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A Hybrid Approach for Fingerprint Image Enhancement

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Abstract— Fingerprints are the oldest and most widely used form of biometric identification. Despite their widespread usage, there are few statistical theories on the uniqueness of fingerprint minutiae. A vital step in studying the statistics of fingerprint minutiae is to reliably extract minutiae from the fingerprint images. Automatic and reliable extraction of minutiae from fingerprint images is a crucial step in fingerprint matching. However, fingerprint images are rarely of perfect quality. They may be damaged and corrupted due to variations in skin and impression conditions. The quality of input fingerprint images plays an important role in the performance of automatic identification and verification algorithms .Thus, image enhancement techniques are employed prior to minutiae extraction to obtain a more reliable estimation of minutiae locations.

This paper presents a hybrid approach for fingerprint enhancement and new implementation of techniques for fingerprint image enhancement using MATLAB. Experimental results show that incorporating the enhancement algorithm improves the verification accuracy, variety of sensitivity levels without compromising security.

Keywords— Fingerprint recognition system, Fingerprint, Identification, Verification, Fingerprint Image Enhancement, FFT, ROI.

I. INTRODUCTION

The most popular and widely used bio-identification system is fingerprint recognition system because of the fact that fingerprints of human are unique and persistent. Fingerprints of even identical twins are different [3]. The fingerprint of an individual is unique and remains unchanged over a lifetime [1]. A fingerprint can be seen as smoothly varying pattern formed by alternating crest (ridges) and troughs (valleys) on the surface of the finger as shown in Fig. 1. The ridges are the dark lines and valleys are the light lines in the fingerprint image pattern [3]. A ridge is defined as a single curved segment, and a valley is the space between two adjacent ridges [1]. Fingerprint identification is commonly employed in forensic science to support criminal investigations, and in various biometric systems such as civilian and commercial identification devices. But, the issue of how many minutiae points should be used for matching a fingerprint is unresolved.

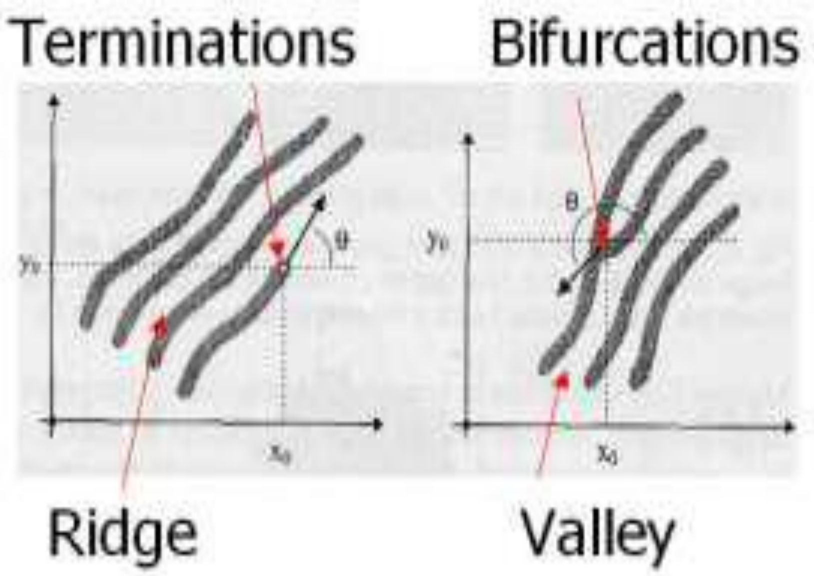

Figure 1. Example of ridge ending and a bifurcation [1]

The fingerprint acquisition can be classified into two major techniques (i) Automatic Fingerprint Recognition with the help of online sensors or other devices. Another technique on latent prints which are obtained by various medias such as ink, powder, paper etc, mostly they are used by crime sections [4].

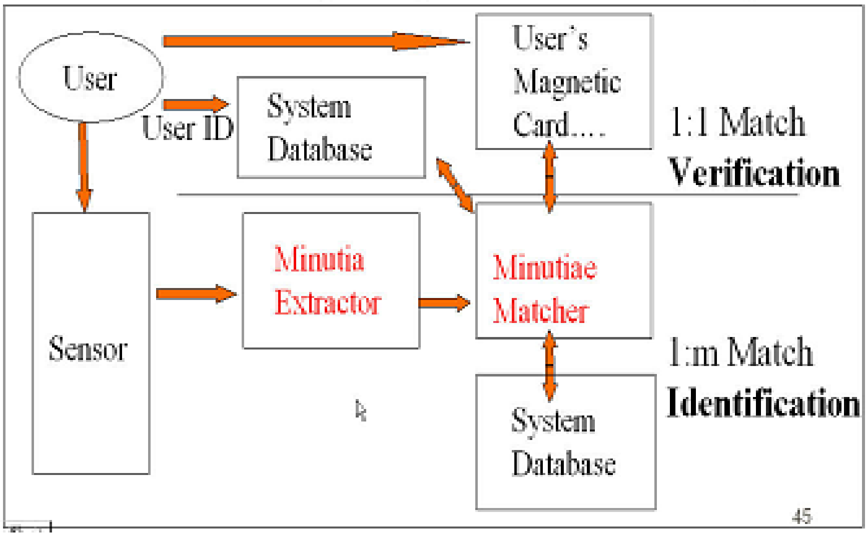

Figure 2: Automatic Finger Recognition System [4].

The fingerprint recognition problem can be grouped into two sub-domains: one is fingerprint verification and the other is fingerprint identification. Verification is to verify the authenticity of one person by his fingerprint. The user has to provide his fingerprint together with his identity information like his ID number [4]. The fingerprint verification system retrieves the fingerprint template according to the ID number and matches the template with the real-time acquired fingerprint from the user. Usually it is the design principle of AFAS (Automatic Fingerprint Authentication System). To implement a minutia extractor, a three-step approach is widely used by researchers. They are fingerprint preprocessing, minutia extraction and post processing level [4].

Fingerprint images are rarely of perfect quality as needed. They may be degraded and corrupted with elements of noise due to many factors including variations in skin and impression conditions. This corruption & degradation can result in a significant number of spurious minutiae being created and genuine minutiae being ignored. A critical step in studying the statistics of fingerprint minutiae is to reliably extract minutiae from fingerprint images. Thus, it is necessary to employ image enhancement techniques prior to minutiae extraction to obtain a more reliable estimate of minutiae locations [1].

II. FINGERPRINT IMAGE ENHANCEMENT

Fingerprint Image enhancement is to make the image clearer for easy further operations. Since the fingerprint images obtained from sensors or other medias are not assured with perfect quality, the various enhancement methods, for raising the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient level of ink, are very useful for keeping a higher accuracy to fingerprint recognition [1].

III. ANALYSIS IN FINGERPRINT IMAGE ENHANCEMENT

A. Verification & Accuracy :-

The author presents a fast fingerprint enhancement methodology and new implementation of techniques for fingerprint image enhancement [1]. The author has also proposed an algorithm of fingerprint image enhancement by using Iterative Fast Fourier Transform (IFFT). Iterative image reconstruction algorithms play an important role in fingerprint identification systems in order to achieve higher degree of efficiency. Author also has designed an approach for removing the false minutia generated during the fingerprint processing and a method to reduce the false minutia to increase the efficacy of identification system. [7].

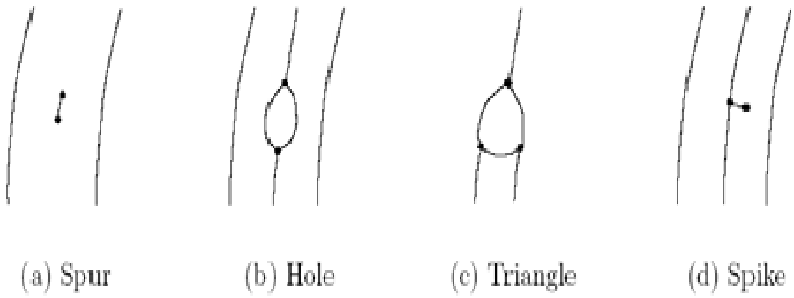

Figure 3. Examples of typical false minutiae structures.

B. Filteration In Fingerprint Image Enhancement::-

Now, a day's various filters were used for fingerprint enhancement, but no one of them has improved 100% quality of fingerprints. By considering these issues author analyzed various filters and proposed a new methodology for finger print pre-processing. For efficient finger print image quality author proposed the use of high boost filter and Gaussian filter.

For the purpose of enhancing curved structures in noisy images, author introduces curved Gabor filters which locally adapt their shape to the direction of flow. Curved Gabor filters enable the choice of filter parameters which increase the smoothing power without creating artifacts in the enhanced image. Curved Gabor filters are applied to the curved ridge and valley structure of low-quality fingerprint images [2]. The author proposed an enhancement method based on gabor filtering in wavelet transformation. Gabor filter is chosen because of the fact that it has both frequency-selective and orientation-selective properties and has optimal resolution in both spatial and frequency domain. [3]. The author used the high boost filter and Gaussian filter for efficient finger print image quality [6].

C. Feature Extraction:-

The author discuss about the enhancement of the finger print image for fingerprint recognition. The target can be mainly decomposed into image preprocessing, extraction of features and feature matching. For each of the sub-task, some classical and up-to-date methods in literatures are analyzed. Based on the result of analysis, an integrated solution for fingerprint recognition is developed for demonstration. Project was developed using MATLAB. [4]. Currently,the methods that are in use are the ones involving the use of Gabor filtering and Fourier filtering. But actually the accuracy of these techniques is far from satisfactory [8].

IV. PROPOSED WORK

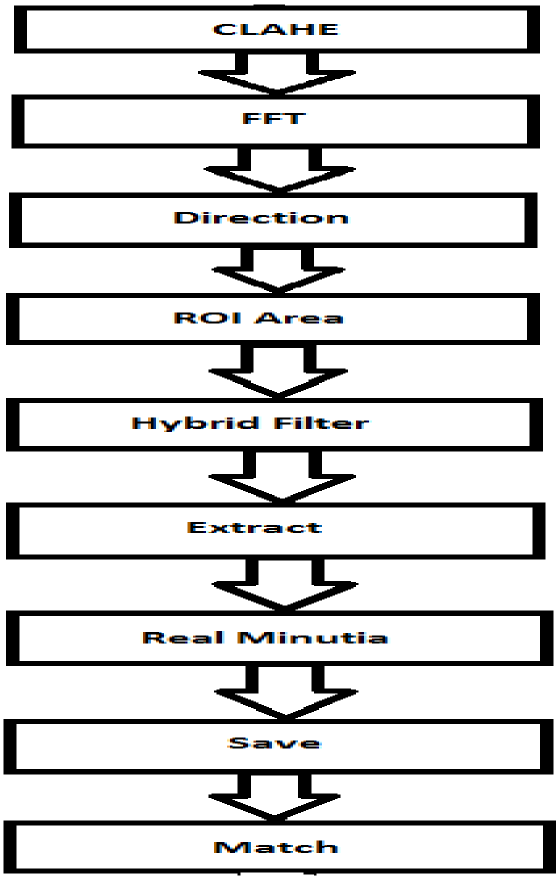

Figure 4. Steps in Fingerprint Enhancement.

A. Clahe

CLAHE (contrast limited adaptive histogram equalization) is applied to enhance the contrast of small tiles and to combine the neighboring tiles in an image by using bilinear interpolation, which removes the artificially induced boundaries. In addition, the 'Clip Limit' factor is applied to avoid over-saturation of the image specifically in homogeneous areas that present high peaks in the histogram of certain image tiles due to many pixels falling inside the same gray level range []. Histogram equalization is applied to enhance the image's contrast by transforming the intensity values of the image (the values in the color map of an indexed image), are shown by the following equation:

$$S_k = T[r_k] = \sum_{j=1}^{k} p_r\,[r_j] = \sum_{j=1}^{k} \frac{n_j}{n}$$

Where sk is the intensity value in the processed image corresponding to rk in the input image, and pr ( ) =1, 2, 3... L is the input fingerprint image intensity level. In other words, the values in a normalized histogram approximate the probability of occurrence of each intensity level in the image.

We split the image into small processing blocks (32 by 32 pixels) and perform the Fourier transform according to:

$$F(u,v) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) * exp\left\{-j2\pi * \left(\frac{u_x}{M} + \frac{v_y}{N}\right)\right\}$$

for u = 0, 1, 2, ..., 31 and v = 0, 1, 2, ..., 31. In order to enhance a specific block by its dominant frequencies, multiply the FFT of that block by its magnitude a set of times. Here the magnitude of the original FFT = abs(F(u,v)) = |F(u,v)|. Get the enhanced block according to

$$g(x,y) = F^{-1}\{F(u,v) * |F(u,v)|^k\}$$

where F^{-1}(F(u,v)) is done by:

$$f(x,y) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} F(u,v) * exp\left\{j2\pi * \left(\frac{u_x}{M} + \frac{v_y}{N}\right)\right\}$$

for x = 0, 1, 2, ..., 31 and y = 0, 1, 2, ..., 31.The k in formula (2) is an experimentally determined constant which we choose k=0.45 to calculate. While having a higher "k" improves the appearance of ridges by filling up small holes in ridges, having too high a "k" can result in false joining of ridges.

B. Direction Estimation

Estimate the block direction for each block of the fingerprint image with WxW in size (W is 16 pixels by default). For this purpose following algorithm can be used :

I. Calculate the gradient values along x-direction (gx) and y-direction (gy) for each pixel of the block. Two Sobel filters are used for this task.

II. For each block, use Following formula to get the Least Square approximation of the block direction. tg2ß = 2 ∑ ∑ $(g_x * g_y)/\sum\sum(g_x^2 - g_y^2)$ for all the pixels in each block. The formula is easily understood by regarding gradient values along x-direction and y-direction as cosine value and sine value. Therefore the tangent value of the block direction is estimated nearly the same as the way illustrated by the following formula $tg2\theta = 2\sin\theta\cos\theta / (\cos^2\theta - \sin^2\theta)$.

C. ROI (Region Of Interest) Area

In general, only a Region of Interest (ROI) is useful to be recognized for each fingerprint image. The image area not having effective ridges and furrows is first discarded since it only holds background information. Finally the bound of the left effective area is sketched out since the minutia in the bound region are confusing with those spurious minutia that are generated when the ridges are out of the sensor.In any fingerprint image, there is a local frequency of the ridges that collectively form the ridge frequency image. The ridge frequency is calculated from the extraction of the ridge map from the image [7].

D. Hybrid Filtering

Hybrid filtering here is a combination of gabor filter, low pass filter, high pass filter (collectively called band pass filter) and angular filter.

1)Low Pass Filter : It is a type of filter used for the image enhancement. It secures the smooth region in the image & removes the sharp variation leading to the blurring effect.

2) High Pass Filter : High Pass Filter mainly filters the high frequency components in an image. It is also applied to sharpen the image.

3) Gabor filter : - The Gabor filter is a two-dimensional filter formed by the combination of a cosine with a two-dimensional Gaussian function and it has the general form:

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

$$x_\theta = x.\cos\theta + y.\sin\theta$$

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

In (1), the Gabor filter is centered at the origin. θ denotes the rotation of the filter related to the x-axis and f the local frequency. σ_x and σ_y signify the standard deviation of the Gaussian function along the x- axis and y-axis, respectively.

E. Minutia Extraction

An accurate representation of the fingerprint image is critical to automatic fingerprint identification systems, as most of on feature-based matching. Amongst all the fingerprint features, minutia point features alongwith corresponding orientation maps are unique enough to discriminate amongst fingerprints robustly; the minutiae feature representation reduces the complex fingerprint recognition problem to a point pattern matching problem. In order to achieve high-accuracy minutiae with varied quality fingerprint images, segmentation algorithm is required to separate foreground from noisy background which includes all ridge-valley regions and not only the background. Fingerprint Image enhancement algorithm needs to keep the original ridge flow pattern without altering the singularity, join together broken ridges, clean the artifacts between pseudo-parallel ridges and the false information should not be introduced. Finally minutiae detection algorithm should be able to locate efficiently and accurately the minutiae points. Filtering is performed finally to remove noise and preserve the ridge structures.

F. Minutuae Matching

At the matching stage, approach is to elastically match minutia. Given two set of minutia of two fingerprint images, the minutia match algorithm concludes whether the two minutia sets are from the same finger or not.

V. Results & discussions

First of all database named "Employees" is created which contains the fingerprints of all the employees. Secondly the actual user interface is shown in figure 6. Afterwards the series of operations are carried on the noisy fingerprint images and we get the desired results.

Figure 5. Database containing fingerprints of Employees

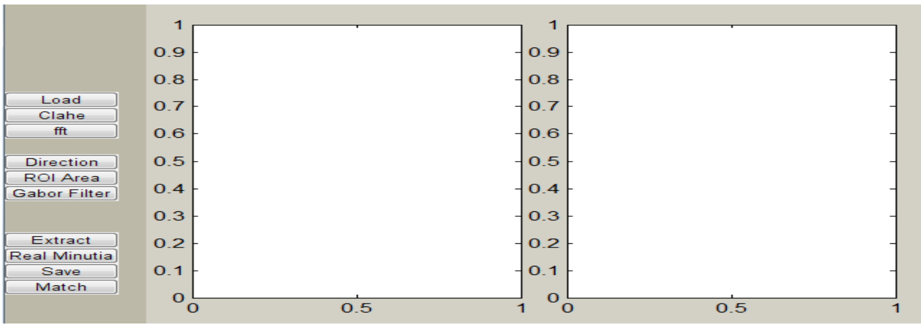

Figure 6. The Actual User Interface


Figure 7(a) Before clahe


Figure 7(b) After clahe

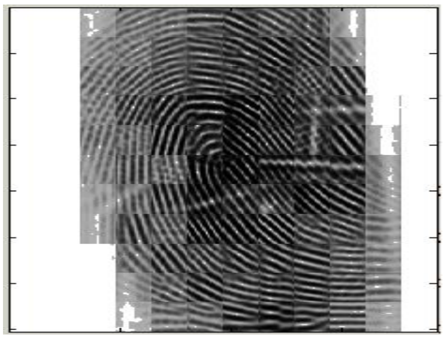
Figure 8 After FFT Operation

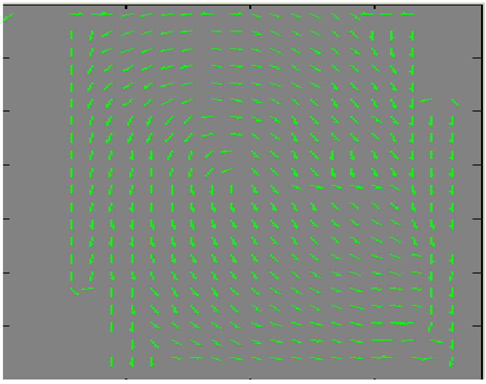

Figure 9. Directions of ridges

Figure 10. After ROI(Area of Interest).

The subsequent operations will only operate on the region of interest.

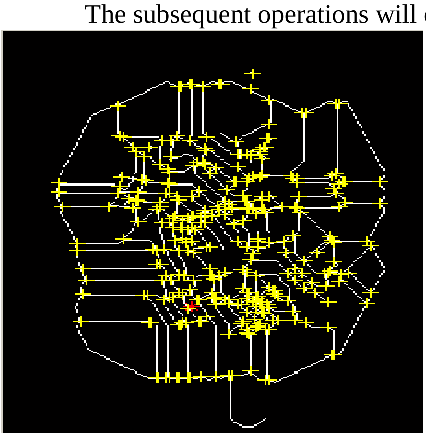

Figure 11(a)

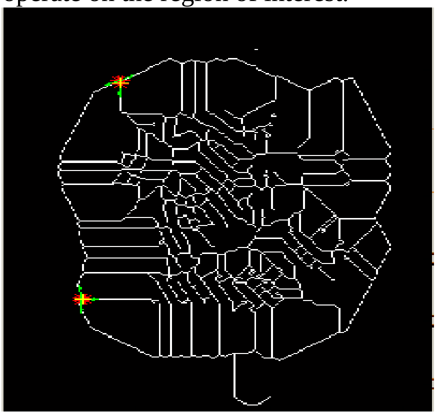

Figure 11(b)

Fig 11(a) After minutia extraction bifurcations are located with yellow crosses & termination are denoted with red stars.
Fig 11(b) And the genuine (right) are labeled with orientations with green arrows.

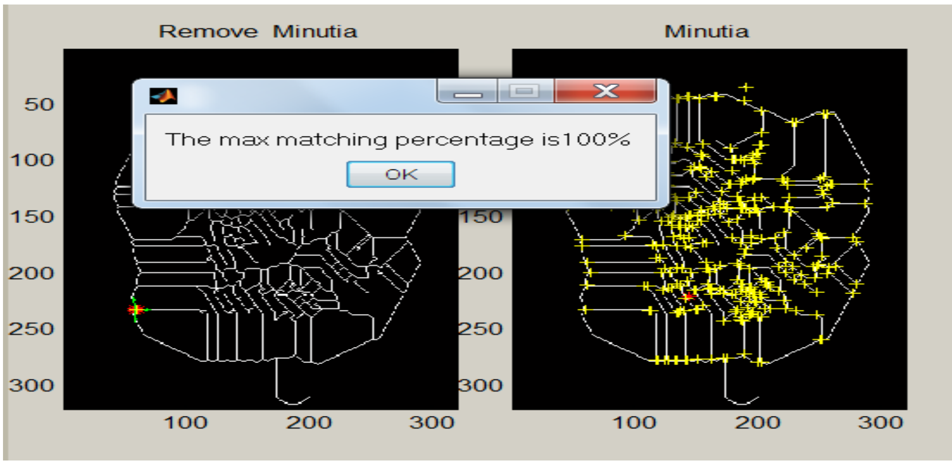

Figure 12. Load two minutia files and do matching.

Table I. Comparison of existing & hybrid approach

Image no.	**Match %age of existing technique**	**Match %age of hybrid technique**
102_7.tif	20.1088	100
105_2.tif	21.7077	100
106_4.tif	21.7417	100
109_3.tif	20.4889	100

In the above table shown we are basically using the already existing approach in which we are matching the two noisy images of a single finger after applying the existing enhancement used in that approach. Finally we are getting the desired percentage of matching the minutia. On the other hand we use that same finger image which is noisy apply all the phases that exist in our hybrid approach & get the percentage of matching the minutia finally.

VI. CONCLUSIONS

We have developed a hybrid fingerprint enhancement algorithm which can adaptively improve the clarity of ridge and valley structures based on the local ridge orientation and ridge frequency estimated from the inputted image. The algorithm also identifies the unrecoverable corrupted regions in the fingerprint and removes them from further processing. In a word, an hybrid filter is applied in fingerprint image processing, then a good quality of fingerprint image is achieved and the performance of the fingerprint recognition system has been improved.

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