual that might have fatty liver condition [30]

In another test subject, a 70 years old participant, distinct red and white colourations were observed in the gall bladder region on the palm (gall bladder region as shown in Fig. 39). With reference to Fig. 40, it was suspected that individual could be suffering from inflammation of the gall bladder.

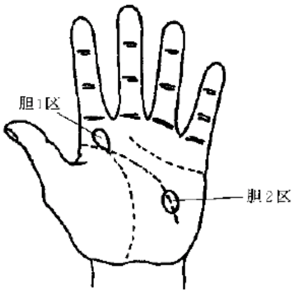

Fig. 39. The gall bladder region on the palm

Fig. 40. Palm of an individual that might have inflammation of the gall bladder [30]

VI. CONCLUSION

This work represents a study to design a system to make predictions based on ROI images through grayscale normalisation and image recognition. It was evidenced that most diseases/conditions do follow some form of pathological patterns or symptomatic features as reflected on the palm. Further studies could be conducted by experimenting with a larger sample size and with different regions of palm colour. The accuracy of prediction could be improved by having more abnormal palm prints included in the model (or at least the same number of abnormal to normal palm prints).

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