Discrete Wavelet Transform (DWT) –

Gray Level Co-occurrence Matric (GLCM) –

Based Fingerprint Recognition Method

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Nur Hidayah Binti Darmizal

ABSTRACT

Fingerprint recognition system has become among the most popular system used either in civilian law or personal security system. Mostly, fingerprint recognition is based on minutiae that is corresponding to features of the image and thus the similarities are evaluated. In this paper, another technique is used to overcome the normal issue of time consumption. Thus, discrete wavelet transform (DWT) and grey level co-occurrence metrics (GLCM) is proposed to have shorter time consumption. Throughout this paper, the project is to evaluate similarities of fingerprint images in terms of false acceptance rate (FAR), false rejection rate (FRR), and total success rate (TSR). The fingerprint images consist of 15 subjects with about four different images each.

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LIST OF ABBREVIATIONS

1. GLCM – Grey-level Co-occurrence Matric
2. DWT – Discrete Wavelet Transform
3. LL – Low Low Pass Filter
4. LH – Low High Pass Filter
5. HL – High Low Pass Filter
6. HH – High High Pass Filter
7. FAR – False Acceptance Rate
8. FRR – False Rejection Rate
9. TSR – Total Success Rate
10. UTP – Universiti Teknologi PETRONAS
11. RT – Right Thumb
12. LT – Left Thumb

CHAPTER 1
PROJECT BACKGROUND

1.1 Background of Study

Normally, fingerprints recognition are identified using the study of minutiae identification. However, for a cost – effective and higher practicality usage, this project highlights the concept of DWT, and GLCM as its main research in the fingerprints recognition industry.

First and foremost, DWT applies the concept of image decomposition. This process involves four sub –bands; LL, LH, HL, HH and this is achieved throughout three different stages of DWT. The LL band alone is used to compute the dominant local orientation of angle 0 and Coherence. On the other hand, by taking another four sub – bands into account and each stage of DWT occurs a process of determining the Centre Area features, and edge parameters. From the process of fingerprint images decomposition, they needed to be compared with the available fingerprint databases. From this comparison, decision of values is then made from the concept of Euclidean Distance. The values are put in an assessment metric in terms of False Acceptance Rate (FAR), False Rejection Rate (FRR), and Total Success Rate (TSR) [5].

Apart from that, to reduce cost in fingerprint recognition, another method used is GLCM. Pixel brightness values (grey levels) of an image is recorded. From these values, there would be a variety of them throughout an image. Based on a single image, the variety of the values combined that present is represented in a matrix form and this matrix is called GLCM. Back in the previous research study, Haralick was the one who gave the idea of feature extraction using GLCM and this leads to the popular usage of GLCM nowadays [4]. Besides, GLCM matrix represent a specific angle occurs on an image and a distance, d that separates two pixels; graytone i and graytone j with corresponding frequencies.

1.2 Problem Statement

Fingerprint recognition is mostly applied using the approach based on minutiae. Nevertheless, this application is consuming too much time and it would affect the efficiency of the results obtained. This is because, in doing research regarding the fingerprint matching system, the results must be not only as accurate as possible but also as fast as possible. Therefore, this paper proposes another simplified method in which it would help in saving time to get the desired output of fingerprint recognition system. The methods studied in this paper are Discrete Wavelet Transform (DWT), and Grey-Level Co-occurrence Matrix (GLCM).

1.3 Objectives and Scope of Study

The main objective for this particular project is to evaluate the fingerprint recognition system in terms of False Acceptance Rate (FAR), False Rejection Rate (FRR), and Total Success Rate (TSR).

Scope of Study

1.3.1 Study about Fingerprint Recognition System

The scope of study in this paper covers topics on

- ⇨ Study and analysis of Image enhancement
- ⇨ Study and analysis of GLCM techniques available
- ⇨ Study and analysis of DWT techniques

1.3.2 Collecting Data and Develop / Improvise code of DWT and GLCM for the Application using MATLAB coding

Data collected is mainly the fingerprint image values gained from the GLCM.

DWT needs to be used to get another view of the image and the values of the original image and the new one can be compared.

1.3.3 Test the Matching Technology and the Whole System

The matching process is mainly involving the evaluation needed and would be based on the calculations mentioned above involving the FAR, FRR, and TSR.

CHAPTER 2
LITERATURE REVIEW

Human beings were created with their own different and unique design of deoxyribonucleic acid (DNA) as well as their fingerprints design. A fingerprint itself can be defined as an impression of the friction ridges of all or any part of the finger. The most trustworthy features in identifying people is by applying the exclusivity of each person when it comes to the fingerprints and the graphical ridge patterns one has [1].

On the other hand, most crucial part in this fingerprint recognition is to find the latent prints. This is said as the latent print brings an important role to further laboratory examination or automated fingerprint identification systems (AFIS) searches are lightly to shed much light on the case, with regard to fingerprint evidence [2].

Another important part to be discussed in this part is regarding DWT method details and also the method applied in GLCM.

2.1 Discrete Wavelet Transform (DWT)

DWT is used to decompose an image into different levels. Each level is divided into sub bands mainly LL, LH, HL, and HH.

From this bands of low-low (LL), low-high (LH), high-low (HL), and high-high (HH), it can be divided into different levels of image decomposition in applying wavelet extraction. There can be one-level, two-level, or even more with the image decomposition.

Wavelet has the properties that other tools of analysis do not have. The properties are decomposition properties, its time-scale localization. These properties make the wavelet as a strong and reliable analysis tool. These characteristics owned by the wavelet thus gives relevancy to the analysis of non-stationary systems. Problems of non-stationality is solved by applying wavelet analysis through the process of performing a local time – scale decomposition of the signal [3]. Variety of scales related to the periodic components of the signal switch over time and this can be identified using this approach of wavelet analysis.

There is no possible way to completely eliminate the edge effects, and the region affected by edge effects also known as “cone of influence”. It is stressed that the spectral information within this cone is likely to be less accurate [3].
Choosing the wavelet analysis as an approach for a research, the major consideration is the trade – off between strong localization that is good in the analysis of sharp transients and weak localization which includes more precise isolation of dominant frequencies.

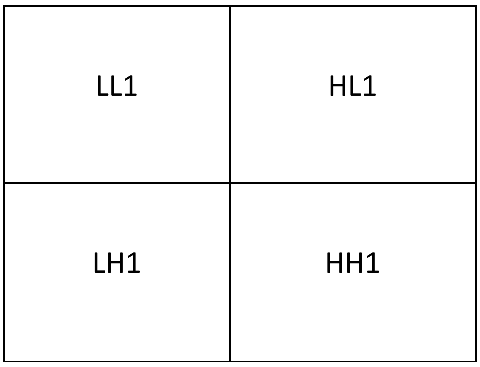


Figure 1 One – level of image decomposition [15]

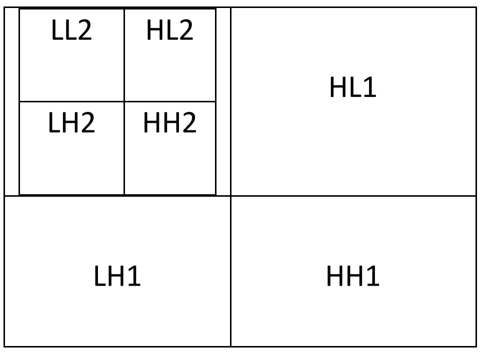


Figure 2 Two – level of image decomposition [15]

For DWT, the technique is used to apply the concept of image decomposition. In order to go through the process, the image is changed to a discrete wavelets form. Therefore, this process involves four sub – bands mainly LL, LH, HL, HH filters. For computation of dominant local orientation in which covers for angle 0 and coherence the filter used LL band alone. In each stage of DWT, there is a process of determining the center area features and edge parameters. The importance of DWT technique is its ability to analyze fingerprint images even with different orientation [1]. For example, in paper [1] the research was about fingerprint recognition using DWT. The concept applied is to use Canberra distance metric.

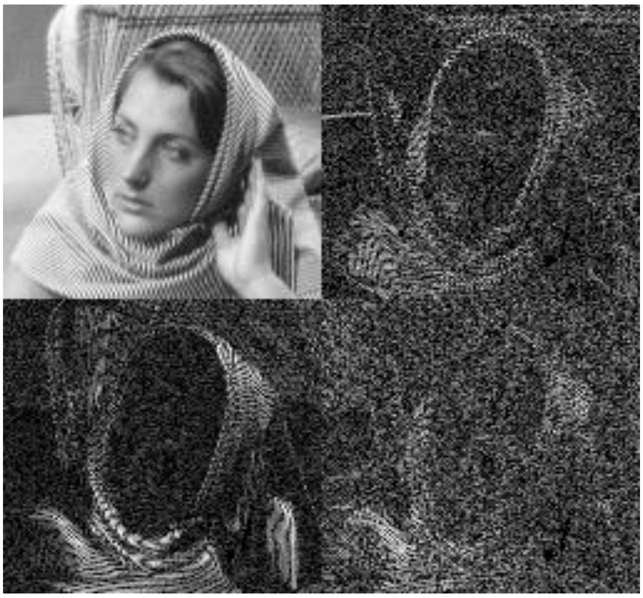


Figure 3 One – Level image decomposition

Figure 4 Two – level image decomposition

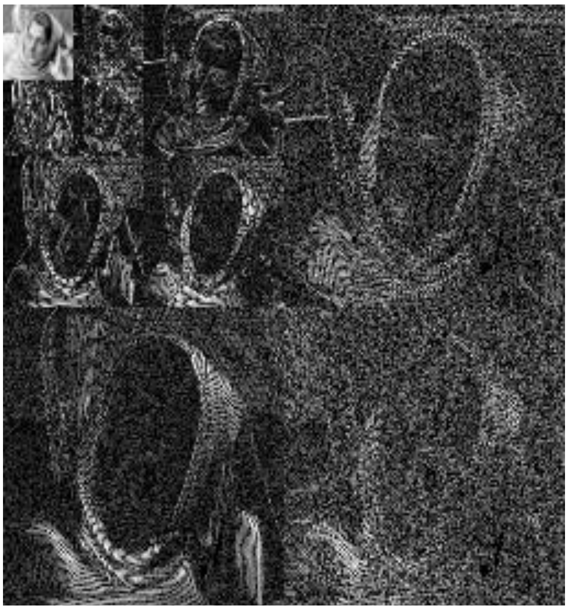


Figure 5 Three – level image Decomposition

Discrete Wavelet Transform (DWT) is a good technique and been chosen among the researchers because it can handle good localization for both in time and spatial frequency domain. In DWT, as there is the decomposition of images into different sub – bands, in which these sub – bands represent the finest scale wavelet coefficients. From the figures for sub – band images and its combinations create some

features and these features have uniquely characterize a fingerprint [15].
From the project done in [15], the database of fingerprint images used consists of 10 people, with 8 images per person. First of all, the core point of the image was detected. Then, it is cropped to get clearer image and the values are obtained. After that, the cropped image was separated to non – overlapping parts. From this sub – image, the 2D transform is applied on each of the sub images.

The values of mean and standard deviation are calculated and then is kept as feature vector [15].

$$Mean\ (m) = \frac{1}{N^2} \sum_{i,j=1}^{N} p\ (i,j) \tag{1}$$

$$Standard\ deviation\ (sd) = \sqrt{\frac{1}{N^2} \sum_{i,j=1}^{N} [p\ (i,j) - m]^2} \tag{2}$$

Where p(i,j) = transformed value in (i,j) for any block or sub – band of size N x N.

Apart from that, Haar Wavelet is also among another method that could be consider to be used as one of the feature extraction method. In [18] for example, the feature extraction method used Haar Wavelet Transform technique. This experiment was done based on 160 low quality of fingerprint images which consist of 40 subjects.

The result obtained are very good despite some of the images do have losses partially of its original image, and the accuracy [18] of this feature still manage to get about 94.37% using one decomposition level and about 96.87% using two decomposition levels of wavelet.

On the other hand, [19], Haar Wavelet is mainly used in compressing large size of image without reducing the quality of the original image. Besides, this feature helps to reconstruct images quality while maintaining any important details of the image. Another important thing is to achieve high compression rates and to obtain better image quality at the same time. Besides, Haar wavelet is among the less complex wavelet transform in representing large data to a smaller one [20]. Haar wavelet is among the simplest technique in transforming from space domain to a local frequency domain. After going through Haar wavelet, there are two components that would be produced from the process. They are average or approximation and the other one is called difference or also known as fluctuation [19].

In whatever image recognition either it is face recognition or fingerprint image detection, it is mainly about the image recognition rate. Therefore, the values obtained from this is very important and needs to be accurate so the objectives are achieved. Thus, an the fingerprint images needs to go through a process of preprocessing image to get a better quality image and gives a higher accuracy in the recognition system.

Besides in this preprocessing images, it is also about enhancing an image for the same objective which is to get a better quality of an image. In order to achieve this, [9] uses Spatial Domain Method and Frequency Domain Method. For the first part, spatial domain method operates straight using pixels. Using coordinates (x,y) of a pixel in the neighborhood (x,y) and after performing the operation, an enhanced image is obtained [9]. On the other hand, the frequency domain method uses the concept of performing and applying Fourier transform on the image. The Fourier Transform of the image now is multiplied by a filter. Then, the inverse transform is applied in getting the enhanced image output.

2.2 Grey – Level Co – occurrence Matrix (GLCM)

GLCM is mostly applies to extract 2nd order statistical texture features. Among the

Second order texture features are [12]:

i) Angular Second Moment (ASM) / Energy

Angular Second Moment or ASM is the actually consists of addition of squares in the GLCM. It is about computing the image homogeneity, in other words to calculate the similarities of pixels in an image.

$$ASM = \sum_{i=0}^{Ng-1} \sum_{j=0}^{Ng-1} Pi^2j \quad (3)$$

Where i,j = spatial coordinates of the function p(i,j), and Ng is the gray tone [12].

ii) Correlation

As for Correlation, it is about the calculation of linear dependency of grey levels for neighboring pixels. This is mostly used to detect changes in an image and widely used is measuring the motion of optical mouse.

$$Correlation = \sum_{i=0}^{Ng-1} \sum_{j=0}^{Ng-1} \frac{(i,j)p(i,j) - \mu_x \mu_y}{\sigma_x \sigma_y} \quad (4)$$

Where i,j = spatial coordinates of the function p(i,j), and Ng is the gray tone, $\mu_x\mu_y$is the mean and $\sigma_x\sigma_y$is the standard deviation for coordinate x,y.

iii) Inverse Difference Moment (IDM) / Homogeneity

Inverse difference moment is where the value for inverse GLCM is high while the local gray level is equal.

$$IDM = \frac{\sum_{i=0}^{Ng-1} \sum_{j=0}^{Ng-1} P_{ij}}{1 + (i-j)^2}$$

(5)

Where i,j = spatial coordinates of the function p(i,j), and Ng is the gray tone.

iv) Entropy

Entropy is about calculating the information or message in a transmitted signal that is loss. Besides, it also gives the amount of information of the image in which might be required for image compression [12].

$$Entropy = \sum_{i=0}^{Ng-1} \sum_{j=0}^{Ng-1} -P_{ij} \times logP_{ij}$$

(6)

Where i,j = spatial coordinates of the function p(i,j), and Ng is the gray tone.

GLCM has also become among most used techniques as it enables [16] a good classification of performance. Apart from that, GLCM is also defined [7] to be the distribution of co-occurring values at a given offset from an image inserted as input.

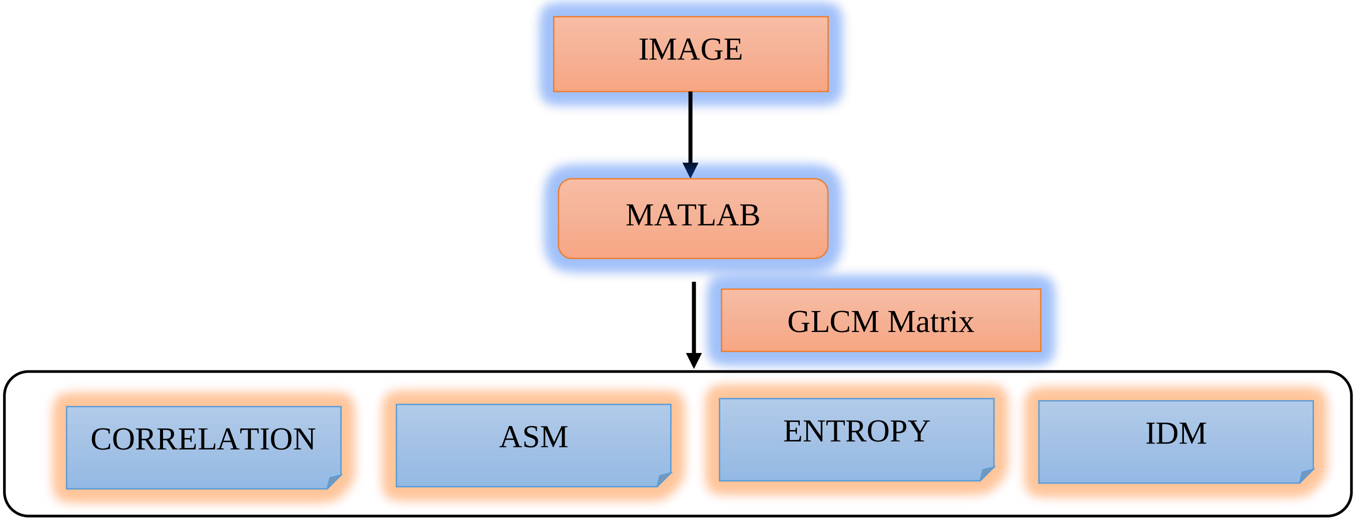


Figure 6 Extraction of Image Features

CHAPTER 3

METHODOLOGY AND PROJECT ACTIVITIES

In this project of fingerprint recognition, the methodology needed to get the project done is by collecting data and fingerprint databases, developing necessary coding of Discrete Wavelet Transform (DWT) and Gray-Level Co-occurrence Matrix (GLCM) concept. Besides, another method that can be used in developing the coding is by combining both concepts of DWT and GLCM. In general, the process of this fingerprint matching follows the flowchart below:

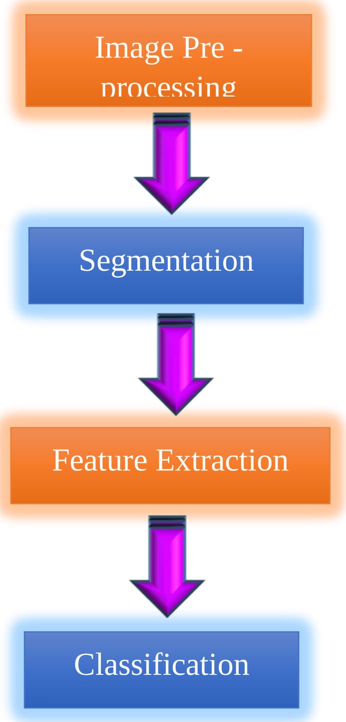


Image pre-processing let the image to go through process of getting a better image either cropped or normalized or any other enhancement of image method. Segmentation on the other hand is to recognize the features of an image and in this paper it is about recognizing the features of the fingerprint images. Then, the feature extraction is the most important part where here DWT and GLCM will be applied. Finally, once the image is extracted, it is classified.

Then, to further achieve the objective of the project, the program needs to be more improved by having the matching system in the coding. Last but not least, the whole is system is then tested and recorded. Basically, in details, the methodology of this project can be represented in this block diagram.

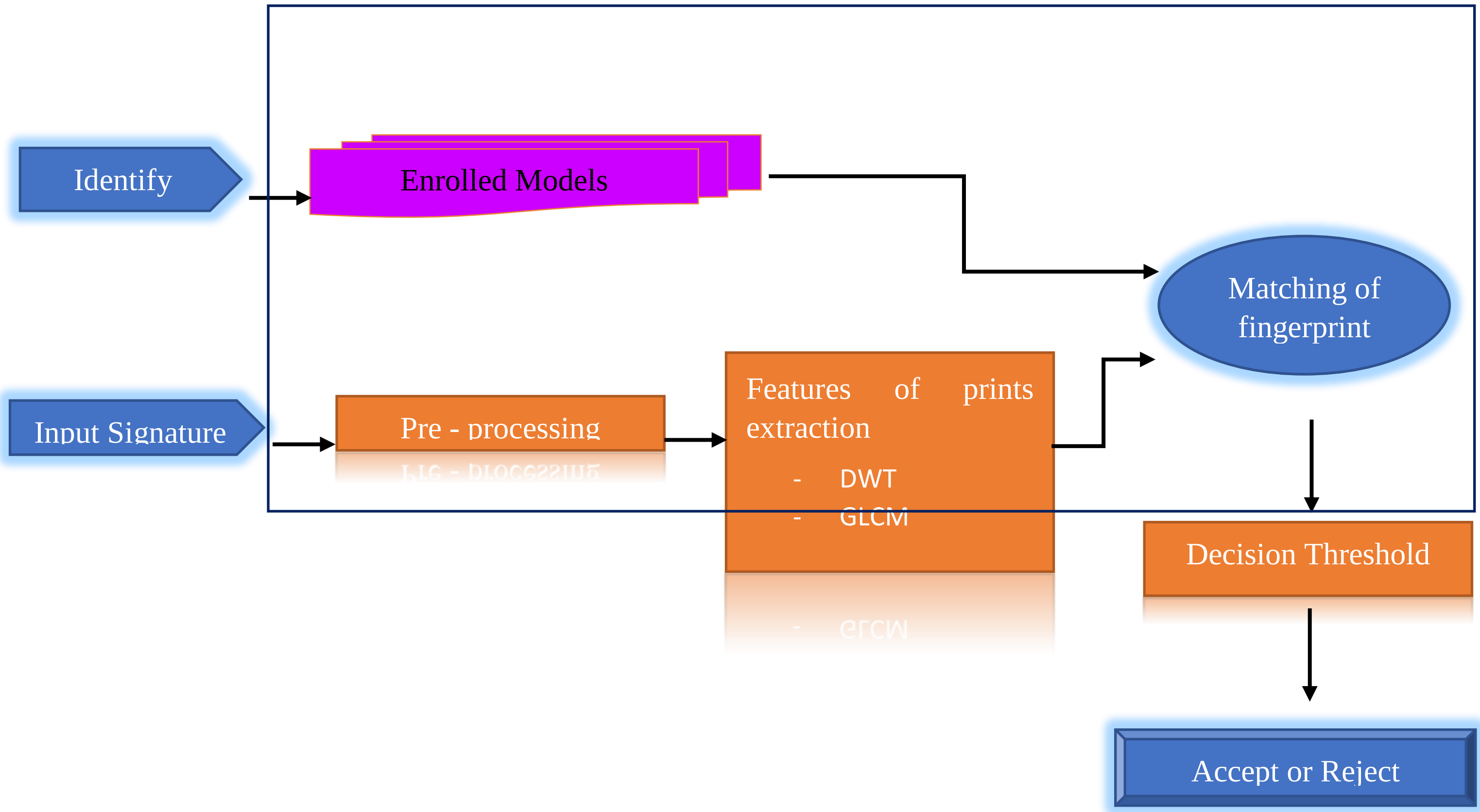


Figure 7 Block Diagrams of Fingerprint Recognition System

The concept of this block diagram work based on this process. First and foremost, for identified claim, a fingerprint is inserted, and it would be checked based on the enrolled models. From the models available, it would go to matching of fingerprint in which this is where we use the evaluation in terms of FAR, FRR or TSR. Based on these values, the fingerprint image would either be accepted or rejected.

On the other hand, for new input the input of new fingerprint images would go through the pre-processing of images either using image cropping, or binarization, or dilation of images. After the image has been processed and a better view of the image is obtained, the image is used to extract its features. In this project, the feature extraction methods used are DWT and GLCM. Then, after feature extraction process the image is evaluated through matching process in terms of FAR, FRR, and TSR.

3.1 FEATURE EXTRACTION TECHNIQUES

As up to this development, the feature extraction techniques to be used is Gray Level Co-occurrence Matrix (GLCM), and Discrete Wavelet Transform (DWT). In addition, another technique to be considered in the feature extraction technique is the Haar Wavelet Transform as mentioned in the literature review part. Besides, DWT has been among the famous feature extraction method as it has the ability to decor relate large image and also to represent an image as a multi – resolution representation [17].

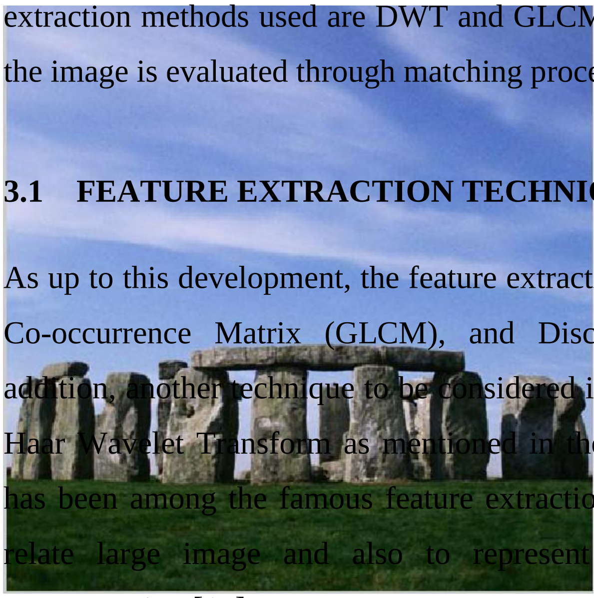


Figure 8 Example of Applying DWT in Feature Extraction

3.2 MATCHING TECHNIQUES

Matching of images is a vital process in this whole project as it is this part where [11] the similarities or dissimilarities are decided. If the image of fingerprint detected is similar, then the output would be accepted, else it shall be rejected. There are many matching techniques available and each with their own advantages and disadvantages. Thus, there is no fixed correct or false technique because the techniques chosen should depend on the application of the images [11].

To indicate the degree of similarity and dissimilarity between two images is called a measure of match [10]. In order to determine the measures of match, the decision to be made is depending upon and specific matching template. Thus, an image with higher measure of match shall be chosen compared to any other information available. Among the matching techniques that can be used are Coefficient of Correlation technique and Nearest Neighborhood technique.

Coefficient correlation technique proposed by M.S. Sussman and G.A. Wright is as an improvement to the least square method [11]. This is because least square method is restricted where it cannot operate properly for any large variation in image intensity function.

Apart from that, another technique to be used is Nearest Neighborhood Technique.

The application for this technique is first represent the image in the form of n – dimensional vectors. To calculate the similarity among the fingerprint images, Euclidean distance is used where less distance gives higher rate of similarities [11].

To get a better output of the matching process another proposed approach is to use the addition of its absolute differences.

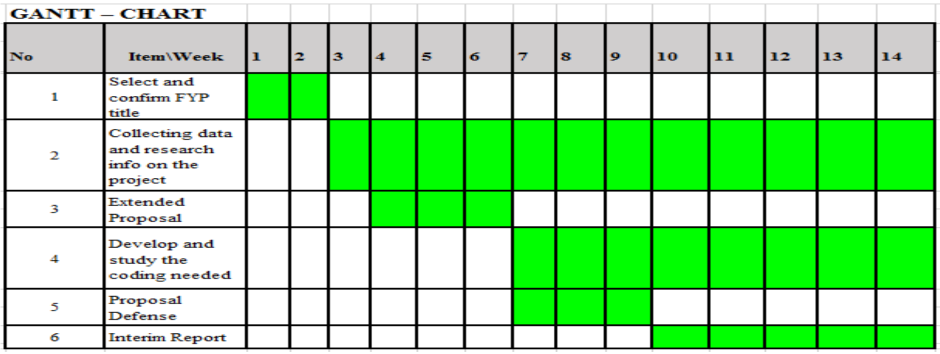
3.3 ASSESSMENT METRICS FOR FINGERPRINT RECOGNITION SYSTEM

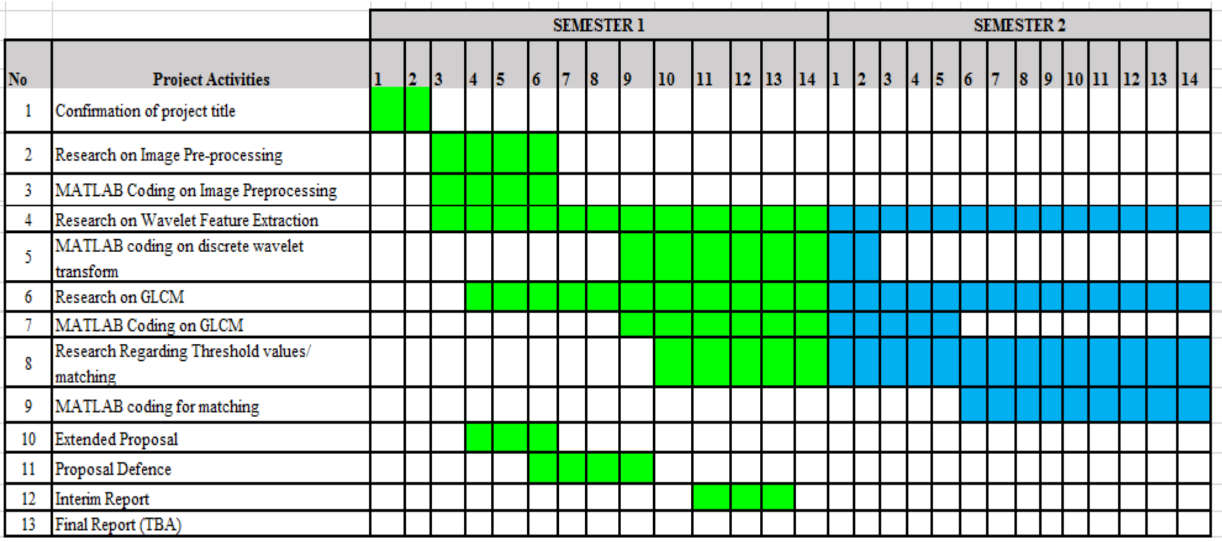
Throughout this project, the evaluation of accepting or rejecting the fingerprint image and to see whether it is a match or not is done based on the evaluation mentioned above. The evaluation in terms of False Acceptance Rate (FAR), False Rejection Rate (FRR), and Total Success Rate (TSR) based on the techniques applies.

Thus, it is outlined to have this metric when reviewing the final output towards the end of this project.

	FAR (%)	FRR (%)	TSR (%)
DWT	x	y	z
GLCM	a	b	c

3.4 GANTT CHART & KEY MILESTONE





CHAPTER 4
RESULTS AND DISCUSSION

4.1 Feature Extraction Technique using GLCM

For the preprocessing images as of now the image used is being cropped to get an enhanced image. From these cropped images the values of GLCM are obtained for each fingerprint of different subjects.

Figure 9 Right Cropped Fingerprint Image

From this part, the cropping done was at the top of the thumbprint to the center of it. This somehow gives quite a wide range and not merely the core point of the fingerprint image, and the GLCM values obtained is of 8 by 8 matrices as shown below:

GLCM Values:

5284	838	645	495	371	372	311	120
913	262	200	206	202	183	156	240
687	245	214	179	161	183	157	377
504	210	199	166	166	170	183	490

398	190	180	180	172	188	191	589
331	188	219	196	180	216	230	854
231	237	216	194	229	244	278	1228
88	192	330	472	607	858	1351	774454

Then, to get a better accuracy, the fingerprint image is cropped at the center and the GLCM values is extracted.

Figure 10 Centered – cropped fingerprint image

GLCM VALUES

1904	1097	404	227	172	120	43	4
988	2008	1057	546	414	414	496	192
364	946	919	510	361	331	466	626
237	502	492	341	269	256	298	867
197	445	330	277	214	206	218	990
178	404	308	241	175	190	208	1252
97	519	419	269	230	202	227	1836

12	200	606	850	1050	1230	1841	21140

In this latest progress of experiments done, another values obtained from GLCM are the statistic values. Throughout the given time, most experiment done is on the method of GLCM and the values obtained are analyzed. Based on the GLCM coding, the statistics value obtained are:

i) Correlation
ii) Homogeneity / IDM
iii) Contrast
iv) Energy / ASM

Figure 11 Image of thumb print for person 1 (1LT1)

Figure 12 Image of thumb print for person 1 (1LT2)

From these, figure 10 shows the left thumbprint for person 1, and figure 11 shows the left thumbprint also for person 1. It is the same person, with the same thumb. In other words, 1LT2 is the database stored in the system, while 1LT1 is the input of the finger print image. Therefore, from stats1, which is the input, the values are compared with stats2, which is from the database. However, from most of the fingerprint images analyzed, there are two strong and consistent values that can be used in analyzing the fingerprint recognition system.

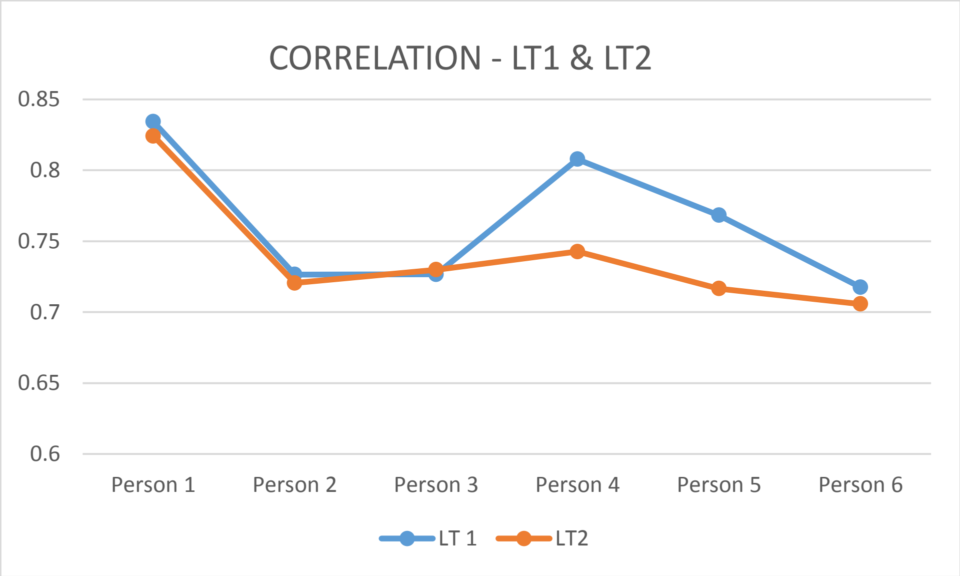


Figure 13 Comparison of Correlation Values

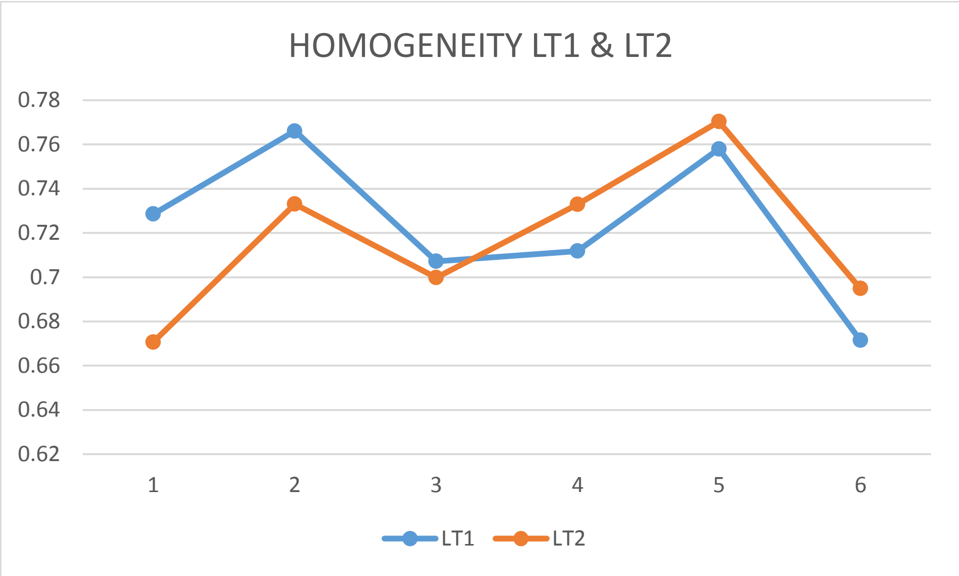


Figure 14 Comparison of Homogeneity values for LT1 & LT2

	Correlation		Homogeneity		Contrast		Energy	
Person	LT 1	LT2	LT1	LT2	LT1	LT2	LT1	LT2
Person 1	0.8343	0.8242	0.7286	0.6707	1.379	2.1617	0.153	0.0659
Person 2	0.7265	0.7206	0.7661	0.7331	3.4047	4.0839	0.3375	0.2633
Person 3	0.7266	0.7299	0.7072	0.6998	2.9385	3.5104	0.1846	0.2027
Person 4	0.8078	0.7427	0.7118	0.7329	2.0313	1.6432	0.1428	0.1876
Person 5	0.7683	0.7166	0.758	0.7704	1.3827	1.4876	0.2282	0.2948
Person 6	0.7176	0.7058	0.6715	0.6949	4.6669	5.8492	0.1602	0.1624

Table 1 Values of Correlation and Homogeneity

From these images, the values of Correlation and Homogeneity are recorded. Once recorded, the values are then compared with another person. The expected output is that the values of different person should not have any difference that is lower than the same person values of Correlation and Homogeneity. This is among the thing to be worked out in completing this project. Base on the table below, among the values that needs some modification is indicated with red labels.

THIS SYSTEM BELONGS TO PERSON 2: RIGHT

THUMBS

Correlation					Homogeneity			
Person	RT1	DIFFERENCES	RT2	DIFFERENCES	RT1	DIFFERENCES	RT2	DIFFERENCES
Person 1	0.8051	0.0502	0.7883	0.033	0.6856	0.0626	0.6343	0.1139
Person 2	0.7707	0.0158	0.7549	0.000	0.7404	0.0078	0.7482	0
Person 3	0.7299	0.0250	0.7375	0.017	0.6671	0.0811	0.6507	0.0975
Person 4	0.8287	0.0738	0.7679	0.013	0.7787	0.0305	0.7588	0.0106
Person 5	0.8035	0.0486	0.8148	0.060	0.6422	0.1060	0.6639	0.0843
Person 6	0.6807	0.0742	0.7579	0.003	0.7687	0.0205	0.7177	0.0305

Table 2 Values of Correlation and Homogeneity

This figure shows the values of Correlation and Homogeneity of system from Person 2 being compared to other people available. The red labels are due to the differences of Correlation that is lower than the green labels of Correlation values. That means, Person 4 and person 6 can access the system provided for Person 2 due to the smaller difference. Nevertheless, the solution available so far is to have both difference of Correlation and Homogeneity right. One needs to get smaller difference for both Correlation and Homogeneity compared to the green labels, only then that person can access the particular system. Else, the access would be denied.

There are also some data obtained based on this research fingerprint images obtained from UTP students, and the results seem to have better improvement. There are still some values of Correlation or Homogeneity of a different person that is lower than the authorized person. However, the Homogeneity values are not. Thus, without the meet for these two values, the system still cannot be accessed by others.

Figure 15 Image of UTP database, Person 4 (4RT1)

Figure 16 Image of UTP Database, Person 4 (4RT2)

The stats values obtained from this system of person 4 are recorded. Then, these values are compared to another person's system.

THIS SYSTEM BELONGS TO PERSON 4: RIGHT THUMBS

Correlation					Homogeneity			
Person	RT1	DIFFERENCES	RT2	DIFFERENCES	RT1	DIFFERENCES	RT2	DIFFERENCES
Person 1	0.9358	0.1555	0.918	0.1377	0.9366	0.1350	0.9021	0.1005
Person 2	0.8024	0.0221	0.84	0.0597	0.8299	0.0283	0.8082	0.0066
Person 3	0.8728	0.0925	0.7552	0.0251	0.8934	0.0918	0.8169	0.0153
Person 4	0.7507	0.0296	0.7803	0.0000	0.8048	0.0032	0.8016	0
Person 5	0.9434	0.1631	0.8931	0.1128	0.8819	0.0803	0.8651	0.0635
Person 6	0.8861	0.1058	0.8995	0.1192	0.8401	0.0385	0.8512	0.0496

Table 3 Values of Correlation and Homogeneity of Person 4 (UTP Database)

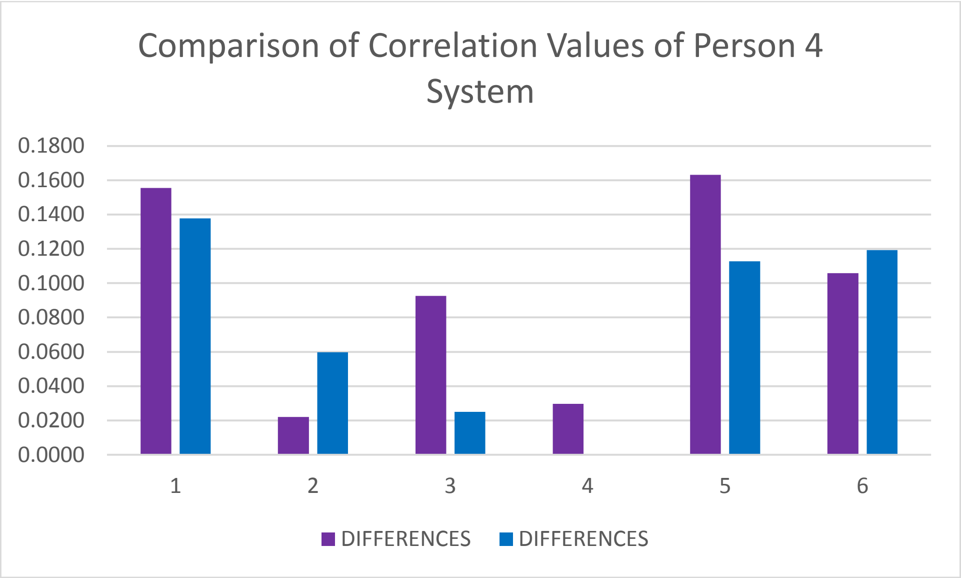


Figure 17 Chart of Correlation values for system of Person 4 compares to others

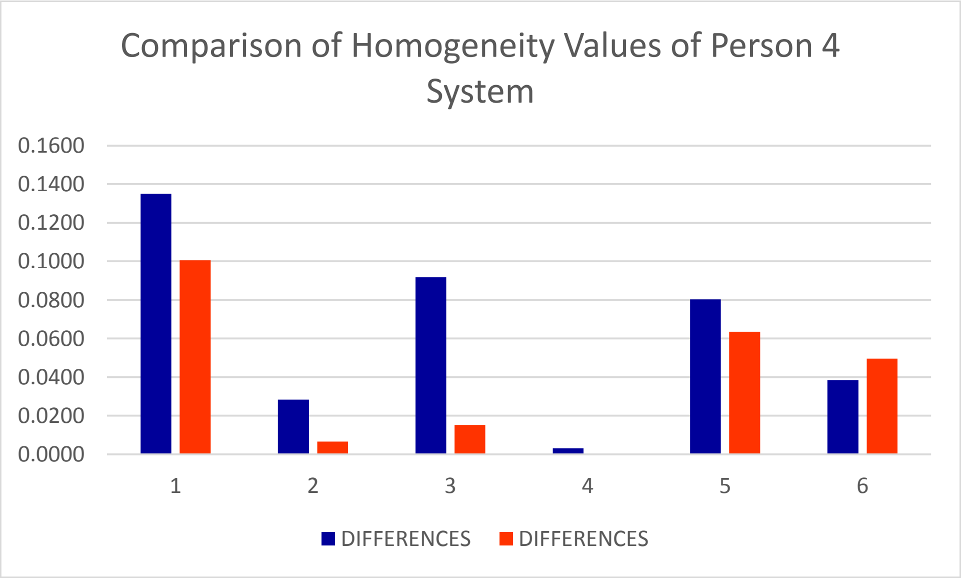
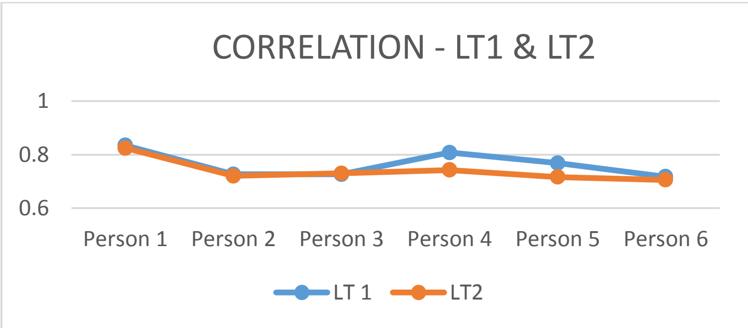
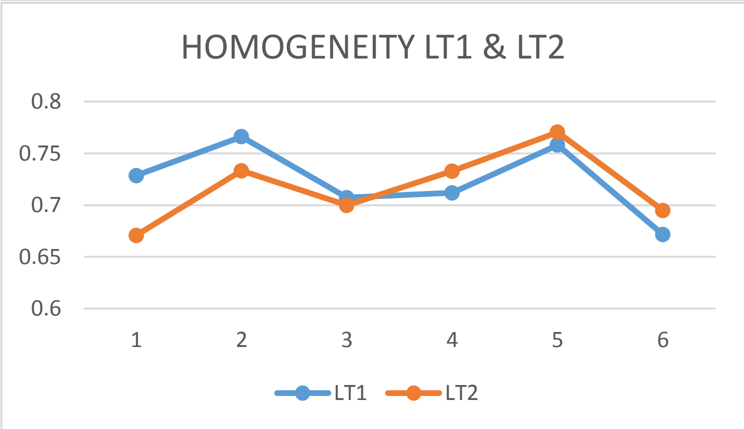


Figure 18 Image of Homogeneity values for Person 4 system compared to others

These charts show the system of Person 4. From the charts it can be observed that the difference for Person 4 is small, as it is the host. Thus, what we want to achieve is to ensure other person get the difference value higher than person 4. From the Correlation chart, Person 2 and Person 3 has a value of difference slightly lower than Person 4 which give these people chance to access the system. But, as shown in the Homogeneity chart, the values of difference for Person 2 and Person 3 is higher than Person 4. Thus, they do not meet the requirement of having small difference for both categories. Therefore, the access is denied.

4.1.1 Grounds in Choosing to Focus Only on Correlation and Homogeneity in GLCM Feature Extraction





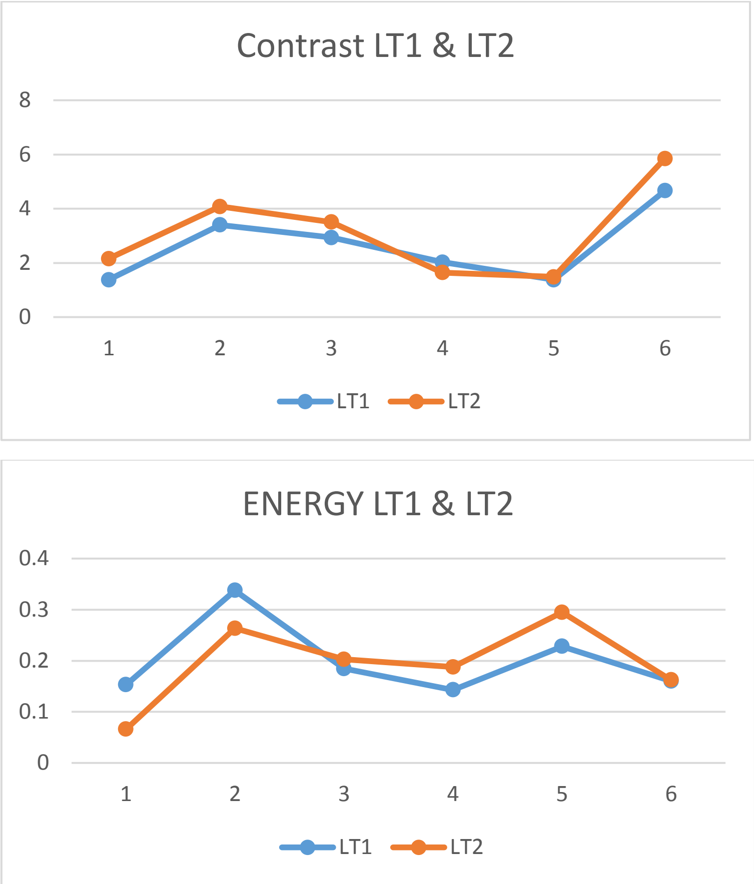


Figure 19 Graphs of four GLCM components

THUMBS LEFT		Correlation	Percentage Error (%)	Homogeneity	Percentage Error (%)	Contrast	Percentage Error (%)	Energy	Percentage Error (%)
Person 1	LT 1	0.834	1.23	0.729	8.63	1.379	36.21	0.153	132.17
	LT 2	0.824		0.671		2.162		0.066	
Person 2	LT 1	0.727	0.82	0.766	4.50	3.405	16.63	0.338	28.18
	LT 2	0.721		0.733		4.084		0.263	
Person 3	LT 1	0.727	0.45	0.707	1.06	2.939	16.29	0.185	8.93
	LT 2	0.730		0.700		3.510		0.203	
Person 4	LT 1	0.808	8.77	0.712	2.88	2.031	23.62	0.143	23.88
	LT 2	0.743		0.733		1.643		0.188	
Person 5	LT 1	0.768	7.21	0.758	1.61	1.383	7.05	0.228	22.59
	LT 2	0.717		0.770		1.488		0.295	
Person 6	LT 1	0.718	1.67	0.672	3.37	4.667	20.21	0.160	1.35
	LT 2	0.706		0.695		5.849		0.162	

Table 4 Values for components of GLCM

From the four graphs, it can be seen that Correlation and Homogeneity component gives better values for each person. The values for each person between the input and database is consistently close. This is important as these values determine if the system can be accessed or not. On the other hand, for Contrast and Energy, the values for the components for each person is far from close just by looking at the Y-axis. Therefore, it is not reliable to use the Contrast and Energy as factors in influencing the access of a system.

Besides, the explanation can also be found by observing the table provided. The values for percentage error was calculated by comparing the fingerprint component values of the input to its database. As calculated, the percentage error for both Contrast and Energy is high, which clearly support the fact that Correlation and Homogeneity components are more reliable to be used in having an access of a system.

4.2 Feature Extraction Technique using DWT

For the progress on DWT, the fingerprint image are able to be viewed in different sights. There are LH, HL, and HH. For now, there seems to be some problem as the image for the LL cannot be read. The calculation in applying DWT for now is the Distance Metric.

Figure 20 Image of Fingerprint

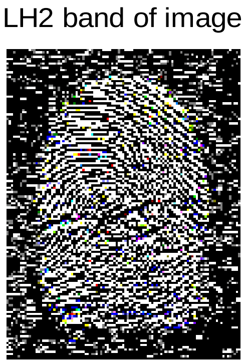


Figure 21   Fingerprint Images after DWT is applied

4.2.1 Grounds in choosing to focus on only HL pass filter in DWT feature extraction

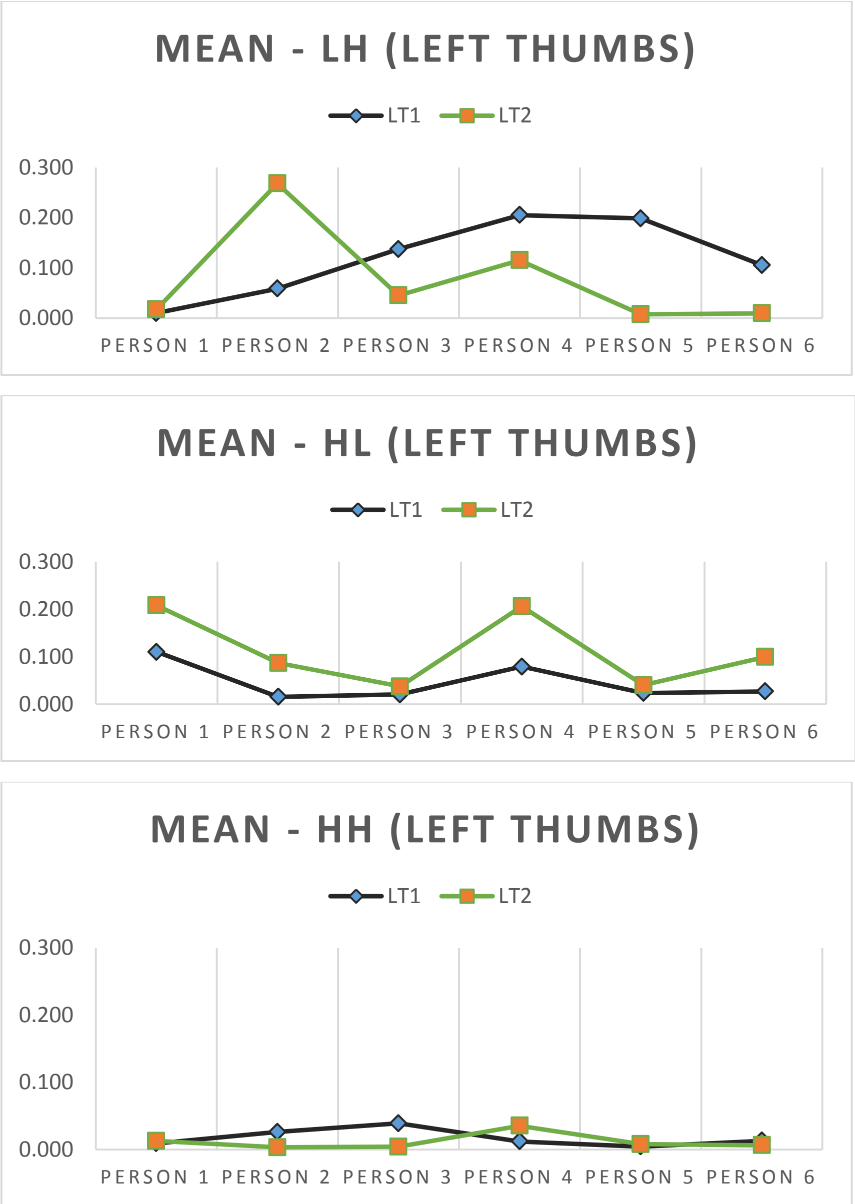


Figure 22   Mean values for LH,HL,and HH pass filters

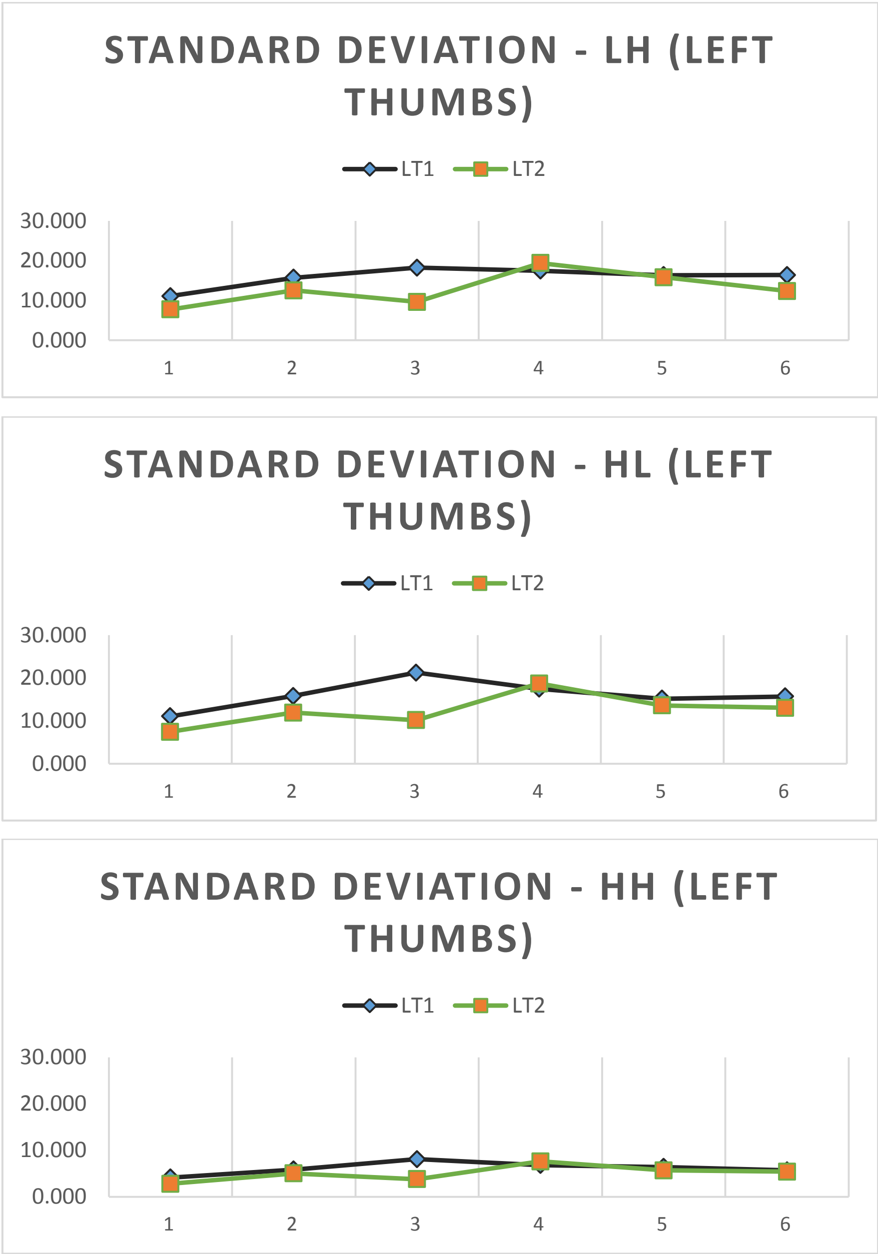
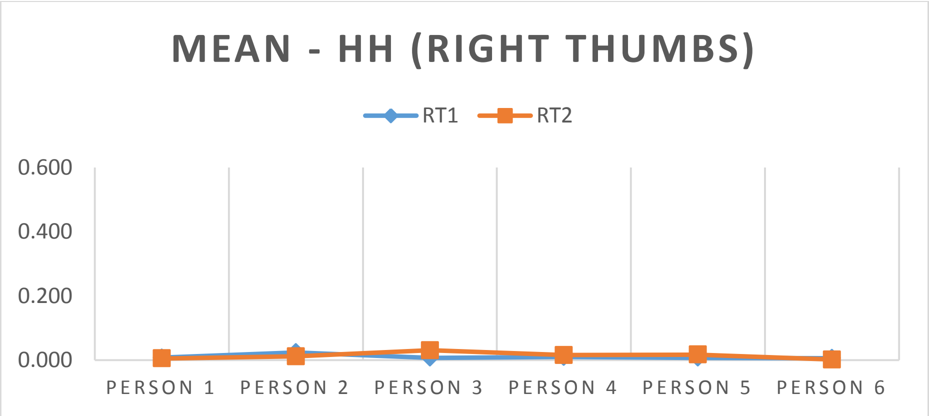


Figure 23 Standard Deviation Values for LH, HL, and HH pass filters

THIS SYSTEM BELONGS TO **PERSON 2: RIGHT THUMBS** - DWT - **HH**

MEAN					STANDARD DEVIATION			
Person	RT1	DIFFERENCES	RT2	DIFFERENCES	RT1	DIFFERENCES	RT2	DIFFERENCES
Person 1	0.008	0.004	0.005	0.006	2.681	3.289	3.657	2.313
Person 2	0.024	0.013	0.012	0.000	6.134	0.164	5.970	0.000
Person 3	0.008	0.004	0.031	0.019	4.437	1.533	5.966	0.004
Person 4	0.010	0.002	0.016	0.004	6.683	0.713	6.747	0.777
Person 5	0.007	0.005	0.017	0.006	4.751	1.219	4.409	1.561
Person 6	0.006	0.006	0.002	0.010	5.667	0.303	5.218	0.752

Table 5 Mean and Standard Deviation values in Accessing the System using HH pass filter



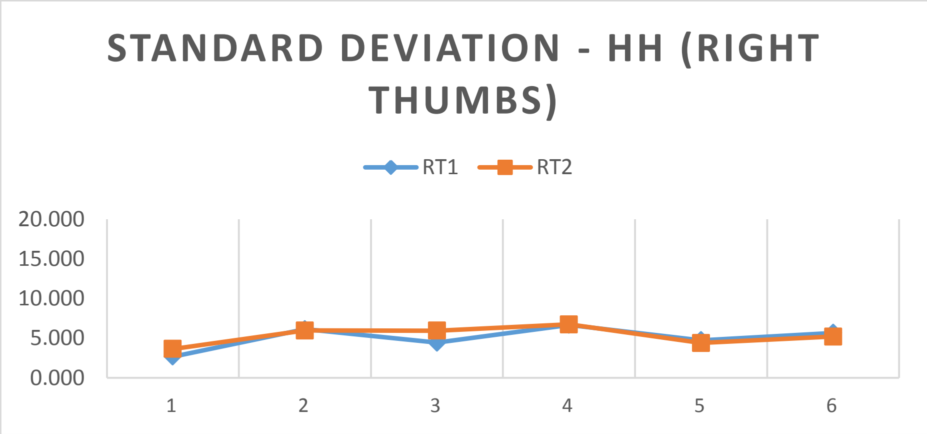


Figure 24 Mean and Standard Deviation for HH pass filter

The graphs show the mean and standard deviation of LH, HL, and HH pass filters. From the graph of left thumb fingerprint images alone, it can be observed that LH pass filter does not have the consistency of values for each person when comparing the input and database or in the graph comparing LT1 and LT2. Thus, it is clear that LH pass filter of DWT component values are not reliable to be used in the system of fingerprint recognition. This is because even for the same person but with different sample, it cannot identify the input and database very well.

From this, there is only two pass filters to choose from then. They are the HL, and HH pass filters. From the graphs alone, HH pass filter shows consistency of values for each person in comparing sample 1 and sample 2. So, if the decision is made solely on the graph observation, HH pass filter would be chosen to focus on. However, with more analysis, the table is constructed. The table, table 4 shows that despite the consistency values for each person HH pass filter values for this project is not reliable. This is because the values are not only close to each other for one particular person, but it is even too close with other people fingerprint images. Therefore, allowing almost everyone to access each other’s system. The red labels show that the values are too low, which is lower than the green labels, thus allowing that person to access another people’s system.

With this analysis made, the only filter to choose upon in this project is non other than the HL pass filter. It has the consistency of values for one particular person, and the values are reliable as it is not too close to other person. This means no one can simply access other people's system. The values and analysis using HL pass filter is shown in the table below:

THIS SYSTEM BELONGS TO **PERSON 2: RIGHT THUMBS** - DWT - **HL**

MEAN					STANDARD DEVIATION			
Person	RT1	DIFFERENCES	RT2	DIFFERENCES	RT1	DIFFERENCES	RT2	DIFFERENCES
Person 1	0.259	0.011	0.308	0.059	7.855	9.555	10.049	7.360
Person 2	0.198	0.050	0.249	0.000	14.246	3.164	17.410	0.000
Person 3	0.513	0.264	0.107	0.141	11.694	5.716	15.174	2.236
Person 4	0.132	0.116	0.123	0.125	17.935	0.525	17.746	0.336
Person 5	0.026	0.223	0.007	0.242	11.236	6.174	11.777	5.633
Person 6	0.097	0.152	0.001	0.248	13.281	4.129	12.888	4.522

Table 6 Mean and Standard Deviation Compared to other Person (for fingerprint recognition system) using HL pass filter

CHAPTER 5
CONCLUSION AND RECOMMENDATION

This project is proposed to have faster method in identifying fingerprint images. This is important as fingerprint recognition system is widely used all over the world. Thus, in order to have efficient and accurate fingerprint recognition system, the methods as DWT and GLCM are introduced and applied in this project. This is because these methods require less time consumption thus making it more effective. Therefore, with less time consumed the evaluation in terms of FAR, FRR, and TSR get to be obtained faster and accurate.

From the obtained results, it can be concluded that these method is applicable with some more modifications needed to be completed. As shown in the result, the difference is small and reliable to be used in the system of fingerprint recognition.

The next process of this project would be on improving the values obtained in terms of improving the image itself. Better improvisation of the method is a must to have an optimum results of this particular project. As of now, the project is going on track. With further effort put into this project, it shall be completed in time with an optimum output.

Another important factor for further research is to use a fingerprint scanner. As for this early research which is to see whether DWT and GLCM is applicable or not in fingerprint recognition system, the fingerprints are obtained solely using the stamp pad. Thus, it affects the color intensity of the image as different people would apply different pressure on the stamp pad and paper, resulting in different intensity of images. However, the methods are applicable. This is when the results for a good image is obtained. That shows the methods are applicable. But for further development and practical use of fingerprint recognition system using DWT and

GLCM as the feature extraction method, it is good to use the fingerprint scanner. This is said as the scanner maintains the color intensity of the image regardless of the pressure applied on the scanner.

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APPENDICES

APPENDIX A

YOUR APPENDIX HEADING