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FINGERPRINT IMAGE ENHANCEMENT AND FEATURE EXTRACTION USING AFE, GABOR FILTER AND FIXED TEMPLATES

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Abstract: **Finger print verification system is the most trustable biometric system in the world. However, finger print matching, especially when the finger print images have low quality or when the matching is performed cross-sensors, is still an open research. The main problem in automatic finger print identification is to acquire reliable features from finger print image with poor quality. So there is a urgent need for finger print image enhancement and Feature extraction. This project proposes a method for finger print image enhancement and feature extraction for low quality finger prints. This project provides a adaptive fingerprint image enhancement method which automatically adjust with parameters based on the input finger print image. The pre-processing method includes global and local analysis for better enhancement. The contrast can be enhanced to provide better visual enhancement using SMQT method. The input low quality fingerprint image should be enhanced and finally it would be segmented in to a binarized mode using Gabor filter. The feature extraction is done using fixed templates. The main modules on the project are Pre-processing using Adaptive Finger Enhancement (AFE), Ridge Segmentation and Feature extraction. This paper can be helpful to increase the verification accuracy on AFIS(Automatic Fingerprint Identification System).**

Keywords: **Adaptive Finger Enhancement (AFE), Gabor filter, AFIS, SMQT**

1. INTRODUCTION

Fingerprints are imparts formed by friction ridges of skin in fingers and thumbs. Fingerprint enhancement and Minutiae extraction is one of the most important steps in automatic fingerprint identification and classification.

The four classes of minutiae classifications are ridge endings, bifurcations, trifurcation and undetermined. Most automatic systems are based on a two class minutiae classification, ridge ending and bifurcation. A ridge ending is defined as the point where a ridge ends abruptly. A bifurcation is defined as the point where a ridge forks or diverges into branch ridges. A good quality fingerprint typically contains about 100-200 minutiae.

A feature extraction procedure generally consists of three steps preprocessing, thinning, feature extraction. The proposed method is based on the preprocessing method named as adaptive fingerprint image enhancement and use of 3 x 3 fixed size templates for feature extraction. Thinning process is used to thin the ridges. Most of the minutiae extraction methods transform fingerprint images into binary images through an Adhoc algorithm.

The images obtained are submitted to a thinning process which allows for the ridge line thickness to be reduced to one pixel. Feature extraction approaches are based on either Threshold or ridge.

Digital image processing and analysis techniques are used today in a variety of problems. The image processing technique posses a broad spectrum of applications, such as remote sensing via satellites and other spacecrafts for weather prediction and crop assessment, image transmission and storage for business applications, medical processing, radar, sonar, and acoustic image processing, robotics, and automated inspection of industrial parts.

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2. OVERVIEW OF FINGERPRINT BIOMETRIC

Fingerprints are the ridge and furrow patterns on the tip of the finger and have been used extensively for personal identification of people. The biological properties of fingerprint formation are well understood and fingerprints have been used for identification purposes for centuries.

However, since fingerprint-based biometric systems offer positive identification with a very high degree of confidence, and compact solid state fingerprint sensors can be embedded in various systems (e.g., cellular phones), fingerprint-based authentication is becoming more and more popular in a number of civilian and commercial applications such as, welfare disbursement, cellular phone access, and laptop computer log-in.

The Fingerprint biometric is generally accepted by clients. Fingerprint identification is, perhaps, the oldest of the biometric sciences. In recent years, fingerprint comparisons have been based on minutiae, i.e., individual unique characteristics within the fingerprint pattern. Within a typical fingerprint image obtained by a live scan device, there is an average of 70-100 minutiae. The Federal Bureau of Investigation (FBI) has shown that no two individuals can have more than 8 common minutiae.

The U.S. Court system has consistently allowed testimony based on 12 matching minutiae in some courts, a lower number of matching minutiae have been allowed.

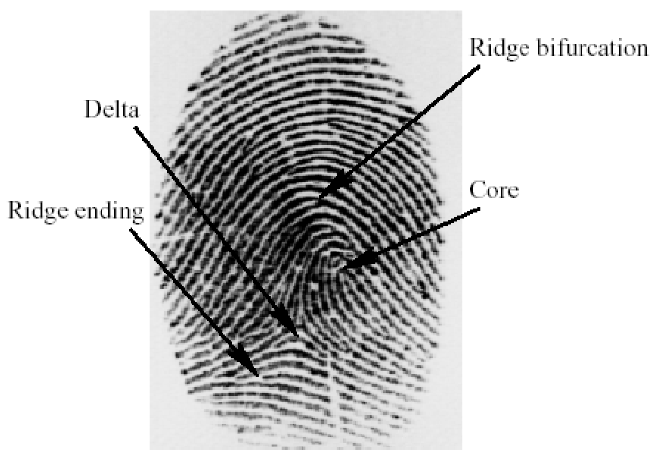

Figure 2. Fingerprint Imag

Fingerprint images contain a large amount of data. Because of the high level of data present in the image, it is possible to eliminate false matches and quickly reduce the number of possible matches to a small number, even with large database sizes. Because of the fact that Fingerprint Imaging Systems use more than one finger image in the match process, the match discrimination process is geometrically increased.

ATMs in Australia are now unlocked by the representative's fingerprint. The representative brings a portable scanning device that plugs into the back of the ATM and connects to the bank's server, which grants him admittance.

2.1 fingerprint classification

The central problem in designing a classification algorithm is to determine what features should be used and how categories are defined based on these features. We make use of two types of fingerprint characteristics for use in identification of individuals. (i) Global features and (ii) Local features. Global features are those characteristics that we can see with the naked eye.

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Global features include:

- Basic Ridge Patterns
- Pattern Area
- Core Area
- Delta
- Type Lines
- Ridge Count

3. METHODOLOGIES

The extraction of minutia points is a critical step in fingerprint verification systems. This is when the analog fingerprint information captured by the scanning device is transformed to a format that can be matched by an automated system. There are two main methodologies to extract minutia information, binary extraction and direct grayscale extraction.

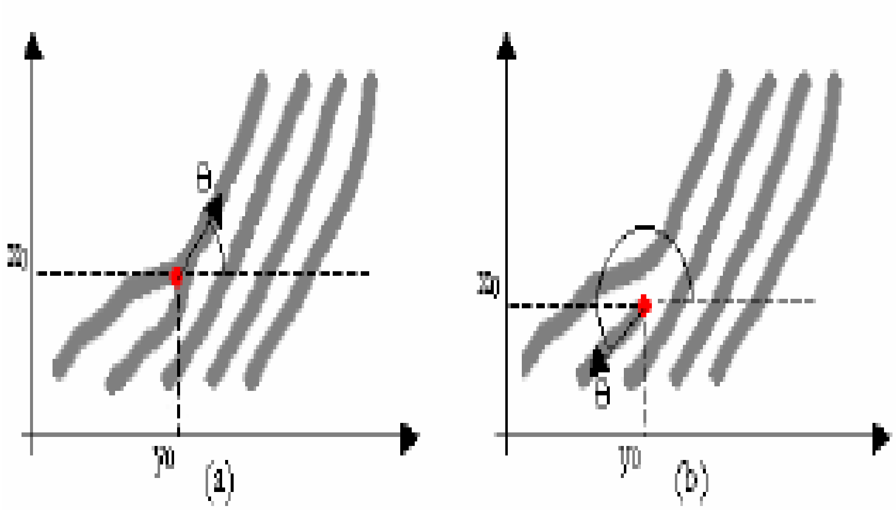

Figure 3 The Basic Properties of (A) Ridge Bifurcations and (B) Ridge Endings.

3. 1binary image minutia extraction

Binary extraction methods first transform the grayscale fingerprint image into a black and white binary image. The grayscale image is transformed to black and white by comparing each pixel value to a threshold value. If the pixel value is lower then the threshold the pixel value is assigned black otherwise it is assigned white. The threshold value is typically some sort of mean value. It can be the average value of all the pixels of the image or it can be the average value of the local neighborhood of the current pixel. Usually, binarization methods based on local mean estimates perform better then global-mean methods since scanning devices do not capture the fingerprint image with the same contrast over the whole scanning surface.

The fingerprint ridges of the binary image are then thinned to only one pixel width to ease the minutia extraction. A sample fingerprint with its corresponding thinned skeleton image is shown in Figure 3.1 The algorithms used to perform the thinning can be run in parallel to improve the system performance.

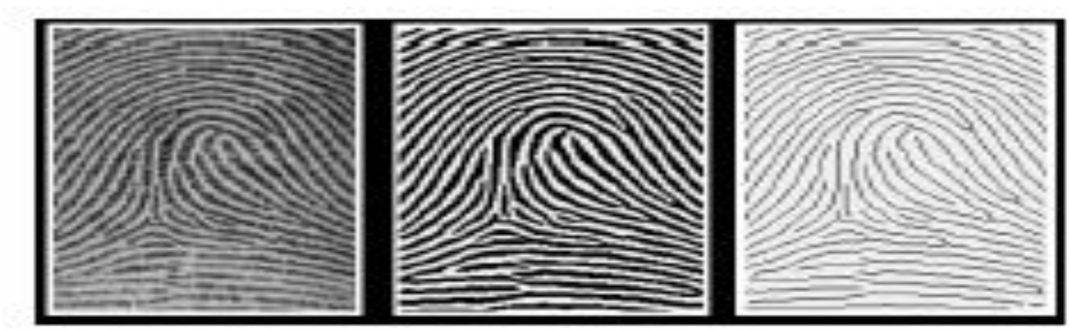

Figure 3.1 A Fingerprint with Its Corresponding Binary Image And Ridge Skeleton.

When the skeleton image is created, it is a simple task to fin the minutia points. Just examines the closest neighbours to all of the pixels and see how many of them are black. If only one neighbour is set, the pixel is a ridge-ending minutia. If two neighbours are set the pixel is not a minutia but only a part of a ridge. If three of the neighbors are set, the pixel is a ridge-bifurcation minutia.

3.2 direct grayscale minutiae extraction

Even though binary methods are quite straightforward they suffer from a few problems that might suggest that a direct grayscale method might be better suited for the minutiae extraction. First of all, the binarization and thinning are quite time consuming and that is a problem in handheld devices today where the computing capacity is still quite limited. Secondly, a lot of information might be lost in the binarization process since the color depth is reduced from 8bits to 1bit. A direct grayscale minutiae detection method was suggested in. The basic idea of the algorithm is to “surf” the ridgelines of the fingerprint in the direction described by the directional image until a ridge ending or bifurcation is encountered. First of all, a square-meshed grid of starting points is superimposed on the grayscale image.

From each of these points the algorithm follows the corresponding ridgeline until the ridge ends or meets another ridge. At each step, the algorithm tries to find a local maximum relative to a section orthogonal to the ridge direction. The new point is then used in the next step of the algorithm as shown in Figure 3.2. A labeling strategy is adopted to ensure that a ridge is only followed once and that all ridge bifurcations are found.

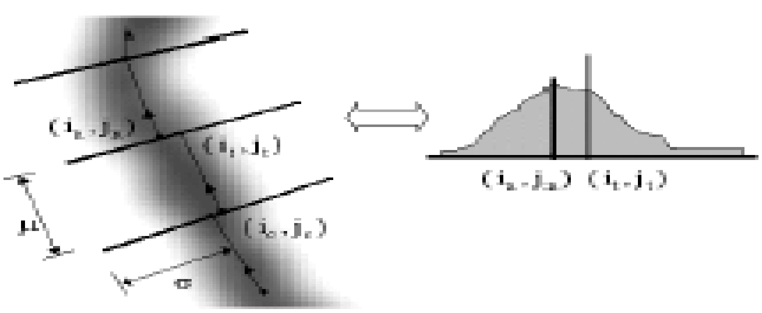

Figure 3.2 Gray Scale Method

The authors tested their proposed method on 150 fingerprint images. The test revealed that their method produced a slightly higher average error rate in terms of dropped and exchanged minutia, but the number of false minutia produced was considerably lower then the number produced by the compared binary approaches. Also, the computational time needed for the suggested direct grayscale extraction method is considerably lower than for the binary approaches. The step size μ and the size of the start point grid are statically decided in the suggested algorithm. However, if they instead were to be decided according to the local ridge frequency, even better results might be achieved.

4. FINGERPRINT ENHANCEMENT

The paper Adaptive fingerprint binarization by frequency domain analysis presents a new approach for fingerprint enhancement by using directional filters and binarization. A straightforward method for automatically tuning the size of local area is obtained by analyzing entire fingerprint image in the frequency domain. Hence, the algorithm will adjust adaptively to the local area of the fingerprint image, independent on the characteristics of the fingerprint sensor or the physical appearance of the fingerprints. Frequency analysis is carried out in the local areas to design directional filters. The merits of this paper is insensitive to varieties in sensors, skin etcetera. The drawbacks of this paper are

- Not fully automatic one
- Poor quality fingerprint cannot support this algorithm.

This paper successive mean quantization transform presents the Successive Mean Quantization Transform (SMQT). The transform reveals the organization or structure of the data and removes properties such as gain and bias.

The transform is described and applied in speech processing and image processing. The SMQT is considered as an extra processing step for the melfrequencycepstral co-efficients commonly used in speech recognition. In image processing the transform is applied in automatic image enhancement and dynamic range compression. The transform has been applied as an extension of the MFCC and the SMQT-MFCC are introduced. A comparison between the MFCC and the SMQT-MFCC has been conducted. The benefit of the SMQT-MFCC is that it extracts only the structure and ignores the level in the signal. This implies that the SMQT-MFCC are robust to bias and gain dissimilarities in speech signals. The transform has also been applied for automatic enhancement of images. A comparison with a histogram equalization has been performed, which showed the advantage of the SMQT. The merits of this paper is , it extracts only the structures and ignores the unwanted levels in the signal. The demerits of this paper are

- Supported for dark images only
- Removing noise is very low performance.

The paper fingerprint image enhancement using sift analysis is Contrary to popular belief, despite decades of research in fingerprints, reliable fingerprint recognition is an open problem. Extracting features out of poor quality prints is the most challenging problem faced in this area. This paper introduces a new approach for fingerprint enhancement based on Short Time Fourier Transform (STFT) Analysis. STFT is a well known technique to analyze non-stationary signals. It extend its application to 2D images. The algorithm simultaneously estimates all the intrinsic properties of the fingerprints such as the foreground region mask, local ridge orientation and local frequency orientation. Furthermore we propose a probabilistic approach of robustly estimating these parameters. The algorithm simultaneously estimates all the intrinsic properties of the fingerprints such as the foreground region mask. The algorithm simultaneously estimates all the local ridge orientation and local frequency orientation. The merits of this paper is the enhancement utilizes the full contextual information (orientation, frequency). The demerits of this paper are 1) enhancement is cannot properly connect for the ridges 2) False minutia can be detected 3) cannot support for all type of fingerprint images.

The paper Fingerprint Image Enhancement Based on Second Directional Derivative of the Digital Image presents a novel approach of fingerprint image enhancement that relies on detecting the fingerprint ridges as image regions where the second directional derivative of the digital image is positive. A facet model is used in order to approximate the derivatives at each image pixel based on the intensity values of pixels located in a certain neighborhood. We note that the size of this neighborhood has a critical role in achieving accurate enhancement results. Using neighborhoods of various sizes, the proposed algorithm determines several candidate binary representations of the input fingerprint pattern. Subsequently, an output binary ridge-map image is created by selecting image zones, from the available binary image candidates, according to a MAP selection rule. Two public domain collections of fingerprint images are used in order to objectively assess the performance of the proposed fingerprint image enhancement approach. The merit of this paper is that enhancement is a automatic tuned process. The demerits of this paper are that it taking too much time

The paper fingerprint enhancement by directional fourier transform Enhances the fingerprint images to support AFIS Working based on non-stationary directional fourier filtering. It smoothed using directional filter. It do Binarization based on threshold. The merits of this paper is it provides better performance for high quality fingers. The demerits of this paper are that it is not suitable for damaged fingers.

The paper matched filter design for fingerprint image enhancement designs a enhancement-filter. Four step filter design is described. They are User specification of appropriate features, local ridge orientation, orientation smoothing and pixel by pixel image enhancement. The merits of this paper is that it provides better local ridge orientation detection. The demerit is time consuming process because of pixel by pixel process.

The paper Pyramid-based Image Enhancement of Fingerprints presents a Reliable feature extraction for accurate biometric recognition. Unfortunately feature extraction is hampered by noisy input data, especially so in case of fingerprints. It proposes a method to enhance the quality of a given fingerprint with the purpose to improve the recognition performance.

A Laplacian like image-scale pyramid is used for this purpose to decompose the original fingerprint into 3 smaller images corresponding to different frequency bands. In a further step, contextual filtering is performed using these pyramid levels and 1D Gaussians, where the corresponding filtering directions are derived from the frequency-adapted structure tensor. All image processing is done in the spatial domain, avoiding block artifacts while conserving the biometric signal well. The merit of this paper is less complex because all work is done in spatial domain. The demerit of this paper is that damaged fingers produce wrong results.

The paper gray-scale image enhancement using the SMQT explores the Successive Mean Quantization transform (SMQT) for automatic enhancement of gray-scale images. The Set theory is used. This method performs both a nonlinear and a shape preserving stretch of the image histogram. The merits of this method are that it enhances fingers with out changing the shape of histogram.

SMQT (successive mean quantization transform)based finger enhancement is done at very beginning. Let x be a data point and $\mathcal{D}(x)$ be a set of $|\mathcal{D}(x)| = D$ data points. The value of a data point will be denoted $\mathbf{V}(x)$.

The form of the data points can be arbitrary, that is $\mathcal{D}(x)$ could be a vector, a matrix or some arbitrary form. The SMQT has only one parameter input, the level L (indirectly it will also have the number of data points D as an important input). The output set from the transform is denoted $\mathcal{M}(x)$ has the same form as the input, i.e. if $\mathcal{D}(x)$ is a matrix then $\mathcal{M}(x)$ is also a matrix of same size. The transform of level L from $\mathcal{D}(x)$ to $\mathcal{M}(x)$ will be denoted

$$\mathrm{SMQT}_L : \mathcal{D}(x) \rightarrow \mathcal{M}(x)$$.

The SMQT function can be described by a binary tree where the vertices are Mean Quantization Units (MQUs). A MQU consists of three steps, a mean calculation, a quantization and a split of the input set.

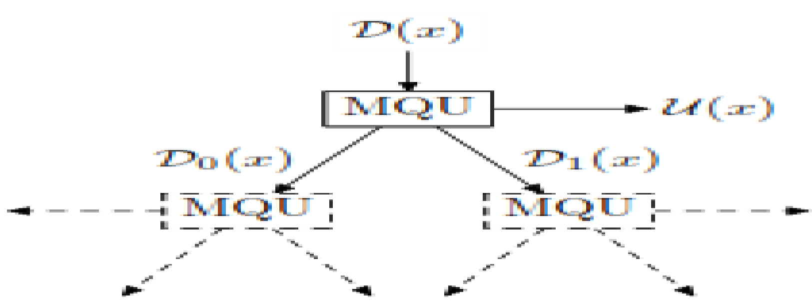

Fig 4.1 : Operation of one MQU unit

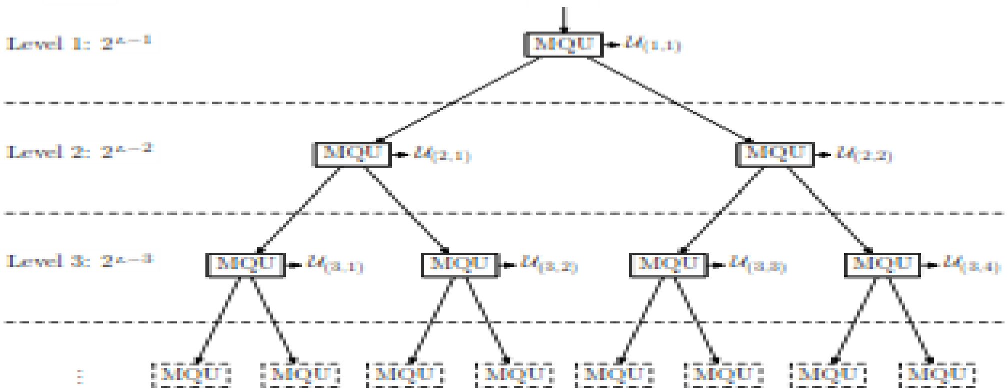

Fig.4.2.The Successive Mean Quantization Transform (SMQT) as a binary tree of Mean Quantization Units (MQUs).

Then the FFT transform is done on the enhanced image. This computes the one-dimensional DFT of each column X, then of each row of the result. The execution time for fft depends on the length of the transform. It is fastest for powers of two. It is almost as fast for lengths that have only small prime factors. It is typically several times slower for lengths that are prime or which have large prime factors. Then a median filter is done on the FFT result. After that a smoothing process is occurred. Then from the histogram of FFT the global parameter is found.

Then the local analysis is done. Here using SMQT2 process and the windows size which is calculated from the global parameter, the local window averaging process is done.

Then the matching filter is processed on the contrast enhanced finger. The pixels which are falling in the specified ranges are processed by median filter and the other area is processed by mean filter. Now we can get the Adaptive finger enhanced image.

The paper improved Adaptive Fingerprint Binarization Segments the fingers into ridge and valley. It Removes the redundant artifacts in the fingerprint mask is introduced to enhancing the final result. The proposed method is entirely adaptive process adjusting to each fingerprint without any further supervision of the user. The merit of this paper is the algorithm is insensitive to the characteristics of the fingerprint sensor and the various physical appearances of the fingerprints. The demerits are that there is No ridge connecting method is proposed. The Noise clearance process blurs the fingerprint.

5. ANALYSIS

The study of the present system was done by analyzing various image processing techniques in use and then designing a system, which overcomes all these existing systems

5.1 existing system

The existing fingerprint feature extraction system is developed without image enhancement process and segmentation schemes. Existing system minutiae detection method faces some difficulty, because this system uses some difficult template matching process. So its Minutiae Detection performance is less and its false minutiae detection is high.

Disadvantages

- It does not contain the Image enhancement process.
- It does not use the segmentation schemes
- Its Minutiae Detection performance is less
- Its false minutiae detection is high.

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5.2 proposed systems

This proposes a method to do enhancement and feature extraction in fingerprint image. The user provides a fingerprint as input and that fingerprint's minutiae informations are extracted accurately using this project. There are three main components in this project. They are Fingerprint enhancement, Ridge segmentation and Minutiae feature extraction.

For fingerprint enhancement Adaptive fingerprint enhancement is used. For Segmentation process Gabor based segmentation is used. For Feature extraction Templates based method is used.

The Adaptive fingerprint enhancement process includes Global analysis, Local analysis and matched filter. The global analysis gathered the global parameters and the local analysis gathers the local informations and the contrast informations are enhanced. The matched filter finally enhances the fingerprint image.

In the Segmentation process the ridges are accurately extracted. This is done using Gabor method. Once the ridge orientation and ridge frequency information has been determined, these parameters are used to construct the even-symmetric Gabor filter.

A two-dimensional Gabor filter consists of a sinusoidal plane wave of a particular orientation and frequency, modulated by a Gaussian envelope. Gabor filters are employed because they have frequency-selective and orientation-selective properties. These properties allow the filter to be tuned to give maximal response to ridges at a specific orientation and frequency in the fingerprint image. Therefore, a properly tuned Gabor filter can be used to effectively preserve the ridge structures while reducing noise.

The even-symmetric Gabor filter is the real part of the Gabor function, which is given by a cosine wave modulated by a Gaussian. An even-symmetric Gabor filter in the spatial domain is defined as:

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

$$x_\theta = -x\cos\theta + y\sin\theta\ ,$$

$$y_\theta = -x\sin\theta + y\cos\theta\ ,$$

where θ is the orientation of the Gabor filter, f is the frequency of the cosine wave, ∂_x and ∂_y are the standard deviations of the Gaussian envelope along the x and y axes, respectively, and x_θ and y_θ define the x and y axes of the filter coordinate frame, respectively.

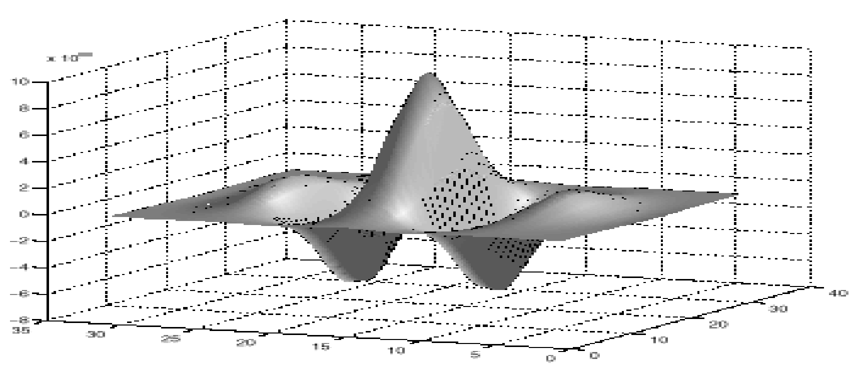


Figure 5.3 An Even-Symmetric Gabor Filter in the Spatial Domain.

The Gabor filter is applied to the fingerprint image by spatially convolving the image with the filter. The convolution of a pixel (i,j) in the image requires the corresponding orientation value *O*(i,j) and ridge frequency value *F*(i,j) of that pixel. Hence, the application of the Gabor filter *G* to obtain the enhanced image *E* is performed as follows:

$$E(i,j)=\sum_{u=-\frac{w_x}{2}}^{\frac{w_x}{2}}\sum_{v=-\frac{w_y}{2}}^{\frac{w_y}{2}} G(u,v;o(i,j),F(i,j))\,N(i-u,j-v),$$

Where *O* is the orientation image, *F* is the ridge frequency image, *N* is the normalized fingerprint image, and σ_x and σ_y are the width and height of the Gabor filter mask, respectively.

The filter bandwidth, which specifies the range of frequency the filter responds to, is determined by the standard deviation parameters σ_x and σ_y. Since the bandwidth of the filter is tuned to match the local ridge frequency, then it can be deduced that the parameter selection of $\sigma_x$and σ_y should be related with the ridge frequency.

However, in the original algorithm by Hong et al., $\sigma_x$andσ_y were empirically set to fixed values of 4*:*0 and 4*:*0, respectively.

A drawback of using fixed values is that it forces the bandwidth to be constant, which does not take into account the variation that may occur in the values of the ridge frequency.

For example, if a filter with a constant bandwidth is applied to a fingerprint image that exhibits significant variation in the frequency values, it could lead to non- uniform enhancement or other enhancement artifacts.

Thus, rather than using fixed values, the values of σ_x and σ_y are chosen to be a function of the ridge frequency parameter, which are defined as:

$$\sigma_x = k_x F(i,j),$$

$$\sigma_y = k_y F(i,j),$$

Where *F* is the ridge frequency image, $k_x$is a constant variable for σ_x, and $k_y$is a constant variable for σ_y. This allows a more adaptable approach to be used, as the values of σ_x and σ_y can now be specified adaptively according to the local ridge frequency of the fingerprint image.

Furthermore, in the original algorithm, the width and height of the filter mask were both set to fixed values of 11. The filter size controls the spatial extent of the filter, which ideally should be able to accommodate the majority of the useful Gabor waveform information. However, a fixed filter size is not optimal in that it does not allow the accommodation of Gabor waveforms of different sized bandwidths. Hence, to allow the filter size to vary according to the bandwidth of the Gabor waveform, the filter size is set to be a function of the standard deviation parameters:

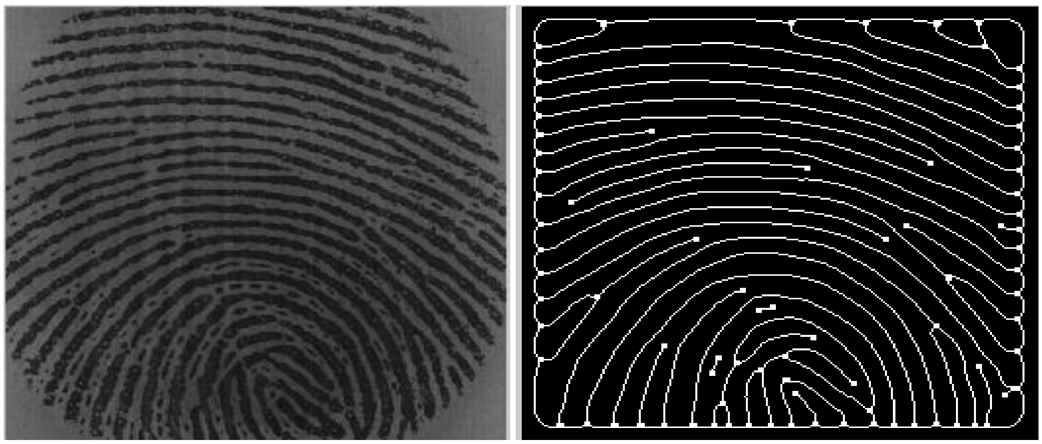
$$w_x = 6\sigma_x,$$

$$w_y = 6\sigma_y,$$

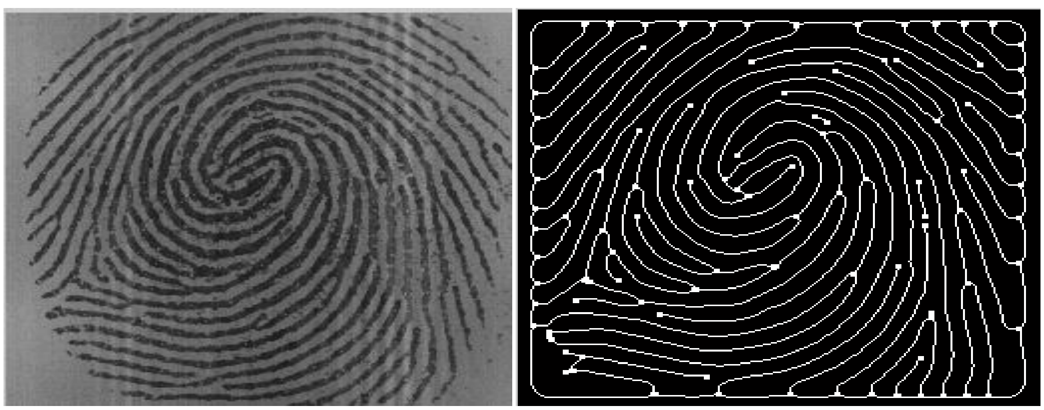
Where w_x and $w_y$are the width and height of the Gabor filter mask, respectively, and σ_x and $\sigma_y$are the standard deviations of the Gaussian envelope along the *x* and *y* axes, respectively. In the above equation, the width and height of the filter mask are both specified as 6σ, due to most of the Gabor wave information being contained within the region [-3σ, 3σ] away from the *y* axis. Hence, this selection of parameters allows the filter mask to capture the majority of the Gabor waveform information.

The Minutiae informations are find out using Templates based feature extraction method. The logical templates in the size of 3x3 are generated and depend upon that the minutiae type Bifurcation and Ridge end are detected and marked.

Comparison for Good, Fair and Poor Quality Fingerprints in the case of Minutiae Detection



Good Quality Original Finger Minutiae info



Fair Quality Original Finger Minutiae Info

Poor Quality Original Finger Minutiae Info
Figure 5.4 comparison

Bifurcation Count Analysis for the existing method (Crossing No Method) and the proposed method for Good , Fair and Poor Quality Fingerprints.

Table 5.1 Bifurcation Count Analysis

Quality Level	Existing Method Bifurcation Count	Proposed Method Bifurcation Count
Good	14	8
Fair	30	18
Poor	48	31

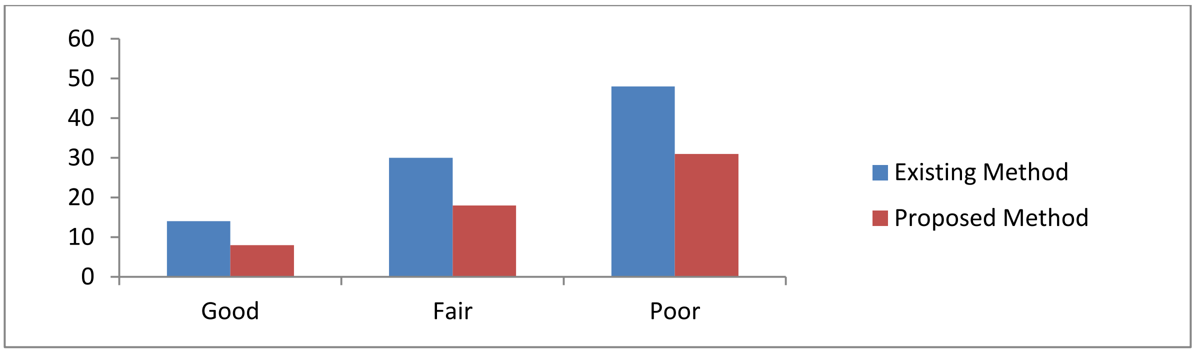


Chart 5.1 : Bifurcation Count Analysis

Ridge end Count Analysis for the existing method (Crossing No Method) and the proposed method for Good , Fair and Poor Quality Fingerprints.

Table 5.2 Ridge end Count Analysis

Quality Level	Existing Method Ridge end Count	Proposed Method Ridge end Count
Good	29	18
Fair	42	25
Poor	59	41

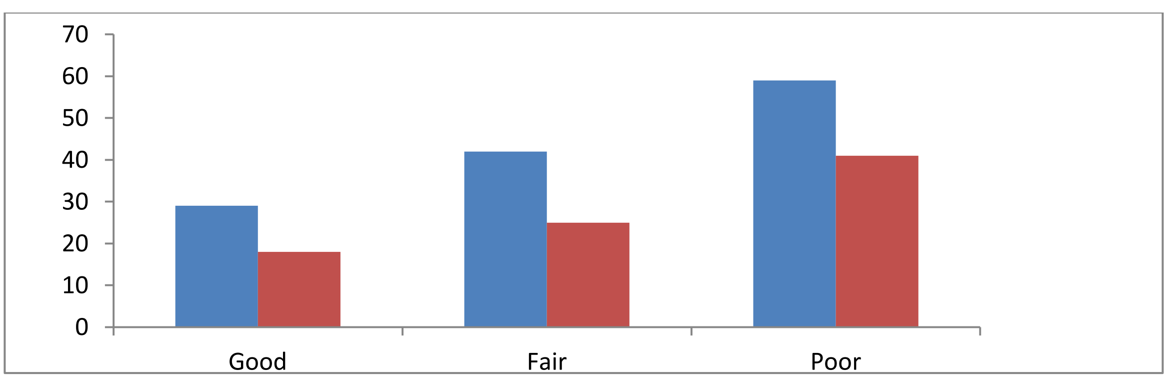


Chart 5.2 : Ridge End Count Analysis

False Minutiae Count Analysis for the existing method (Crossing No Method) and the proposed method for Good , Fair and Poor Quality Fingerprints.

Table.5. 3: False Minutiae Count Analysis

Quality Level	Existing Method False Minutiae Count	Proposed Method False Minutiae Count
Good	18	1
Fair	31	3
Poor	40	7

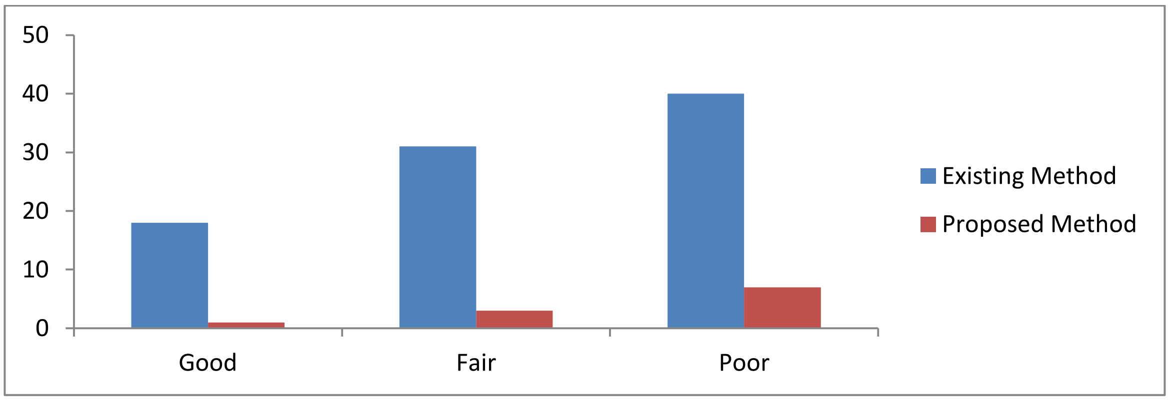


Chart 5.3: False Minutiae Count Analysis

6. CONCLUSION

This dissertation develops a advanced technique for Fingerprint minutiae extraction for fingerprint images. The fingerprint image enhanced using adaptive fingerprint enhancement. Ridge structures are segmented using gabor method. The segmented ridges are set to thinned version using morphological way. Then 3×3 fixed templates are applied for minutiae extraction and post processing is carried to detect and eliminate false minutiae. The size of the templates are selected as 3×3 in the view of the fact that it generates very good results.With limited time consuming and less memory occupation in detecting the position if the minutiae accurately with less false minutiae.

By this novel method it improves the efficiency of old method and got reduced time and space complexity using fixed non orientation based 3×3 template instead of applying the orientation based variable length and width template.

REFERENCES

[1] H. Fronthaler, K. Kollreider and J. Bigun, “Pyramid-based Image Enhancement of Fingerprints”,2006

[2] Mikael Nilsson, Mattias Dahl, and Ingvar Claesson,”gray-scale image enhancement using the smqt”,2005.

[3] FVC2000. (2010) [Online]. Available: http://bias.csr.unibo.it/fvc2000/

[4] FVC2002. (2010) [Online]. Available: http://bias.csr.unibo.it/fvc2002/