FACE RECOGNITION METHOD USING GABOR WAVELETS (GWS)

by

MUHAMMAD HANIS BIN ABU BAKAR

FINAL PROJECT REPORT

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
32610 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the Electrical
& Electronics Engineering Programme Universiti
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Approved by,

____

MRS NORASHIKIN BT YAHYA
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
JANUARY 2015

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.

MUHAMMAD HANIS BIN ABU BAKAR

ABSTRACT

Facial features can be used to recognize and identify the characteristics of a person. In this project, Gabor Wavelet (GW) based recognition technique is proposed whereby the GW is used to extract the facial feature of a person. The face recognition system consist of four (4) major stages namely image preprocessing, feature extraction, matching technique and classification technique. In feature extraction stage, the input images are converted into grayscale image prior to applying the 2D GWs. The resulting feature vectors are used to test the similarity score with the feature vectors of the facial image in the database. The chi-square is used to measure the distance in the matching stage whereby a comparison is made between feature vectors obtained from input face image with the one in the database. If the distance value is below a preset threshold, the face image is classified as a valid user and will be granted access to the system. We also investigate the effect of change in illumination to the proposed recognition algorithm. The results generated in this experiment indicate that the performance of the technique is severely affected by change of illumination. This shows that the use of GW alone for extracting the feature will not give a robust face recognition system in change of illumination. It is proposed that GW combined with other feature extraction technique might be able to address this issue. A suitable feature extraction method is local binary pattern (LBP) as it able to extract the local feature of an image whereas the GW extract the global feature. It is expected the hybrid of GW-LBP will improve the performance of the face recognition algorithm

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LIST OF ABBREVIATIONS

GWs	Gabor wavelets
RGB	Rgb2gray
2D	Two dimensional
PIN	Personal identification number
FT	Fourier transform
BPN	Back propagation neural network
PCA	Principal component analysis
SVM	Support vector machine
PGE	Multiscale pyramidal gabor wavelet eigenface
LBP	Local binary patterns
GWT	Gabor wavelet transform
JAFFE	Japanese female facial expression
IFT	Inverse fourier transform
DV	Distance value
LDA	Linear discriminant analysis

CHAPTER 1

INTRODUCTION

1.1 Background

Today, our technology is advancing forward. A biometrics identification is commonly used and still in development. The term “biometrics” is derived from the Greek words “bio” (life) and “metrics” (to measure). This technology depends on the physical characteristics of an individual such as fingerprints and retina, voiceprint, pattern of the iris of the eye and facial pattern. Sometime, they functioned to be as security, work at factory and others. However, there are some data or information are mostly restricted to be accessed except only as some authorized personnel. So, some identity authentication methods should be built to make sure another non-authorize personnel cannot access that important information.

Therefore, there are many solutions for the humans to recognize and identify each other and also same goes to the machines. Nowadays, many technologies have used identification systems for many years. Password or personal identification number (PIN) are the most common methods used for person verification and identification. However, the main problem for that system is they are not special and for the worst case is someone will have possibility to forget his/her own security number or even have been stolen. Some research have been run to develop some applications to overcome this problems. At last, they get interested in systems of a biometrics identification [11]. By using techniques of pattern recognition, that systems will be able to identify and recognize that person using their specified characteristics. Thus, fingerprint and retina and iris recognition will mostly use in several methods. However, that techniques are uneasy to be handle when are used.

For the next generation smart environment, there are a natural place for the face recognition from video and voice recognition. Both of them sometime become passive, unobtrusive, do not restrict user movement and inexpensive. The face recognition also one of the well-known biometric identification. Even though there are published work on face recognition techniques, this field continues to be an active research area. The face recognition is considered as non-intrusive and user-friendly techniques as it does not require the user to go through tedious scanning process unlike other biometric recognition technique such as iris, retina and fingerprints. [11] There are three main process are used such as acquisition, normalization and recognition [11]. The function of acquisition is to detect and track a face image patches in a dynamic scene. Next, normalization is a segmentation, alignment and normalization of the face images. Lastly, recognition is a representation and modelling of the face images [11].

In this report, we have cover four (4) Chapters. For introduction in Chapter 1, we discussed about background of face recognition. We also mentioned the problem statement and objective of this project. Next, literature review in Chapter 2, there are some researchers about Gabor Wavelet's fundamental and some other methods. Then, methodology in Chapter 3, we described the project work flow step by step. All the details about this project flows have been included in Gantt chart. Lastly, Chapter 4 about conclusion of this project.

1.2 Problem Statement

By using GWs for 5 scales and 8 orientation, Gabor facial feature is extracted from an image through convolution between facial image and GWs. However, the use of 40 filters can computationally expensive. In this project, we need to investigate the best filters out of 40 filters for feature extraction. Different image database with varying illumination and facial expression be used to run this experiment. A typical problem associated with face recognition system is that it often fail to recognize images captured under different illumination. We hypothesis that by using Gabor wavelet as the feature extraction method, the system will be able to give correct detection for images under different illumination.

1.3 Objective and Scope of Study

In this project, GWs application will be used, to extract Gabor facial feature from input face image. Applying Gabor function to an image involves 3 main stages, namely taking Fourier transform (FT) of the image, multiplying it with a Gaussian window centered at various frequency and taking inverse FT of the result [13]

The objective of this project is:

- To develop a face recognition system based on Gabor wavelet
- To evaluate the face recognition system in terms of accuracy and correct rejection rate.

CHAPTER 2

LITERATURE REVIEW

2.1 Gabor Wavelet (GWs)

Several Gabor-based face recognition techniques was proposed in the past couple of years. In [1], Balamurugan et. al proposed a face recognition system that uses Gabor Wavelet (GW) as feature extraction method before being input to the Back Propagation Neural Network (BPN). Murugan et al in [2] uses Gabor, Log Gabor and Discrete Wavelet Transform to extract facial features prior to dimensionality reduction using Principal Component Analysis (PCA). The Gabor-PCA method resulted in better performance than PCA alone, when measured in terms of recognition accuracy. In [3], another hybrid of Gabor and PCA is proposed whereby the Support Vector Machine (SVM) is used as the classifier whereby the performance of the technique is tested with FRGCv2 and ORL face database. The results presented in [3] are compared with other PCA-SVM technique [14] [15] [16] and have shown a better classification rate of 99.9 %.

Huang et al in [4] proposed a face recognition that uses Multiscale Pyramidal Gabor Wavelet Eigenface (PGE) as main method. The result shown in [4] are compared with 2D Gabor basic and achieved recognition rate of 97%. In [5], same method have been proposed by Liu et al to improve a face recognition by using GW and Adaboost Algorithm. GW is used to extract the face features while adaboost algorithm is used to detect the face and the eyes. Caplier et al in [6] proposed an efficient statistical face recognition across pose using Local Binary Patterns (LBP) and GW. Another method have been used in [7] to identify the face recognition where Gabor feature extraction is combined with fractal coding to reduce dimension of Gabor feature image. In [8], Kumar et al proposed a face recognition system that uses GW where neural network classifier is used as the identification task. Lihong et al in [9] proposed a new method with combination between Two-Dimensional Principal Component Analysis (2DPCA) and PCA to extract Gabor features for face recognition based on Gabor.

In [2], PCA method will be apply to function as tracking an accuracy rate of the face recognition. To get an optimum of resolution in both spatial and frequency domains, Gabor filter works as a band pass filter for local spatial frequency distribution. The Gabor represent for a face image which convolve between the face images and Gabor filters.

The Fourier transform is commonly used as analyzed for frequency properties of a given signal. However, there are some problems will occur such as losing of time information and a certain frequency cannot be located smoothly. To overcome this problems, we can use a technique of time-frequency analysis [12]. As for information, when the time duration get larger, the bandwidth becomes smaller. The Gabor function is proved to achieve the lower bound and performs the best analytical resolution in the joint domain. In [12] shown a Gaussian modulated by a sinusoidal signal:

$$\boldsymbol{\varphi(t) = e^{(-\alpha^2 t^2)} e^{j2\pi f_0 t}} \quad ; \quad \boldsymbol{\phi(f) = \sqrt{\frac{\pi}{\alpha^2}}\, e^{\left(-\frac{\pi^2}{\alpha^2}(f-f_0)^2\right)}} \tag{1}$$

Where;

$\alpha =$ the sharpness

$f_0 =$ the modulated center frequency of $\varphi(t)$

In 1980, 2D Gabor wavelet have been pioneered by Daugman. GWs can captured the properties of spatial localization and orientation selectivity. The reason GWs has been success used in the face recognition because its properties have a localization in a space optimally and domains has be used frequently [3]. The 2D Gabor filter can be define in the spatial domain [5]:

$$\boldsymbol{\varphi(x,y) = \frac{f^2}{\pi\gamma n} e^{-\left(\frac{f^2}{\gamma^2}{x_r}^2 + \frac{f^2}{n^2}{y_r}^2\right)} e^{-j2\pi f x_r}} \tag{2}$$

$$\boldsymbol{x_r = x\cos\theta + y\sin\theta \;\; ; \;\; y_r = -x\sin\theta + y\cos\theta}$$

Where;

θ = the orientation of the major axis of the elliptical Gaussian

f = frequency of the modulating sinusoidal plane wave

γ = ratio between center frequency

n = size of the Gaussian envelope

The 2D Fourier transform of $\boldsymbol{\varphi(u,v)}$ is shown below:

$$\boldsymbol{\varphi(u,v) = e^{\left(-\pi^2\left(\frac{\gamma^2}{f^2}(u_r-f)^2+\frac{\eta^2}{f^2}v_r\right)\ \right)}} \tag{3}$$

$$\boldsymbol{u_r = u\cos\theta + v\sin\theta \;\; ; \;\; v_r = -u\sin\theta + v\cos\theta}$$

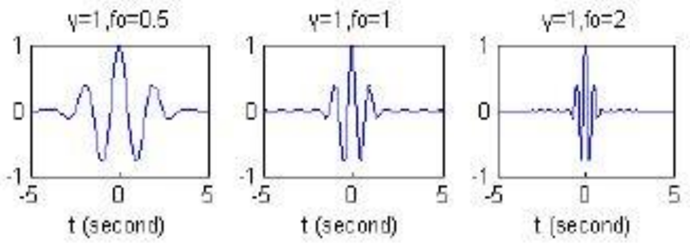

Figure 1: The real part of φ(u,v)

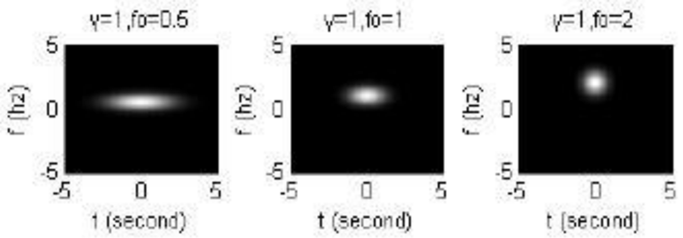

Figure 2: The magnitude of the Gabor transform of φ(u,v)

The 2D wavelet transform is defined as:

$$\boldsymbol{\psi_\theta\left(b_x, b_y, x, y, x_0, y_0\right) = \frac{1}{\sqrt{b_x b_y}}\psi_\theta\left(\frac{x-x_0}{b_x} + \frac{y-y_0}{b_y}\right)} \tag{4}$$

Usually GWT has only used 2D filter for the face recognition. Here some steps which have been used before this [4]:

a) Fourier transform is using to transform Gabor functions and face images in spatial domain into frequency domain.

b) Inverse Fourier transform is applied for getting Gabor facial features in spatial domain

There are some advantages of using GWs such as invariance to some degree with related to homogenous illumination changes, endurance against facial hair, glasses and image noise [8]. From this formula

$$\boldsymbol{\Psi}_{u,v}(\boldsymbol{z}) = \frac{\|\boldsymbol{k}_{u,v}\|^2}{\delta^2} \boldsymbol{e}^{\left(-\frac{\|k_{u,v}\|^2\|z\|^2}{2\delta^2}\right)[\boldsymbol{e}^{ik}_{u,v}{}^{z} - \boldsymbol{e}^{-\frac{\delta^2}{2}}]}, \tag{5}$$

we can produce and got 40 Gabor filters when using 5 scales multiply with 8 directions [6] [7]. Besides that, using this formula $G(x,y,u,v) = f(x,y) * \Psi_{u,v}(z)$, we can get a different scales and directions [7] [9] [10].

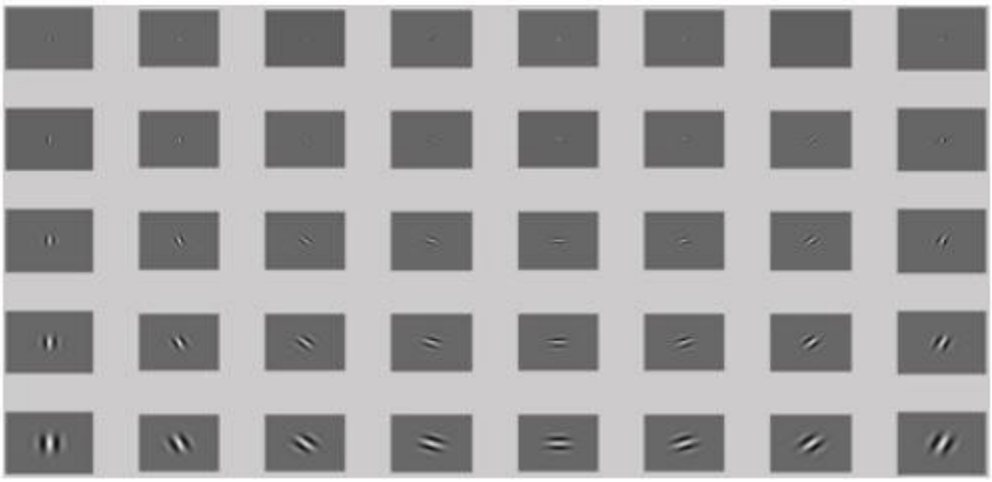

Figure 3: 40 Gabor filters (5 scales and 8 directions)

To eliminate DC's filter component, $\boldsymbol{e}^{-\frac{-\delta^2}{2}}$ function is added because to avoid dependence of the image absolute brightness in 2D GWT. This can solve a condition of light's changes from giving impact to the image model [7]. There are two steps to reduce dimensional of Gabor transform. Firstly, using a proper sampling, ρ and secondly, using an improved Fisherface algorithm [10].

Here some result what we get by using Jaffe database. As you can see, in Figure 4, a face image will be converted into grayscale format by using rgb2gray (RGB). Then, the face image will be extracted using gaborenergy formula and the results of that will produce the magnitude response as shown in Figure 6. In the Figure 5 shown the local energies of the 20 bands created by truncating the Gaussian masks beyond the band limits, ranked in decreasing order.

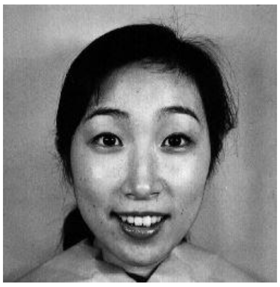

Figure 4: Sample of Jaffe face image

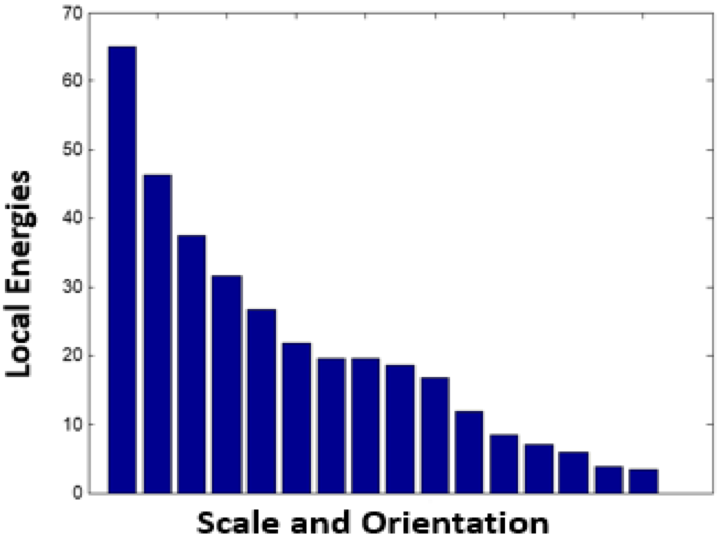

Figure 5: Graph of Local Energies

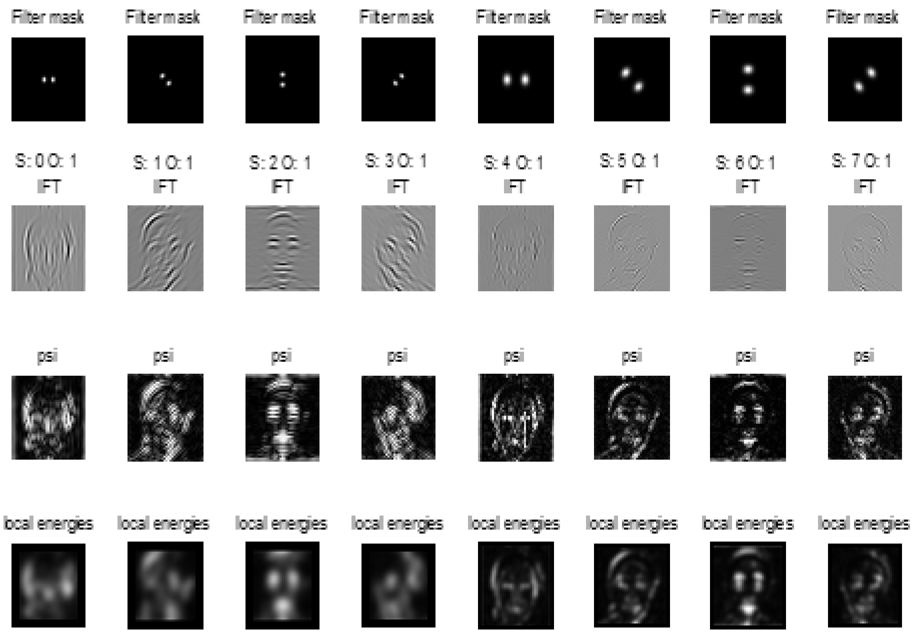

Figure 6: Feature extraction using GWs. Top row: magnitude of the Fourier transform of image in Figure 4 multiplied with the Gaussian masks at orientation 1. Second row: inverse Fourier transforms of the panels above. Third row: the ψ(g) transformations of the p

In Figure 6, the face image will be filter in frequency domain as seen in filter mask. While data image in inverse Fourier transform (IFT) will operated in space domain. The magnitude responses for this face image will be taken from psi part as our data. The local maxima can be found in the local energy function. However, local energies don't make any assumptions about the shape of the features which it is trying to detect whereas only looking for points of local maximum phase congruency. To ensure the image can be appear in psi form, this equation is derived as:

$$\boldsymbol{\Psi}(\mathbf{g}) = \left|\frac{\mathbf{1}-\boldsymbol{e}^{-2\propto g}}{\mathbf{1}+\boldsymbol{e}^{-2\propto g}}\right| \tag{6}$$

Where;

$\mathrm{g} = \text{grey value of the reconstructed image}$

$\text{if } \mathrm{g} \to \pm\infty, \Psi(\mathrm{g}) \to 1$

$\text{if } \mathrm{g} = 0, \Psi(\mathrm{g}) = 0$

To calculate energy of discrete time signals, there are specified equation that will used:

$$\mathbf{E} = \sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{n}} \boldsymbol{x_i}^{\mathbf{2}} \tag{7}$$

Where;

$\mathrm{x_i} = \text{the intensity of the filtered pixel in the i th image for filter}$

$\mathrm{i} = \text{divided by its mean value}$

$\mathrm{n} = \text{the total number of images}$

2.2 Chi-square as the Distance Metric

In [18] David C.H. defined "chi-square' as a statistical distribution and a hypothesis testing procedure that produces a statistic. This chi-square can provides a relationship between two or more groups, criteria or populations. In the other hands, this method is more reliable and stable than the Euclidean distance, Mahalanobis distance and Minkowski distance. The chi-square distance metric is given as

$$\boldsymbol{x}_{\omega}^{2}(\boldsymbol{x}, \boldsymbol{\xi}) = \boldsymbol{\Sigma}_{j,i}\, \boldsymbol{\omega}_{j} \frac{(x_{i,j}-\xi_{i,j})^{2}}{x_{i,j}-\xi_{i,j}}, \tag{8}$$

Where;

x = defined sample to compare with the histograms

ξ = define as model to compare with the histograms

ω_{j} = weight of region j

$\mathrm{i} = \mathrm{i} -$ th bin in the histogram

$\mathrm{j} = \mathrm{j} -$ th is the local region

CHAPTER 3

METHODOLOGY/ PROJECT WORK

3.1 Project Methodology

1) *Image and Face Detection*

   At beginning of process, an input face image need to be acquired. From that input, the region of interest (ROI) exact of the face will be extracted.

2) *Feature Extraction*

   To start this process, the input face image must be convert into grayscale image using rgb2gray (RGB). At this stage, the facial feature extraction will be using 2D GWs which functioned to expressed as energy values at different scale and orientation. The last result of feature vectors will be using at next process.

3) *Image and Face Detection*

   This is a final stage which to authenticate someone's identity in the database is same with the present. To get this result, Chi-square metric method is needed to calculate the distance between feature vectors obtained from input face image with the database. If the scorer is match below threshold, it means that one is a same identity with the database.

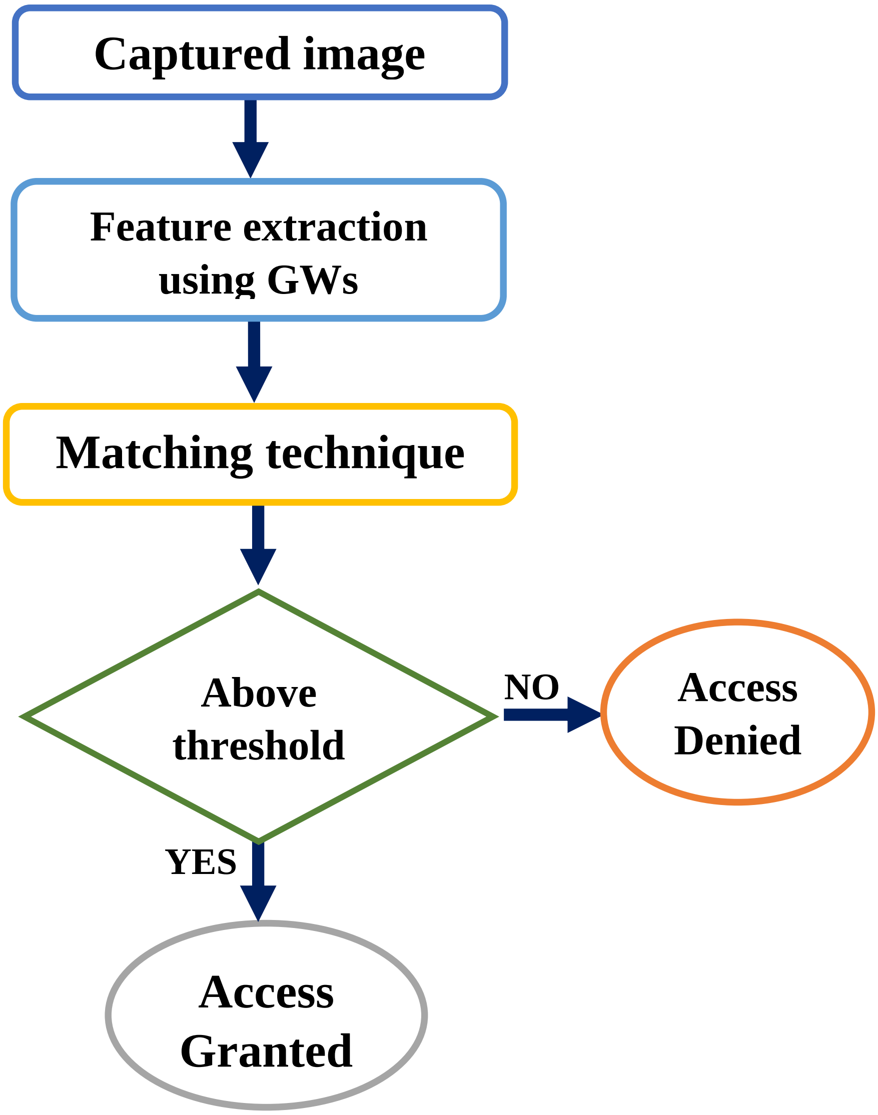

Figure 7: The process of the face recognition using GWs

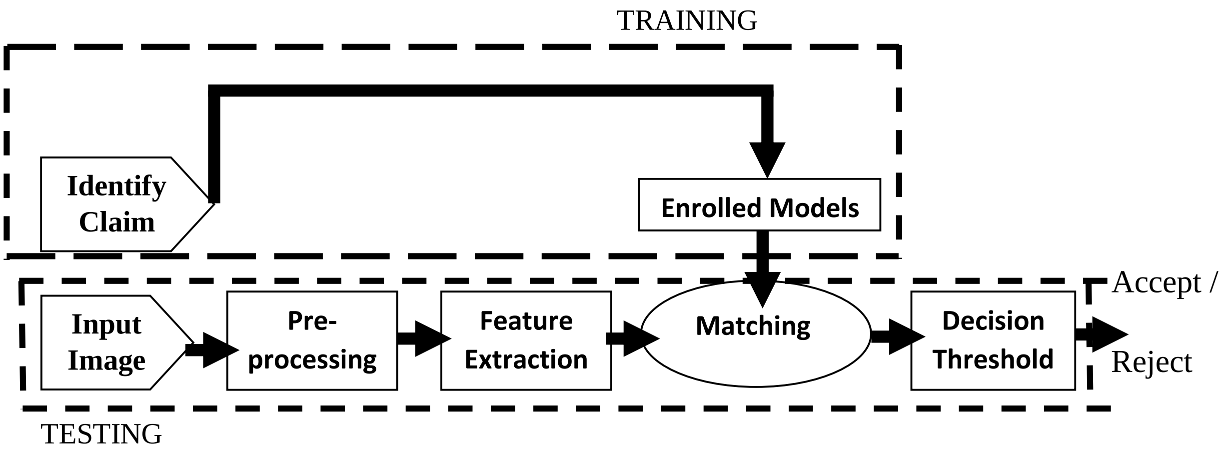

Figure 8: Block diagram process of the face recognition using GWs

3.2 Tools and Software

- Matlab R2014a
- Face Database 94
- Microsoft Excel 2010
- Microsoft Word 2010
- Adobe Photoshop 2010

3.3 Key Milestone and Gantt Chart

FYP 1															
No	**Tasks/ Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Selection of Project Topic														
2	Preliminary Research Work on Gabor Wavelet and its application														
3	Submission of Extended Proposal														
4	Understand and make research the Gabor Wavelet MatLab coding														
5	Preparation for Proposal Defense														
6	Proposal Defense presentation														
7	Generate coding and make experiment using Face94 database														
8	Choose 6 images with different expressions for test and determine the similarity score														
9	Preparation for Interim Report														
10	Submission of Interim Draft Report														
11	Submission of Interim Report														

FYP 2																
No	**Tasks/ Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1	Project Work Continuation															
2	Submission of Progress Report															
3	Project Work Continuation															
4	Pre-SEDEX															
5	Make some optimization by using own face image															
6	Submission of Draft Final Dissertation															
7	Submission of Final Dissertation (soft bound)															
8	Submission of Technical Report															
9	Viva															
10	Submission of Project Dissertation (hard bound)															

	Process
	Key Milestone

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Database

The experiments conducted in this section are by using image database obtain from face 94 database [17]. This database contains facial expression of 153 people. For this project, we decided to use only 10 people having 20 different expressions. The images are cropped in order to extract the facial area having dimension of 200 x 180 pixels. In addition, the images are converted to grayscale. In this project, images of five (5) males and five (5) women are used as our input data. The images of different individual are shown in Figure 9.

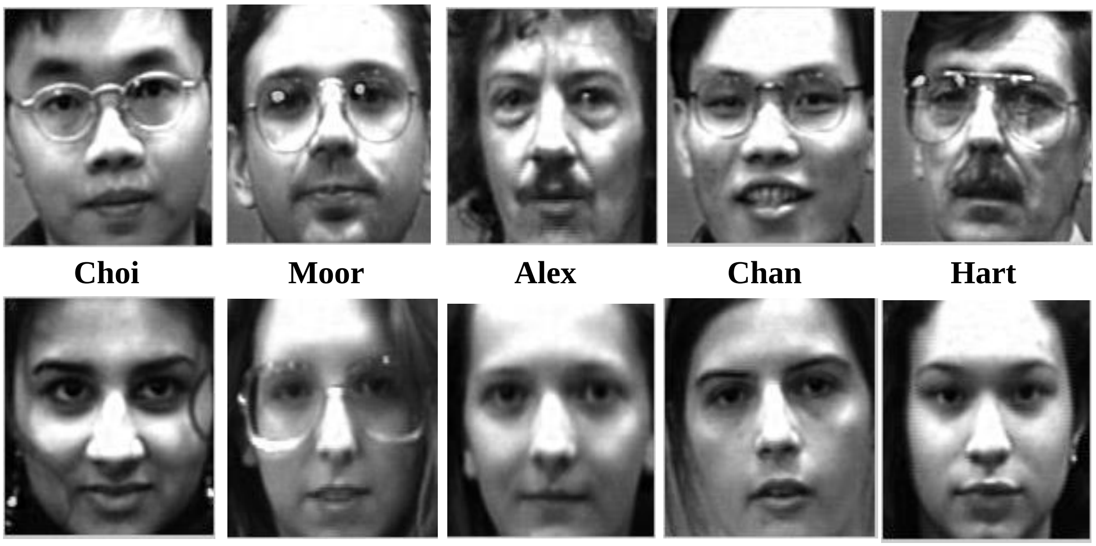

Figure 9: Examples of 10 people's faces.

4.2 Experiment 1: Training and Testing Image

For each person, we divided the images of a person into 2 categories, one for training and the other for testing. For the training, we used 15 images while only 5 images for testing. In Figure 10 shown 15 training image with different expressions of Alex's image while in Figure 11 shown 5 testing image with different expressions of Alex's image. To determine the distance between images, we calculate the DV between images of a same person. Let denote this as intraDV. On the other hand, the interDV corresponds to the DV between images of two different persons. The values of intraDV of the images are tabulated in Table 1.

Figure 10: 15 expressions of Alex's image for training image.

Figure 11: 5 expressions of Alex's image for testing image.

Table 1: The minimum and maximum IntraDV of 10 persons shown in Figure 9		
Persons	Minimum	Maximum
Alex	0.36	2.16
Choi	1.25	11.90
Moor	0.76	5.97
Ayda	2.27	12.70
Chan	0.25	9.27
Hart	0.22	1.61
Amma	0.52	8.14
Erza	0.13	5.60
Clara	0.16	2.04
Alice	0.20	4.52

From Table 1, the minimum intraDV among the 10 person is 0.13 whereas the maximum value is 12.70. Small values of intraDV indicate high similarity between the images and on the other hand large values of intraDV indicate low similarity between the images. The big different between the minimum and maximum intraDV will not affect the real implementation of the face recognition algorithm because the input images will be compared to the average of 10 intraDV values. In the next section, method to determine the threshold value of correct face images will be discussed.

4.3 Experiment 2: Setting the Threshold Value

In this experiment, the average values of intraDV of 10 person are calculated and tabulated in Figure 12. It can be seen from Figure 12, the average intraDVs vary between 0.75 and 2.72. From these intraDVs, the threshold of the face recognition algorithm can be determined. That is, as long as one of the DV value between the test image and 10 images in the database giving lower than the threshold, $\tau < 3$, the test image will be considered as a genuine person so access will be granted.

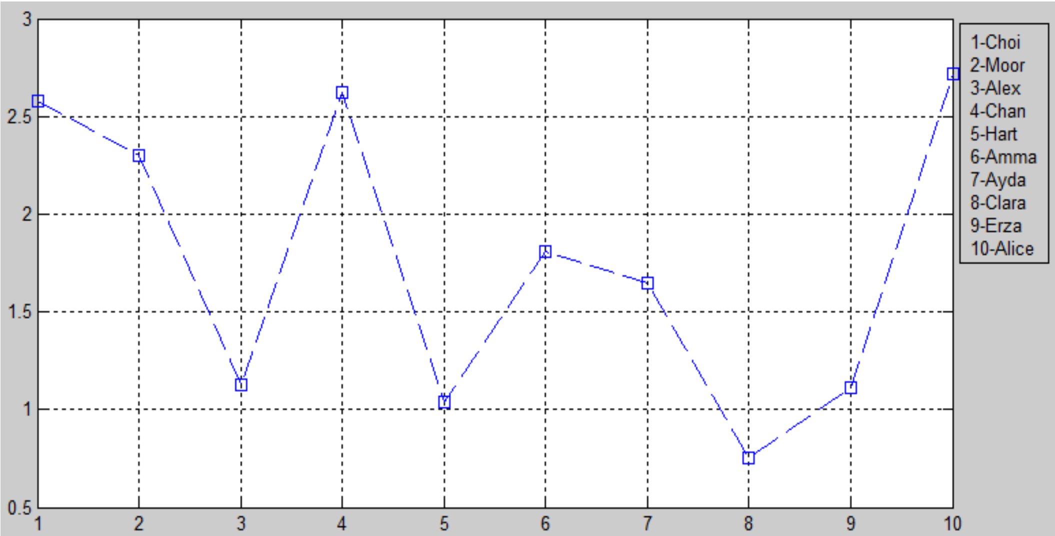

Figure 12: The average intraDV for the images of the ten (10) persons

For illustration, we tabulate the DVs between all the images in the database as shown in Figure 12. From Figure 12, it is clear that the lowest value of DV corresponds to intraDV. Notably, the lowest intraDV is recorded by Clara and the highest is by Alice.

	Choi	Moor	Alex	Chan	Hart	Amma	Ayda	Clara	Erza	Alice
Choi	2.58	11.75	26.81	11.41	13.95	33.65	18.53	49.58	49.66	23.75
Moor	11.75	2.30	12.27	7.14	15.08	18.88	14.95	51.07	44.33	19.12
Alex	26.81	12.27	1.13	12.45	35.88	4.62	12.08	40.37	28.91	18.69
Chan	11.41	7.14	12.45	2.62	16.91	20.68	9.71	38.72	38.65	14.49
Hart	13.95	15.08	35.88	16.91	1.04	49.36	32.62	88.23	88.82	47.53
Amma	33.65	18.88	4.62	20.68	48.35	1.81	13.56	36.88	22.46	19.02
Ayda	18.53	14.95	12.08	9.71	32.62	13.56	1.65	24.81	25.10	14.64
Clara	49.58	51.07	40.37	39.20	88.23	36.88	24.81	0.75	7.87	16.75
Erza	49.66	44.33	28.91	38.65	88.82	22.46	25.10	7.87	1.11	13.01
Alice	23.75	19.12	18.69	14.49	47.53	19.02	14.64	16.75	13.01	2.72

Figure 13: The average for the Alex's images with others persons

4.4 Experiment 3: Testing of the Face Recognition Algorithm

In this experiment, using 5 test images of each person, we calculate the DV values between each test image to all images in the database. This DV values are listed in Table 2. In Table 2, the highlighted columns correspond to intraDV of same person images, whereas the non-highlighted are for interDV. Notably, the values of intraDV are less than the preset threshold, $\tau < 3$ and will be considered as genuine user. For example, the intraDVs of the 5 images of Alex are between 0.70 and 1.43, which is less than 3. On the other hand, the interDV values of Alex with other person are all greater than 3 with the lowest value of 4.47, that is with Amma. This shows that our selected threshold can be used for this face recognition system. Similar observation can be seen from the DV values of the test images of 9 other persons.

Table 2: DV values between each test image for each person

Alex	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	0.92	28.62	12.44	14.85	13.92	35.85	4.47	31.94	45.27	20.75
2	1.43	24.11	9.40	14.35	9.94	31.19	6.48	31.18	43.00	16.61
3	1.38	28.43	12.26	16.74	13.58	34.54	5.85	34.27	48.30	21.60
4	1.43	24.06	9.18	10.54	9.06	32.97	5.94	26.97	36.57	14.33
5	0.70	26.44	11.99	12.10	11.04	34.79	4.94	28.61	39.71	17.41

Hart	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	36.58	15.17	15.17	34.09	17.76	0.98	50.04	90.92	90.00	48.72
2	35.11	14.09	14.13	31.82	16.76	0.84	48.22	88.52	87.70	47.67
3	38.35	16.91	17.71	34.58	19.78	1.01	51.36	95.19	93.82	52.85
4	43.53	20.02	19.63	40.95	21.78	1.58	59.01	99.73	99.75	56.67
5	31.08	12.19	13.45	27.84	14.86	0.98	42.99	83.29	83.02	44.71

Choi	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	19.67	2.56	8.62	14.04	7.30	11.23	25.72	45.84	47.41	19.94
2	22.64	2.13	11.50	13.78	10.50	14.54	28.11	45.37	45.18	22.59
3	28.67	1.75	12.37	18.39	12.57	15.55	35.01	48.35	47.44	23.66
4	26.17	1.65	11.15	18.53	10.96	10.48	34.03	53.95	53.73	26.73
5	26.56	1.91	12.56	18.75	12.87	17.49	31.95	44.49	45.77	21.60

Amma	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	3.74	35.02	21.47	12.59	20.95	51.52	1.71	21.20	34.56	20.12
2	4.25	35.24	20.61	13.31	21.11	51.27	1.07	20.74	35.01	18.40
3	8.90	45.25	32.15	16.75	30.51	66.15	2.26	20.62	34.32	26.38
4	6.98	41.70	28.19	15.67	27.22	60.87	2.72	20.73	34.95	23.60
5	4.69	33.76	19.19	12.66	19.75	50.50	1.30	18.25	32.26	15.06

Moor	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	15.20	7.30	1.94	13.36	5.15	11.73	22.74	44.95	48.06	17.92
2	9.02	10.24	2.15	9.61	6.48	18.62	13.28	34.95	42.16	15.16
3	10.37	10.34	2.48	12.40	5.62	11.50	18.81	47.53	52.55	22.67
4	10.92	9.17	1.70	10.56	5.75	16.78	15.99	36.82	42.69	14.72
5	9.22	10.21	1.77	11.54	6.10	15.30	15.65	40.94	47.68	18.70

Erza	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	24.15	46.02	40.73	21.03	34.10	83.66	18.73	1.03	7.23	12.19
2	28.43	50.16	44.49	26.08	38.68	89.58	21.90	0.69	8.65	12.89
3	29.64	51.51	46.28	27.11	40.14	91.59	22.70	0.79	8.71	13.61
4	28.75	49.59	44.17	26.17	38.04	88.81	22.62	0.76	8.30	12.27
5	34.15	54.11	49.19	28.94	41.80	95.17	28.07	1.06	6.20	14.14

Ayda	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	14.23	32.93	26.66	1.95	19.40	55.62	12.41	14.31	13.95	14.99
2	11.55	22.18	18.23	1.29	11.78	38.59	12.29	22.29	21.57	15.52
3	12.69	21.13	17.08	1.23	11.13	37.79	13.01	21.32	20.08	13.37
4	13.64	15.50	13.75	1.30	8.57	29.11	14.98	26.98	25.56	14.34
5	10.45	16.07	12.46	1.08	7.50	29.85	12.01	24.40	24.87	12.65

Clara	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	39.40	50.80	51.76	23.86	39.02	88.93	35.87	7.93	0.62	17.72
2	41.53	51.65	52.69	25.37	40.26	90.63	37.66	7.80	0.49	17.45
3	43.92	53.80	55.54	28.77	42.93	94.68	40.35	7.52	0.72	18.69
4	43.47	51.90	54.99	27.10	41.22	91.49	40.79	9.57	0.86	19.51
5	41.96	50.82	52.29	26.40	39.76	90.09	38.64	7.56	0.54	16.56

Chan	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	12.20	12.16	6.67	13.56	2.34	15.56	22.56	42.24	44.61	15.96
2	11.90	11.80	7.24	12.14	2.09	14.42	22.09	42.97	44.36	16.74
3	12.16	10.84	6.55	10.14	1.71	14.98	20.70	39.86	41.00	14.31
4	12.73	12.48	7.29	11.03	2.10	16.02	21.31	40.19	41.64	14.42
5	13.77	9.55	5.93	14.48	2.53	14.59	23.88	42.02	44.38	15.10

Alice	Alex	Choi	Moor	Ayda	Chan	Hart	Amma	Erza	Clara	Alice
1	20.03	24.19	19.60	15.12	14.34	48.89	20.71	11.93	14.45	1.54
2	21.68	22.53	17.75	18.04	12.48	43.78	24.75	18.00	20.17	2.58
3	18.33	23.48	18.60	15.71	13.75	47.51	19.31	12.34	16.37	1.52
4	19.01	21.51	17.14	14.37	12.10	44.34	20.62	14.32	16.72	1.59
5	16.62	23.41	18.63	13.47	13.87	48.36	16.60	10.32	14.52	1.45

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In this work, a Gabor-based face recognition technique is developed and tested. Using Face94 database, experiments are conducted, in order to train the system and to set the threshold value for correct detection. The number of images taken from the database are from 10 persons. In the first experiment, 20 different face expression of one person are divided to 2 categories; which are 15 images for training and 5 images for test. In the second experiment the threshold value is set at $\tau < 3$, which was obtained from the average values for intraDV of 10 persons. This means, if the DV value is lower than the threshold, the image is considered as a genuine person and access is granted. In the next stage, the method are able to correctly identify the test image as one of the person available in the database.

For further work, the Gabor-based face recognition should be tested with images under different illumination and under noisy condition. This test will give some indication on the robustness of the technique under such condition which commonly occur in practical scenario.

The face recognition technique can be further improved if another feature extraction technique is used in addition to Gabor wavelet. For example, using Local Binary Pattern (LBP), the local feature of an image can be extracted. Since Gabor wavelet extract the global feature of an image, combining it with LBP will improve the robustness of the face recognition algorithm.

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