ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

AN ENHANCEMENT ALGORITHM USING GABOR FILTER FOR FINGERPRINT RECOGNITION

[1] EINAS ALMARGHNI AZZOUBI, [2] ROSZIATI BINT IBRAHIM
Faculty of Computer Science and Information Technology, University Tun Hussien Onn Malaysia
E-mail: [1] Einas.Azzoubi@hotmail.com, [2] rosziati @uthm.edu.my

ABSTRACT

Fingerprint recognition is being widely applied in the personal identification for the purpose of high degree of security by matching processes between two human fingerprints. Many different techniques have been proposed to have a satisfactory fingerprint identification. The widely used minutiae-based representation does not utilize a significant component of the rich discriminatory information available in the fingerprints. Local ridge structures cannot be completely characterized by minutiae. Further, minutiae-based matching has difficulty in quickly matching two fingerprint images containing different numbers of unregistered minutiae points. We introduced an enhancement algorithm using Gabor filter based matching to capture both local and global details in a fingerprint as a compact fixed-length Fingercode. The improved filtering used to feather extraction in our proposed algorithm with eight different directions. The last step of our proposed algorithm is fingerprint matching, which is based on the Euclidean Distance (ED) between the two corresponding Fingercodes. The proposed algorithm can be personalized according to the value of Euclidean Distance (ED) and threshold (TH). If the ED is less than TH or equal to zero, it means that the two fingerprint images came from the same person. We compared our proposed algorithm (enhanced) with algorithm (without enhanced). The values of false acceptance rate (FAR), false reject rate (FRR) and equal error rate (EER) are lower than the algorithm (without enhanced). Also, the result based on proposed algorithm are also presented and based on the result, it gives higher accuracy and recognition rate.

Keywords: *Fingerprint Recognition; Gabor Filter; Fingercode; Matching; Euclidean Distance*

1. INTRODUCTION

Fingerprints have been used for over a century and are one of many forms of biometrics [1] to identify an individual and to verify their identity [2]. Fingerprint identification is commonly employed in forensic science to support criminal investigations and in biometric systems, such as civilian and commercial identification devices. Hence, there is a widespread use of fingerprints [3].
Fingerprint recognition is being widely applied for personal identification with the purpose of high degree of security [4] by matching processes between two human fingerprints. However, some fingerprint images captured in variant applications are poor in quality, which corrupted the accuracy of fingerprint recognition [5]. With identity fraud in our society reaching unprecedented proportions and an increasing emphasis on the emerging personal automatic identification applications, biometrics-based verification, especially fingerprint-based identification, is receiving a lot of attention [6].
Fingerprint matching techniques can be classified into three types: Correlation-based matching, Minutiae-based matching and Non-Minutiae feature-based matching. Minutiae-based matching is the most popular and most widely used technique, being the basis of the fingerprint comparison [8].
The widely used minutiae-based representation does not utilize a significant component of the rich discriminatory information available in the fingerprints. Local ridge structures cannot be completely characterized by minutiae. Further, minutiae-based matching has difficulty in quickly matching two fingerprint images containing different numbers of unregistered minutiae points [9]. Algorithm is designed to recognise fingerprint images using a bank of filters (Gabor Filter) to capture both local and global details in a fingerprint with eight different directions. Table 2 shows the advantage of filter bank based fingerprint matching and disadvantages of minutiae based approach for fingerprint matching.

2. RELATED WORK

Fingerprint recognition is being widely applied for personal identification with the purpose of high degree of security. Fingerprint recognition requires

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

minimal effort from the user, does not capture other information than strictly necessary for the recognition process and provides relatively good performance. Also, another reason for the popularity of fingerprints is the relatively low price of fingerprint sensors, which enable easy integration into PC keyboards, smart cards and wireless hardware [10].

Some fingerprint images captured in variant applications are poor in quality, which corrupted the accuracy of fingerprint recognition. Consequently, fingerprint image enhancement is usually the first step in most Automatic Fingerprint Identification Systems (AFISs), while fingerprint matching is the last step in AFIS.

Many researchers have proposed fingerprinting approaches and they tried to find the best algorithm that can produce fingerprint images with minimum noise and has maximum performance Table 1 shows some previous work used different techniques, database and rates of their algorithm. Lin Hong et al. (2000) has developed a novel filter bank based fingerprint matching to capture both local and global details in a fingerprint as a compact fixed-length FingerCode. Fingerprint matching is based on the Euclidean distance between the two corresponding FingerCodes [9]. Then, it is improved by Lifeng Sha et al. (2003), where they first proposed a new rotation-invariant reference point location method and then combined the directional features with Average Absolute Deviation (AAD) feature to form an oriented FingerCode [11]. Dhamal (2013) has presented a fingerprint matching scheme that utilized both the frequency and orientation information available in a fingerprint with eight Gabor filters are used to extract features from the template and input images. The primary advantage of their approach is computationally attractive matching capability and compact length of FingerCode [12].

Table 1: Review of Various Fingerprint Enhancement and Matching Techniques

Author	Techniques Used	FAR, FRR and VR	Data Base Used
Lin Hong et al. (1997)	Alignment based elastic matching algorithm	FRR=15%	MSU: contain 10 images per finger from 70 individuals. Total 700 images size: 640×480
Lin Hong et al. (2000)	Filtering bank based matching	FAR=1.92% FRR= 10.006%	MSU_DBI, consists of a total of 2672 images
Afsar et al. (2004)	Gabor filter based Enhancement and CN concept for Minutiae Extraction	FAR=1% FRR=7%	FVC 2000 800 fingerprints from110 different fingers
Kaur et al. (2008)	Histogram Equalization and FFT for enhancement and CN Concept for Minutiae Extraction	VR=75%	N/A
Saleh et al. (2011)	Minutiae-based matching, FFT for enhancement	FAR=0.171% FRR=0.166%	FVC2000
Chaudhary et al. (2012)	Filtering based matching and Gabor Filter	FAR=0.350% FRR=21.49%	DB1_B, DB2_B, DB3_B, DB4_B, PNG, VeriFinger_Sample_DB
Gopi et al. (2012)	Gabor Filter And Frequency Domain Filtering	Recognition rate= 95%	FVC 2002
Liu et al. (2012)	Gabor filter based Enhancement and CN concept for Minutiae Extraction	FAR=0.085% FRR=1.4% VR=99.75%	2000 fingerprint images of 200 individuals at 500dpi size: 256×360
Virk et al. (2012)	Histogram Equalization for enhancement and CN Concept for Minutiae Extraction	FAR=0.06% FRR= 6.9%	FVC2000
Dahmal (2013)	Filtering based matching and Gabor Filter	FAR=0.0% FRR= 6.333%	SmallDB, NewDB, FingDB. SmallDB contains 4 different. NewDB is a small database containing the 14 images. The FingDB contains fingerprint images of 21 persons

Fingerprint matching techniques can be classified into three types: Correlation-based matching, Minutiae-based matching and Non-Minutiae feature-based matching.

In this paper presents a proposed algorithm by improving Gabor filter with eight directions, both the global flow pattern of ridges and valleys, local characteristics (inter-ridge distances, ridge orientation) are used for feature extraction and FingerCode (Feature vector) for fingerprint with a short fixed length code. FingerCode is suitable for fast matching by Euclidean distance. Table 2 shows the advantage of filter bank based fingerprint

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

matching and disadvantages of minutiae based approach for fingerprint matching.

Table 2: The Advantage of Filter Bank Based Fingerprint Matching and Disadvantages of Minutiae Based Approach for Fingerprint Matching

The advantage of filter bank based fingerprint matching	The disadvantages of minutiae based approach for fingerprint matching
• Both the global flow pattern of ridges and valleys and local characteristics (inter-ridge distances, ridge orientation) are used for feature extraction • They generate a short fixed length code, ***FingerCode*** (Feature vector) for fingerprint • ***FingerCode*** is suitable for fast matching (by Euclidean distance), storage on smartcard and indexing • The obtained representation is scale, translation and rotation invariant.	• A good quality fingerprint contains between 60 and 80 minutiae, but different fingerprints have different numbers. • Reliably extracting minutiae from poor quality fingerprints is very difficult. • Minutiae extraction is time consuming. • Variable sized minutiae-based representation does not easily help in indexing fingerprint database.

3. PROPOSED ALGORITHM

I. The Old Algorithm

In ref. [9] and [12] the algorithm is designed to recognize the fingerprint images using a bank of filters (Gabor Filter) to capture both local and global details in a fingerprint with eight different directions. As is well known, the Gabor filter is a very useful tool for texture analysis in both domains and hence combines the advantages of both filters. The algorithm reads an image (fingerprint), the crucial step in fingerprint recognition is core point and region of insert determination. The Filter of region of interest in eight different directions by using a bank of 2D Gabor filters (eight directions are required to completely capture the local ridge characteristics in a fingerprint while only four directions are required to capture the global configuration). The last step is compute the average absolute deviation from the mean (AAD) of gray values in individual sectors in filtered images to define the feature vector or the FingerCode. The fingerprint image matching is based on the Euclidean distance (ED) between two fingercodes. The algorithm mainly focused on four steps as following:

- Determine a reference point and region of interest for the fingerprint image.
- Tessellate the region of interest around the reference point.
- Filter the region of interest in eight different directions using a bank of Gabor filters (eight directions are required to completely capture the local ridge characteristics in a fingerprint while only four directions are required to capture the global configuration.
- Compute the average absolute deviation from the mean (AAD) of gray values in individual sectors in filtered images to define the feature vector or the FingerCode.

II. The Enhancement Of Algorithm

The proposed algorithm (enhanced) is designed to recognize fingerprint images with the improving of filtering (Gabor filter). The improving is by separate two dimensional Gabor filter (2D) to two one dimensional (1D). The algorithm reads an image (enhanced fingerprint image). The proposed algorithm as shown in Figure 1 starting with the input fingerprint images, the input of fingerprint image should be in Gray-scale. The last step in the proposed algorithm is fingerprint matching between the input fingerprint image and database image as following:

- **Input:** Gray-scale Fingerprint image.
- **Output:** Recognized fingerprint image.
- The fingerprint image enhancement is performed to improve the image quality by using Fast Fourier Transform FFT
- Find the centre by calculate the core point Cropping: crop the image after determine the core point.
- Sectorization by divide the image to sectors.
- Normalization and Filtering by using Separate Gabor Filter.
- The final feature vectors
- The fingerprint match/non match is based on Euclidean distance

Journal of Theoretical and Applied Information Technology
30th April 2015. Vol.74 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

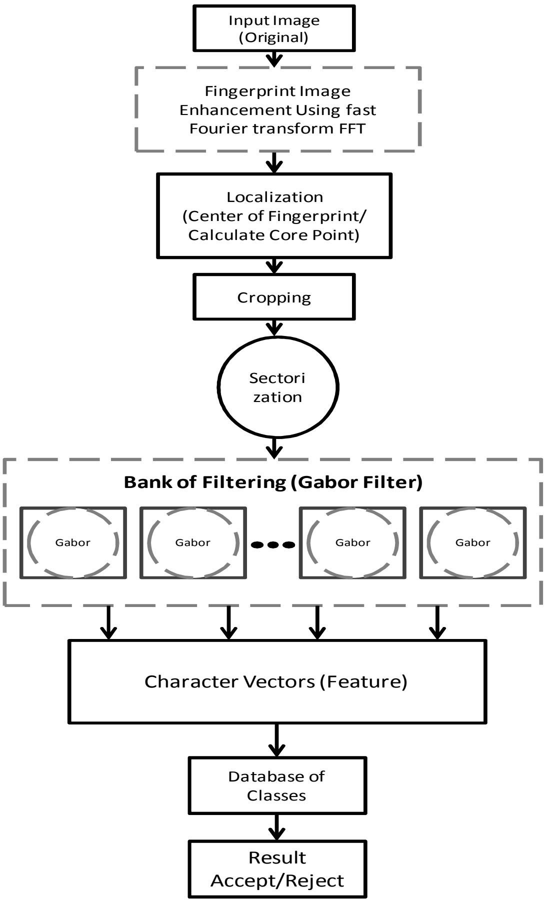

Figure 1: The General Mechanism Of Fingerprint Recognition Of Proposed Algorithm Using Bank Of Filtering Based Fingerprint Matching.

A. The Fingerprint Image Enhancement

Fingerprint image is one of the noisiest of image types. This is due predominantly to the fact that fingers are our direct form of contact for most of the manual tasks we perform [20], finger tips become dirty, cut, scarred, creased, dry, wet, worn, etc. So the obtaining of a good fingerprint image is not always easy and the fingerprint image must be pre-processed before minutiae extraction or matching. The image enhancement step is designed to reduce this noise and to enhance the definition of ridges against valleys. The first step is to enhance the fingerprint image using Short Time Fourier Transform STFT analysis [21] [29]. The performance of a fingerprint matching algorithm depends critically upon the quality of the input fingerprint image. While the quality of a fingerprint image may not be objectively measured, it roughly corresponds to the clarity of the ridge structure in the fingerprint image, and hence it is necessary to enhance the fingerprint image. The algorithm for image enhancement consists of stages as summarized below.

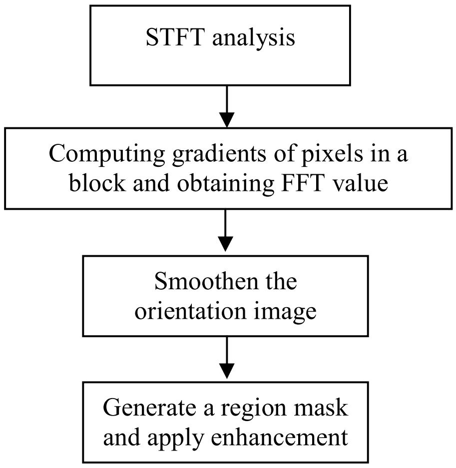

Figure 2: The Algorithm Of Fast Fourier Transform Technique (FFT)

B. Get Core Point Of The Enhanced Fingerprint

The reference point is defined as: the point of the maximum curvature on the convex ridge [18], which is usually located in the central area of fingerprint. The reliable detection of the position of a reference point can be accomplished by detecting the maximum curvature using complex filtering methods [30]. They apply complex filters to ridge orientation field image generated from original fingerprint image. The reliable detection of reference point with the complex filtering method. In our proposed algorithm used an improved scheme for core point positioning [30] [31]. The algorithm of an improved scheme for core point positioning as following:

- Segmentation of Image, Binary Erosion and Closing
- Pixel-Wise Orientation
- Logical Matrix
- Border of the Logical Matrix
- Complex Filtering Output
- Corresponding Core Point

Figure 3: The Algorithm Of An Improved Scheme For Core Point Positioning

C. Tessellation Of Region Of Interest

After finding out the core point fingerprint images will test by cropping or resizing is to make the

Journal of Theoretical and Applied Information Technology
30th April 2015. Vol.74 No.3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

image to be smaller so the processing will be faster. The circular region around this core point was tessellated into sectors, used 5 concentric bands around core point. Each band is 20 pixels wide and segmented into sixteen two sectors. Thus there were total 16 x 5 = 80 sectors and the region of interest was a circle of radius 100 pixels, centered at the core point.

D. Filtering (Gabor Filter)

The Gabor function has been recognized as a very useful tool in computer vision and image processing, especially for texture analysis, due to its optimal localization properties in both spatial and frequency domain. There are lots of papers published on its applications since Gabor (1946) proposed the 1-D Gabor function. The family of 2-D Gabor filters was originally presented by Daugman (1980) as a framework for understanding the orientation-selective and spatial–frequency selective receptive field properties of neurons in the brains_ visual cortex, and then was further mathematically elaborated [22] [32].
Gabor Filters, Can remove noise, preserve true ridge and valley structures and provide information contained in a particular orientation. The improving of filtering by using separate 2D Gabor filter for two of one dimensional. Since two-dimensional Gabor filter can be separated into one dimensional Gaussian low pass filter and one-dimensional Gaussian band pass filter to the perpendicular as shown in Figure 4, a new set of separable Gabor filters are implemented for feature extraction and filtering with eight different directions. This separable Gabor filtering consumes approximately 2 times faster than the conventional Gabor filtering with comparable enhancement results.
An even symmetric 2D Gabor filter had the following general form in the spatial domain as in:

$$G(x,y,\theta,f) = \exp\left\{-\frac{1}{2}\left[\frac{x_\theta^2}{\sigma_x^2} + \frac{y_\theta^2}{\sigma_y^2}\right]\right\}\cos(2\pi f x_\theta) \quad (1)$$

Separate the two-dimensional Gabor filter is divided into a one-dimensional band-pass filtering and a one-dimensional low-pass filtering as following:

$$G_1(x,f) = \exp\left\{-\frac{1}{2}\left[\frac{x^2}{\sigma_x^2}\right]\right\}\cos(2\pi f x) \quad (2)$$

$$G_2(y) = \exp\left\{-\frac{1}{2}\left[\frac{y^2}{\sigma_y^2}\right]\right\} \quad (3)$$

$$G(x,y,f)_{Total} = \sum G_1(x,f)G_2(y) \quad (4)$$

Where:

F: frequency of the sinusoidal plane wave along the direction θ from the x-axis. σ_x^2 and σ_y^2 : space constants of the Gaussian envelope along x and y axes respectively. The fingerprint image filtering with eight selected orientations, and practical eight-direction: 0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135°, 157.5°. Once the localization and filtering is done, the fingerprint image matching with database images (Fingercode). Fingerprint matching refers to finding the similarity between two given fingerprint images. Fingerprint matching was based on finding the Euclidean distance between the corresponding fingercodes. The translation invariance in the Fingercode was established by the reference point. Approximate rotation invariance was achieved by cyclically rotating the features in the FingerCode itself. The matching between feature vectors of input fingerprint and database based on Euclidean distance, for each input fingerprint and its template fingerprint, we compute the matching score for features depend on the nearest distance, when the distance equal zero it means the input fingerprint match with candidate of the database.

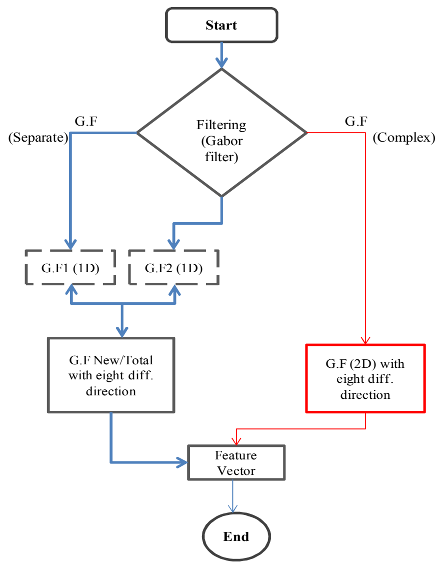

Figure 4: The Mechanism Of Gabor Filter (Filtering) Improvement

E. Matching

Fingerprint matching refers to finding the similarity between two given fingerprint images. Fingerprint matching was based on finding the euclidean distance between the corresponding fingercodes.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The translation invariance in the Fingercode was established by the reference point. Approximate rotation invariance was achieved by cyclically rotating the features in the fingercode itself. The matching between feature vectors of input fingerprint and database based on euclidean distance, for each input fingerprint and its template fingerprint, we compute the matching score for features depend on the nearest distance, when the distance equal zero it means the input fingerprint match with candidate of the database. The bellow table shows the comparison between two algorithms the old method .vs. proposed of enhancement algorithm.

Table 3: The Comparison Between Two Algorithms The Old Method .Vs. Proposed Of Enhancement Algorithm

The old Method	The proposed of an enhancement algorithm
• The original image with (poor and good quality) used to get the reference point. • No cropping • Filtering bank: using 2D Gabor Filter.	• The input image used as an enhanced image by using Fast Fourier Transform FFT to remove the noise and to get the reference point. • Cropping: center point take 175 x 175 pixel area. • Filtering: Using a bank of improve of 2D set of Gabor filter (separate 2D Gabor filter for two of 1D) within eight different direction.

4. EXPERIMENTAL RESULTS

In our experimental results, some of fingerprint images 256 x 256 image 8-bit grayscale @ 500 dpi have been tested of proposed algorithm, In order to test the validity of our implementation; we have used the publicly available database. Three from the International Fingerprint Verification Competitions (FVCs) databases have been used, for each competition; databases were acquired using different scanner as summarize below:
FVC 2000, FVC 2002 and FVC 2004 (DB1_B _2000, DB1_B_2002, DB1-B_2004, DB2_B_2000, DB2_B_2002, DB2_B_2004, DB3_B_2002, DB3_B_2004) [26] [27] [28]. The following table shows the database which used to evaluate the performance of the proposed technique.

Table 4: Fvcs Fingerprint Images Databases

Database No.		Competitions	Image Size	Resolution	Sensor type
DB1	DB1_B	FVC 2000	300x300	500 dpi	Low-cost optical sensor
DB2	DB1_B	FVC 2002	388x374	500 dpi	Optical sensor
DB3	DB1-B	FVC 2004	640x480	500 dpi	Optical sensor
DB4	DB2_B	FVC 2000	256x364	500 dpi	Low-cost capacitive sensor
DB5	DB2_B	FVC 2002	296x560	569 dpi	Optical sensor
DB6	DB2_B	FVC 2004	328x364	500 dpi	Optical sensor
DB7	DB3_B	FVC 2002	300x300	500 dpi	Capacitive sensor
DB8	DB3_B	FVC 2004	300x480	512 dpi	Thermal sweeping Sensor

5. ROC CURVE

The receiver operating characteristic (ROC) curve is used. An ROC curve is a plotted of false reject rate (FRR) against false acceptance rate (FAR); the curve is drawn in log-log scales for better comprehension (Maio et al., 2002). To draw the curve in the positive portions of x- and y-axis, FAR and FRR values are multiplied by 100 before applying the logarithm on them. Figure 5 shows the ROC curve of the proposed matching algorithm. To get one curve, only one column of the FAR matrix is drawn against one column of the FRR matrix, after multiplying with 100 and applying the logarithm on both. As can be shown, the recognition performance is good by comparison with the curve of a good recognition performance system seen in (O'Gorman, 1998). As show in Figure 5 the curve is going to the top right portion of the plotting area whereas is good recognition performance curve in (O'Gorman, 1998) is going to the bottom left portion of the plotting area, this is because in the proposed matching algorithm, lower scores are associated with matching fingerprints and higher scores are associated with mismatching fingerprints.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

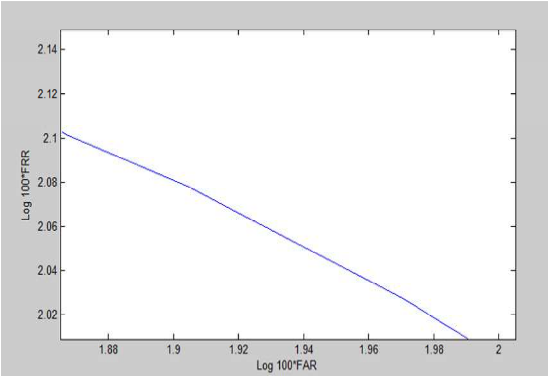

Figure 5: The Roc Curve

The second experiment is plotting the Receiver Operator Characteristic (ROC) indicates the inverse relationship of FAR and FRR rates by plotting them against each other where the false reject rate function in false acceptance rate. The EER is then found by extending a 45-degree line from the point of origin (0,0). Where this line crosses the curve is the EER at FAR=FRR as shown in the below figure.

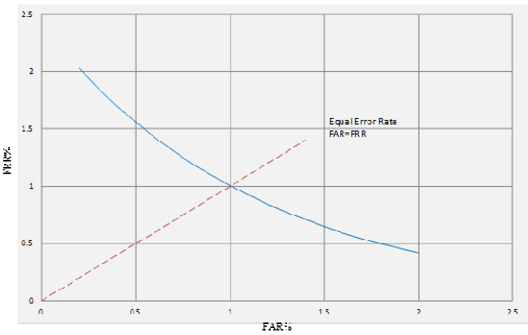

Figure 6: The Roc Curve By Plotting The Relationship Between Far% .Vs. Frr%

In Figure 7 we have used the Receiver Operator Characteristic (ROC) indicates the inverse relationship of FAR and FRR rates by plotting them against each other at different thresholds. The FAR is given by the percentage of comparisons between different fingers where the matching score is below the threshold. The FRR is given by the percentage of comparisons between different samples of the same finger where the matching score is above the threshold. The point at which these two probabilities cross is called Equal Error Rate (ERR) or Crossover error rate at Crossover point as highlighted in Figure 7.

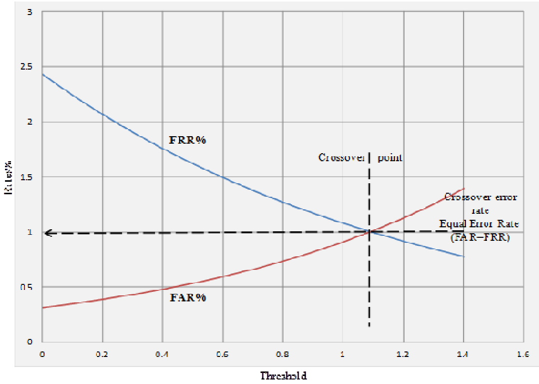

Figure 7: The Roc Curve By Plotting The Relationship Between Rates .Vs. Threshold

The performance of a biometrical system is usually measured in terms of false accept rate (FAR), false reject rate (FRR) and equal error rate (EER). The false accept rate is the percentage of invalid inputs that are incorrectly accepted (match between input and a non-matching template). The false reject rate is the percentage of valid inputs that are incorrectly rejected (fails to detect a match between input and matching template). The overall results of the proposed algorithm showed that the proposed algorithm for fingerprint recognition using Gabor filter succeeded in the enhancement algorithm and achieved better results. The best results were obtained based on the rates of false acceptance, false reject and equal error also the percentage of recognition rate and accuracy as summarized below in Table 5.

Table 5: The Percentage Of FAR, FRR, EER, Accuracy And Recognition Rate Of Three Algorithms

Algorithms / Percentage%	Without enhancement algorithm	Enhancement algorithm
FAR%	0.96	0.883
FRR%	8.17	1.116
EER%	4.565	0.9995
Reco. Rate%	90.87	98.001
Acc.%	95.435	99.0005

Figure 8 shows the comparison of the rates of false acceptance, false reject and equal error for two algorithms, in our proposed algorithm (enhanced) the false acceptance rate is 0.883% and it's better than algorithm (without enhanced) as its rate is 0.96%. Also, in our proposed algorithm (enhanced) the false reject and equal error rates are 1.116 %,

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

0.9995% and it's better than algorithm (without enhanced) as its rates are 8.17%, 4.565%. In figure 7 shows The comparison of recognition rate and accuracy of the algorithms, in our proposed algorithm (enhanced) the recognition rate and accuracy are 98.001%, 99.0005% and it's better than algorithm (without enhanced) as its percentages are 90.87% and 95.435%.

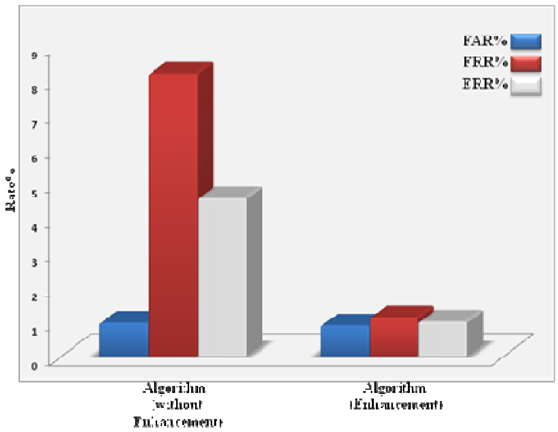

Figure 8: The Comparison Of False Acceptance Rate And False Reject Rate For The Algorithms

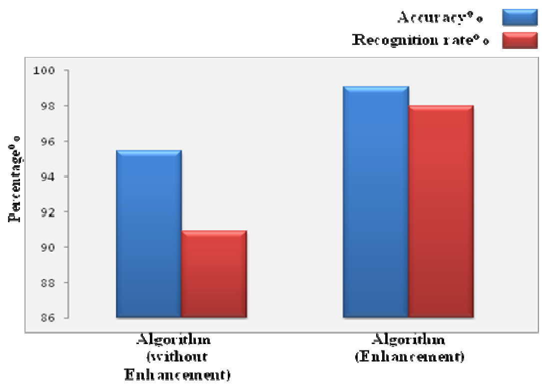

Figure 9: The Comparison Of Recognition Rate For The Algorithms

5. CONCLUSION

Fingerprint Recognition is one of the well known and reliable Biometrics Authentication Techniques. We have presented an enhancement algorithm for fingerprint recognition using a bank of filtering that utilizes both the frequency and orientation information available in a fingerprint. Gabor filters are used to extract features from the template and input images by eight different directions with a short fixed length. Hence, the process of extracting in many oriented components from a fingerprint image is an expensive process because it entails filtering of the image by a bank of Gabor filters in many directions. The separating of two dimensional of complex Gabor filter 2D into two one dimensional 1D filters on the x and y axes is an efficient method to reduce the time of image filtering process. The filtering is based on fingerprint matching by computing the Euclidean distance between the template Fingerprint and the input Fingerprint (FingerCodes). The image of fingerprint should be in gray-scale level @500 dpi, size 256 x 256 image 8-bit. In our algorithm the input fingerprint image enhanced by using fast Fourier transform FFT in future we are working to handle the filtering of fingerprint image in a good quality. This algorithm was implemented by using MATLAB version 7.12.0 (R2011a). Experimental result of the value of rates showed that, the proposed algorithm (enhanced) obtained better results than the algorithm (without enhanced). The robustness of the proposed algorithm is proven from the high percentage of accuracy and recognition rate. In addition, the proposed algorithm had low percentages of false acceptance rate, false reject rate and equal error rate.

REFRENCES

[1] Neeraj Singla and Sugandha Sharma, "Biometric fingerprint indentification using artificial neural network," International Journal of Advanced Research in Computer Science & Technology (IJARCST), vol. 2 issue 1, 2014.

[2] Urvashi Chaudhary and Shruti Bhardwaj, "Fingerprint image enhancement and minutia extraction," International Journal of Advance Research in Computer Science and Management Studies, vol. 2, Issue 5, 2014.

[3] Raymond Thai, "Fingerprint Image Enhancement and Minutiae Extraction, the School of Computer Science and Software Engineering, the University of Western Australia, 2003.

[4] Mustafa Salah Khalefa, Zaid Amin Abduljabar and Huda Ameer Zeki, "Fingerprint Image Enhancement by Develop Mehtre Technique," Advanced Computing: An International Journal (ACIJ), Vol. 2, No.6, 2011.

[5] K.Kanagalakshmi and Dr.E.Chandra, "Frequency Domain Enhancement Algorithm Based on Log –Gabor Filter in FFT Domain," Global Journal of Computer Science and Technology, vol. 12 Issue 7 Version 1.0, 2012.

[6] Prateek Verma, Maheedhar Dubey, Praveen Verma, "Correlation based method for identification of fingerprint- a biometric

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

approach," International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249 – 8958, vol. 1, Issue 4, 2012.

[7] Einas Azzoubi and Rosziati Bint Ibrahim, "An Efficient Approach for Fingerprint Recognition using Gabor Filter-Bank Based Fingerprint Matching," Fourth World Congress on Information and Communication Technologies (WICT), 8-11 Dec. 2014.

[8] Amira Saleh, Ayman Bahaa and A. Wahdan, "fingerprint Recognition," Computer and systems engineering department Faculty of Engineering /Ain Shams University, Egypt, 2011.

[9] Anil K. Jain, Fellow, IEEE, Salil Prabhakar, Lin Hong, and Sharath Pankanti, "Filterbank-Based Fingerprint Matching," IEEE Transactions On Image Processing, vol. 9, No. 5, 2000.

[10] Davide Maltoni, Dario Maio, Anil K. Jain, and Salil Prabhakar, "Handbook of Fingerprint Recognition," Springer Publishing Company, Incorporated, 2009.

[11] Lifeng Sha, Feng Zhao, and Xiaoou Tang, "Improved Fingercode For Filterbank-Based Fingerprint Matching," Department of Information Engineering, The Chinese University of Hong Kong, 0-7803-7750-8/03/$17.000, IEEE, 2003.

[12] Dhamal Rajani Balaso, "A Novel approach for Fingerprint Matching using Gabor Filters," International Journal of Latest Trends in Engineering and Technology (IJLTET),vol. 3 Issue2, 2013.

[13] Jain, A., Hong, L., Pankanti, S. and Bolle R., "An identity authentication system using fingerprints," In Proceedings of the IEEE, vol. 85, pp. 1365–1388, 1997.

[14] F. A. Afsar, M. Arif and M. Hussain, "Fingerprint Identification and Verification System using Minutiae Matching," National Conference on Engineering Technologies, 2004.

[15] Manvjeet Kaur, Mukvinder Singh and Parvinder S. Sindhu, "Fingerprint Verification System using Minutiae Extraction Technique," Proceedings of World Academy of Science, Engineering and Technology, vol. 36, Dec. 2008.

[16] Vijay V. Chaudhary and S.R. Suralkar, "An Efficient Method For Fingerprint Recognition For Noisy Images," IJCSC International Journal of Computer Science and Communication, vol. 3, No. 1, pp. 113-117, 2012.

[17] Kondreddi Gopi, J.T Pramod, "Fingerprint Recognition Using Gabor Filter And Frequency Domain Filtering," IOSR Journal of Electronics and Communication Engineering (IOSRJECE), 2278-2834 vol. 2, Issue 6, PP 17-21, 2012.

[18] Lili Liu and Tianjie Cao, "The Research and Design of an Efficient Verification System Based on Biometrics," International Conference on Computer Science and Electrical Engineering, 2012.

[19] Ishpreet Singh Virk and Raman Maini, "Fingerprint Image Enhancement and Minutiae Matching in Fingerprint Verification", Journal of Computing Technologies, vol. 1, Jun. 2012.

[20] Tico, Marius, Pauli Kuosmanen, and Jukka Saarinen, "Wavelet domain features for fingerprint recognition," Electronics Letters 37, no. 1 : 21-22, 2001.

[21] O. Gorman, L., Nickerson, J.V., "An approach to fingerprint filter design, Pattern Recognition," 22 (1), 29–38, 1989.

[22] Jianwei Yang, Lifeng Liu, Tianzi Jiang, and Yong Fan, "A Modified Gabor Design method for fingerprint image enhancement," Pattern Recognition, Letters, Elsevier, 24, 1805 – 1817, 2003.

[23] Kenneth Nilsson and Josef Bigun, "Localization of corresponding points in fingerprints by complex filtering, Pattern Recognition," Letters 24, 2135-2144, 2003.

[24] S. Chikkerur,C. Wu and Govindaraju, "A Systematic approach for feature extraction in fingerprint images," ICBA, 2004.

[25] D. Maio, D. Maltoni, R. Cappelli, J. L. Wayman, A. K. Jain, "FVC2000: Fingerprint Verification Competition," IEEE Transactions on Pattern Analysis and Machine Intelligence, 24 3 402 412, 2002.

[26] Fingerprint Verification Competition, "FVC2000. Retrieved from http://bias.csr.unibo.it," 2000.

[27] Fingerprint Verification Competition, "FVC2002. Retrieved from http://bias.csr.unibo.it," 2002.

[28] Fingerprint Verification Competition, "FVC2004. Retrieved from http://bias.csr.unibo.it," 2004.

[29] J. C. Yang, D. S. Park, "*Fingerprint Verification Based on Invariant Moment Features and Nonlinear BPNN*," International Journal of Control, Automation, and Systems, 6 6 800 808, 2008.

[30] Kenneth Nilsson and Josef Bigun," *Localization of corresponding points in fingerprints by complex filtering*," Pattern Recognition Letters 24, 2135-2144, 2003.

[31] S. Chikkerur,C. Wu and Govindaraju, " A Systematic approach for feature extraction in fingerprint images," ICBA, 2004.

Daugman, J.G., "Two-dimensional spectral analysis of cortical receptive field profiles," Vision Research 20, 847–856, 1980.