Fourier Cleaning of Fingerprint Images

Zakirullah and Zawar Hussain

Abstract—**Usage of finger orient imaging for personal identification is one of the oldest and widely used techniques. One of the important steps in fingerprint matching procedure is to reliably extract the discriminating features called minutiae. However, some of the acquired images are of poor quality. Therefore, one must resort to the pre-processing the images. There are various preprocessing techniques has been identified like the Gabor filtering. However, one limiting factor in these enhancement techniques is their dependence on the extraction of orientation estimates. These estimates remain no longer reliable under some noisy conditions. In this paper we avoided the explicit estimate of the orientation information and relied on the Fourier sinusoidal pattern. We have used Fourier cleaning in the form of notch filter, highpass filter and binarization along with Gabor filter to enhance the fingerprint images. The conducted experiments do suggest a modest rise of around 20-25% in true minutiae matching rate in these poorly visible fingerprint regions.**

Index Terms—**AFIS, binarization, gabor filter, highpass filter, notch filer.**

I. INTRODUCTION

Personal identification is an important task in areas such as information security, law enforcement and physical access of the buildings etc. Traditionally personal identification can be in the form of password, personal identification number, secret questions, identification cards etc. Along with these, some physical and behavioral characteristics of humans can also be used for identification. Biometrics is the name given to the science of automated identification of personals based on their physical and behavioral characteristics [1]. Human characteristics that can be used in a given biometric systems include face, fingerprint, iris, retina, hand geometry, finger geometry, voice etc. Among all these, fingerprint is one of the most widely used and researched method [2]. The reason for this common usage of fingerprint in biometric identification is that fingerprint is found to be unique and remains invariant with the passage of considerable time [3].

The structure of fingerprint consists of a sinusoidal pattern of ridges and furrows on the surface of a fingertip [4]. The black lines are designated as ridges and the white lines are called furrows or valleys. These ridges flow in parallel but intersect and terminate at some points. These local discontinuities points in the fingerprint image are known as minutiae [4] and constitute what can be referred to as discrimination feature set. The most commonly used minutiae in current AFIS are ridge bifurcations and ridge endings [5]. The ridge bifurcation is the point where the ridge joins or diverge into two other ridges and the ridge ending is the point where a ridge terminate abruptly and pre-maturely [4]. A good quality fingerprint image should typically contain 40-100 minutiae [4]. A Fingerprint image with minutiae is shown in Fig 1.

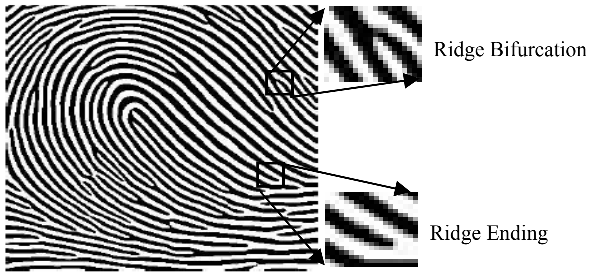

Fig. 1. Fingerprint with Ridge Bifurcation and Ridge Ending is shown.

Quality of the fingerprint is considered to be a limiting factor in the performance of minutiae extraction's algorithm [4]. If the fingerprint is of poor quality then ridges are not well defined and hence cannot be detected with ease. On the other hand, a poor quality fingerprint might result in the creation of spurious minutiae at the cost of ignoring genuine minutiae [4]. Now in order to improve the quality of the fingerprint we need an enhancement procedure. Fingerprint enhancement can be applied either on binary image or grayscale image [7].

Gray-level enhancement [8] has been used previously where we assume that the local ridge frequency and orientation can be reliably estimated. However for poor quality fingerprint images this assumption is no longer valid. Although in [2] [6], enhancement obtained reliable orientation but failed when the fingerprint images are noisy. Among steerable filters, directional enhancement can be easily computed [9], [10]. The problems with steerability approaches are uncertainty in computing orientation as these are point wise operators and a large number of basis filters are required in order to achieve a high orientational resolution.

In this paper, to avoid the explicit orientation and frequency estimation, we have used Fourier cleaning in the form of notch filter, highpass filter and binarization along with Gabor filter for the enhancement of fingerprint images.

II. FINGERPRINT ENHANCEMENT

A. Gabor Algorithm

The main steps of Gabor algorithm include normalization, local orientation estimation, local frequency estimation, and filtering [4]. A bank of Gabor filters tuned

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to local ridge orientation and ridge frequency, is applied to the ridge and valley patterns in the normalized input fingerprint image to obtain an overall enhanced fingerprint image. The filters can be categorized as bandpass filters to remove the high frequency noise and preserve true ridge pattern.

B. Fourier Transform

As stated, that the acquired fingerprint images contain noises. If we are working in spatial domain the noise pattern characterized by the frequency contents is not that obvious and localized. Due to this lack of localization, we are turned to the Fourier domain analysis. And once we obtain the Fourier transform of the fingerprint image and find the pattern of the noise, we can apply related filters for cleaning this noise. However, in Fourier domain not all of the spatial features are well-preserved and distributed so we have to rely on a sequence of carefully calculated appropriate filtering steps. Since designing and implementing a filter, in a hit and trial manner, in frequency domain is easier than in spatial domain, making Fourier domain is our natural choice.

C. Notch Filter

A notch filter rejects or passes frequencies in predefined neighborhoods about a center frequency with a limited bandwidth. Due to the symmetry of the Fourier Transform, notch filter must appear in symmetric pair about the origin.

D. Highpass Filter

Highpass filters are those which pass the high frequencies and suppressed the low frequencies. High frequencies are associated with edges in a given image. So if we pass the high frequencies and suppressed the low frequencies in a ratio manner then the edges of the image will become clearer.

E. Binarization

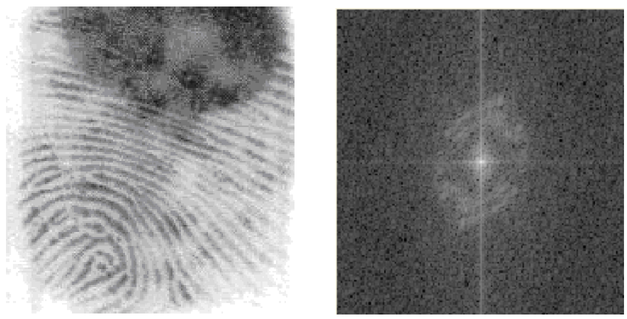
Binarization is a process in which we convert a grayscale image into a two-level image. For fingerprint images binarization comes naturally because in fingerprint image we have two regions i.e. ridge and valley. So if we make the ridge black and valley white, image pattern will be more visible. In order to do this binarization, thresholding is required. Thresholding is statistical decision theory problem whose objective is to minimize the average error incurred in assigning pixels to one of the two groups. This is based on two parameters: one is the probability density function (PDF) of the intensity level of each class and the next is the probability that each class occur in a given application. However estimating PDF is usually a computationally difficult task when the image is noisy. So an alternative method called, Otsu's method is used [11].

III. Implementation

We have applied the following steps for enhancing the images.

A. Step 01: Fourier Transform

In this step, fingerprint image is converted into frequency domain by finding its Fourier Transform. Fourier transform displays the noise pattern in the fingerprint image. In Fig 2, original input image and its corresponding Fourier spectrum is given.

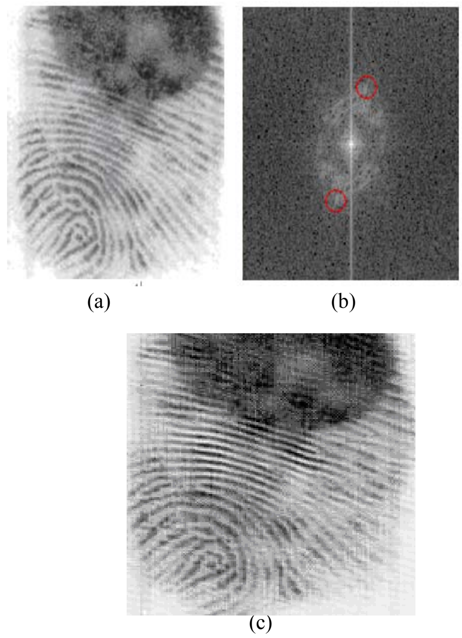


(a) (b)

Fig. 2. (a) Original image and its corresponding (b) Fourier spectrum. This Fourier spectrum is the magnitude only

B. Step 02: Notch Filtering

If we look at the Fourier spectrum, the white ring at the center is somewhat disturbed. The white ring is more spread at the top and bottom. Now we apply notch filter on the input fingerprint image. For this purpose Fourier Spectrum is utilized. Notch filter is useful when noise at a particular location in a given Fourier Spectrum exist. The notch filter rejects a band of frequency at the location where the notch is applied, and passes rest of the frequencies. The input fingerprint image, Fourier spectrum with notches and the output fingerprint image are shown in Fig 3. The output fingerprint image is much cleaner than the input fingerprint image especially at the center, and hidden ridges in the black portion of the fingerprint image are now visible to some extent.



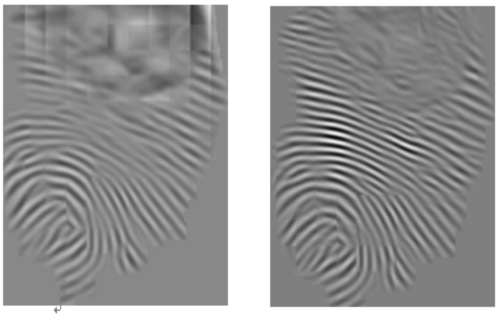
(a) (b)

(c)

Fig. 3. (a) Original image. (b) Fourier spectrum of the original image. on fourier spectrum the circles show the location where notch filter is applied. (c) Output image. this image is the result of the notch filtering.

C. Step 03: Gabor Filtering

In this step output fingerprint image of the notch filtering is fed as an input to the Gabor filters for further enhancement. In Fig 4, we have provided the results and the details of the Gabor filtering are omitted for the brevity purposes. The result of the Gabor filters is more enhanced when the fingerprint image was first processed with notch filtering than the result when the original image was given as an input without processing with notch filtering.



(a) (b)

Fig. 4. (a) Result of the gabor filters when the original fingerprint image is given as an input. (b). Result of the gabor filters when output of the notch filtering is given as an input. We see some activity in the blocked region.

D. Step 04: Highpass Filtering

As Gabor filters does have an inherent smoothing so most of the noise is suppressed. The result of Gabor filter is now passed through the high pass filter, in order to enhance the ridges further. For this purpose Butterworth highpass filter is used. The result is given in Fig 5 (a).

E. Step 05: Gabor Filtering

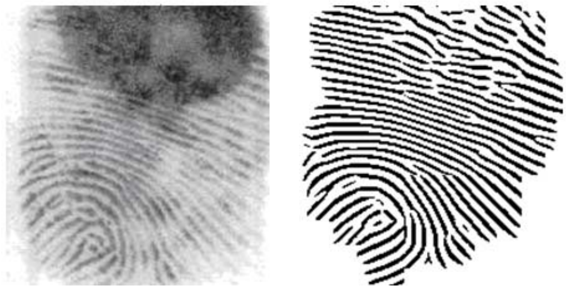
In this step Gabor filters is applied once again. The result of the High pass filtering, given in Fig 5 (a), is used as an input to Gabor filters. This step further enhances the fingerprint image by enhancing the ridges and removing the noise. The latest result is given in Fig 5 (b).

(a) (b)

Fig. 5. (a) Result of the Highpass filter. The ridges are more enhanced as compared to images of Fig 4(b). (b) Result of the Gabor filters. The ridges are more smoothly enhanced. The hidden activity in the upper portion is now more clearly visible.

F. Step 06: Binarization

This is the final step in which the gray-scale fingerprint image is converted into binary image. The Otsu's Algorithm is used in order to find the optimum threshold value. Based on this threshold value binarization is performed. The enhanced binary fingerprint image along with the original fingerprint image is given in Fig 6.

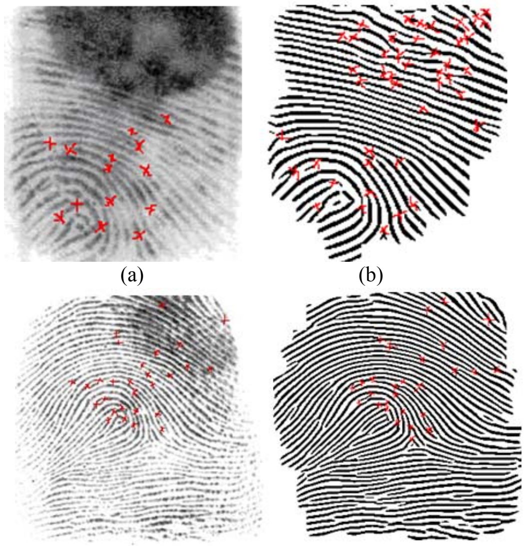


(a) (b)

Fig. 6. (a). Original fingerprint image. (b). Enhanced binarized fingerprint image. Ridges are more visible in (b) than (a).

IV. Minutiae Extraction

The fingerprint images given in Fig 7 (a) and (c) are the original latent fingerprints images. In order to find the minutiae matching rate these fingerprint images were given to two fingerprint experts and were asked to extract true minutiae. The extracted minutiae are marked with crosses. In fingerprint image (c) minutiae only in that area are found which correspond to (a). Fingerprint images (b) and (d) are the enhanced images of (a) and (c). Experts also extracted minutiae from both of these enhanced fingerprint images. The total minutiae, matched minutiae, false minutiae and percentage matched minutiae are given in Table I.



(a) (b) (c) (d)

Fig. 7. (a) is the original image, (b) is the enhanced image of (a). (c) is the complete original image and (d) is the enhanced image of (c). These are latent fingerprints.

TABLE I: Total Minutiae, False Minutiae, Matched Minutiae and Percentage

Image	Total Minutiae	False Minutiae	Matched Minutiae	Percentage
a	15	2	13	13/24=54%
b	24	0	13	
c	37	13	19	19/24=79%
d	24	0	19	

V. CONCLUSIONS

Gabor Filtering algorithm for fingerprint image enhancement is a good first step but if the images are noisier, then this algorithm does not perform well. So in order to improve the enhancement performance of Gabor algorithm, we need to do some other processing of the images in order to remove some of the dominant noise present. To remove this dominant noise from the images, Fourier domain is the best choice. As clear from the images of the Fig 4 (b) which is preprocessed with notch filter and then passed from Gabor filters and 4 (a) is not preprocessed but directly passed through Gabor filter. The result of preprocessed with notch filter is improved than the second one. Similarly the enhanced image given in the Fig 6 (b) is clearly cleaned. The percentage matching of minutiae for the enhanced fingerprint images are 79% while for the original images it is 54%, so 25% improvement in minutiae extraction occur. Hence we can conclude safely that Gabor filter in conjunction with the frequency domain filters is one of the best choices for fingerprint image enhancement.

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