# Fingerprint Image Enhancement using Composite Method

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## *Abstract*

*In automatic fingerprint recognition system the quality of fingerprint image is an important because the performance of the automation recognition system is highly depends on the input Fingerprint Image. A fingerprint image may not always be well defined due to elements of noise that corrupts the clarity of ridge structure. Most of the fingerprint recognition system based on the ridge and valley structure or minutiae based. Thus Fingerprint Image enhancement techniques are often used to reduce the noise and enhance the structure of ridges and valleys for minutiae detection. In this paper we propose a composite method based work on the contrast enhancement, frequency and spatial domain filtering, and quick mask on gray scale images and this composite method shows satisfactory results. These set of operation are applied on FVC2002 database.*

**Keywords:** Fingerprint, enhancement, filtering, ridges and valleys, quick mask, highpass filter, lowpass filter etc.

## 1. Introduction:

The most important and interesting ability of human is to recognize the object. Object recognition is a process involving perception and associating the resulting information. Visual perception means deriving information from a specific scene. From the psychological point of view the actual perception process involves some information processing stages. The formation of the image on human eye retina is the mental process of the projected image; several models have described this process. The aim of scientists is to design machines that emulate human abilities. Biometric system is an important area of research in recent years. The biometric system having two important utility 1) authentication or verification of persons identity and 2) Identification in which persons identity is verify by biometric sign. The biometric system consists different signs fingerprint, face, iris, hand, pam etc. Out of these signs fingerprint is the oldest and more reliable sign used for identity.

The most common method use to acquire the fingerprint image is to obtain the impression by rolling an inked finger on paper and then scanning it using flat bed scanner. This method may result in highly distorted fingerprint images and thus it should be carried out by a trend professional. The new advanced way of obtaining fingerprint images is to scan the image using a CCD (Charge Couple Device) camera. This live scan method proves better images and therefore it does not need expertise but highly distorted images are still possible because of dryness of skin, skin disease, sweat, dirt or humidity. The overall quality of the fingerprint is depends greatly on the condition on the skin. Dry skin tends to cause inconsistent contact of the finger ridges with scanners planet surface, causing broken ridges and significant numbers of light pixels replacing ridge structure. For very oily or wet skin the valleys tend to fill up with moisture causing them to appear dark in the image similar to ridge structure. Both of these conditions contribute noise and degradation to the image and cause increase number feature detection errors and reduce performance. Following figure1 and 2 shows the types of image affected by various sources of degradation on the gray scale. Wet and dry finger images are suffers from randomly position false minutiae skeleton objects. Where as wrinkles and scars images create more structured patterns of false minutiae [1] [2].

a) Wet Finger  b) Dry Finger  c) Wrinkle

*Figure 1: effect of various sources of degradation on the gray scale image.*

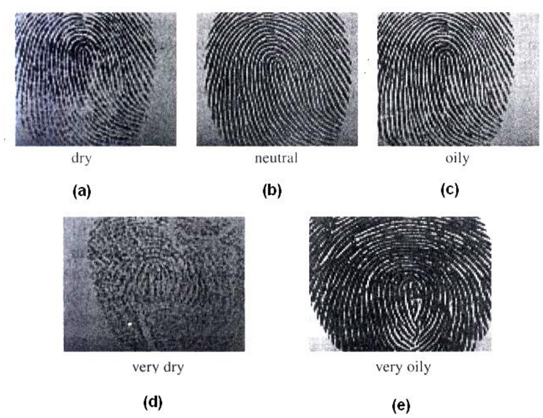



*Figure 2: Variations in skin conditions and indistinguishable ridge structures.*

In above figures shows that the types of image affected by various sources of degradation reduce the quality of the fingerprint image. To improve the quality and increase the performance of the fingerprint recognition system there is an indeed need of good enhancement technique. If the quality of input fingerprint image is not good then the automatic fingerprint identification or authentication is extremely difficult [3] [4] [5] [6]. In the experimental part of our paper we have applied intensity mapping to enhance the contrast, spatial and frequency domain filtering for noise removal and quick mask for connecting the gap between broken ridges.

## 2. Fingerprint Image Enhancement

Enhancement is a process for improving the appearance or stability for particular image and its applications. In fingerprint recognition system the enhancement is an essential step for feature extraction and matching. The overall performance of the system is highly depends on quality of fingerprint image i.e. good quality input image gives good performance whereas poor quality image gives poor performance. But in most of the cases a fingerprint image contains region of good, medium and poor quality, where in the ridge and valley pattern are very noisy and corrupted due to the various reasons as specified above as shown in figure 1 and 2. Such type of image found to be more difficult for ridge and minutiae extraction. In order to improve the good performance of these extraction algorithms in poor quality fingerprint images, there is a need of an enhancement algorithm to improve the image quality for genuine minutiae extraction. The overall objective of the fingerprint image enhancement is to improve the ridge and valley structure. General-purpose image enhancement techniques do not satisfy the result of fingerprint enhancement. However contrast enhancement, normalization, filtering, and binarization founds to be an effective steps.

### 2.1 Intensity mapping:

The term spatial domain refers to the aggregate of pixels used to compose the image. Spatial domain methods are procedures that operate directly on the pixels. Spatial domain process will be denoted by the expression:

$g\ (x,y) = T\ [f(x,y)]$………(I)

Where, *f(x,y)* is the input image, g(x,y) is the processed image and T is an operator on *f* defined over some neighborhood of *(x,y)*. In addition T can operate on a set of input images such as performing the pixel by pixel some of k images for noise reduction. The principal approach in defining a neighborhood about a point *(x,y)* is used a square or rectangular sub-image area centered at *(x,y)*. Center of the sub-image is moved from pixel to pixel starting, say, at the top left corner. The operator T is applied at each location *(x,y)* to yield the output, *g*, at that location. The process utilizes only the pixels in the area of the image spanned by the neighborhood. Although other neighborhood shapes such as approximation to a circle sometimes are used, square and rectangular arrays are the most predominant because of their ease of implementation. In above equation no. (I) T becomes a gray level operator also called a gray level or mapping transformation function [7] [8]. The general approach is to use a function of the values of *f* in a pre-defined neighborhood of *(x,y)* to determine the value of g at *(x,y)*.

## 2.2 Frequency and Spatial Filters:

Frequency transformation decomposes an image from its spatial-domain form of bright intensities into a frequency domain form of frequency components [11]. Frequency domain shows the frequency of brightness variations, the direction of variation patterns and the amplitude of the waveforms representing the patterns. Certain frequency components or clouds in the spectrum characterize some fingerprint features [12]. Besides enhancing details, overall appearance of fingerprint must be conserved as latent or fingerprint specialist are used to dealing with a certain class of these images, we must keep the subjective information brought by the background. This background information is usually removed by Appling high-pass filter.

The foundation for linear filtering in both spatial and frequency domain is the convolution theorem which can be written as :

$$f(x,y) * h(x,y) \Leftrightarrow H(u,v)F(u,v) \quad \ldots\text{(II)}$$

and conversely,

$$f(x,y)h(x,y) \Leftrightarrow H(u,v) * G(u,v) \quad \ldots\text{(III)}$$

Where, *f(x,y)* is the input image with *h(x,y)* filter mask, *F(u,v)* is fourier transform, and *H(u,v)* is filter transfer function. The symbol "*" indicates convolution of the two functions and the expressions on the sides of the double arrow constitute a Fourier transform pair. Basically in frequency domain lowpass and highpass filters are used for enhancement. In frequency domain filtering a filter transform function modifies *F(u,v)*. If high frequency components of *F(u,v)* are attenuates and low frequencies relatively unchanged then the applied filter is lowpass filter. The net result of low pass filter is image blurring i.e. smoothing. Because of lowpass filter blurs an image the high pass filter is used to sharpness the image attenuating the low frequencies and leaving the high frequencies of the Fourier transform relatively unchanged. High pass filter is defined as follows:

$$H_{\text{hp}}(u,v) = 1 - e^{-D^2(u,v)/2\sigma^2} \quad ..\text{(IV)}$$

Where, σ is the standard deviation, *D(u,v)* the distance from point *(u,v)* to the center of the filter.

Fingerprint requires the enhancement of small areas and details. A possible way of processing the image is by considering not only the pixel itself, but also the neighborhood of it at every location in the image [8] [11]. Linear filtering of image *f* of size M-by-N with the filter kernel *w* of size m-by-n can define as follows [7]:

$$g(x,y) = \sum_{s=-(m-1)/2}^{(m-1)/2} \sum_{t=-(n-1)/2}^{(n-1)/2} w(s,t)\, f(x+s, y+t) \quad \text{(V)}$$

Where, x=0,1,2,…….M-1, and y=0,1,2,…….N-1. In the experimental work we have used the average filter mask of size 5-by-5.

## 2.3 Quick Mask Edge Detector:

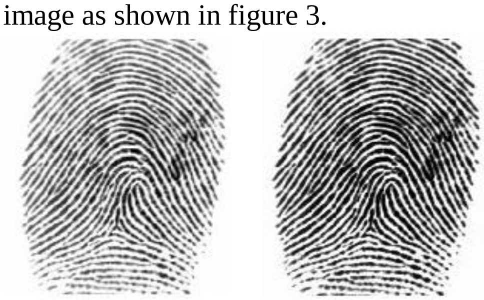
One of the principal approaches for edge detection is based on the use of mask also called as filter, kernels, templates, and windows. There are two basic principles for each edge detector mask. The first is that the numbers in the mask sum to zero. If a 3-x-3 area of an image contains a constant value such as all ones then there are no edges in that area. The result of convolving that area with the mask should be zero. If the numbers in the mask sum to zero, then convolving the mask with constant area will result in the correct answer of zero. The second basic principal is that the mask should approximate differentiation or amplify the slope of the edge. Therefore, there is a question to select the appropriate mask to detect the edges of image. The number of mask used for edge detection is almost limitless. Researchers have used different techniques to derive mask and then experimented with them to discover more masks. The few famous and more applicable masks for edge detection are Kirsch, Prewitt, Sobel, Canny, Roberts, Laplacian etc. The another most important mask is quick mask created by Dwayne Philips. Except quick mask above all masks are compass gradient or directional edge detectors. This means that to detect all eight directional connectivity neighbors each mask is having there eight different mask it means that each of the eight masks detect an edge in one direction. Therefore the directional edge detectors can detect an edge in only one of the eight directions. If you want to detect only left to right edges, you would use only one of the eight masks. If, however you wanted to detect all of the edges, you would need to perform convolution over an image eight times using each of the eight masks. The quick mask is so named because it can detect edges in all eight directions in one convolution this as obvious speed advantages when you want to detect all the edges [9].

## 3. Experimental Results:

In the experimental work we have applied here a specified set of composite algorithm operation on the various fingerprint images, which are collected from FVC2002 database (DB1 and DB2). The images of varying quality are used to evaluate of our composite algorithm through MATLAB and its relevant toolboxes. The steps of our composite method is as follows:

1. Input fingerprint Image
2. Map input image using Intensity mapping
3. Fast Fourier transform (FFT) of intensity mapping image.
4. Multiply (convolve) transformed with High-pass filter transfer function
5. Inverse of FFT (IFFT)
6. Convolve inverse FFT image with Quick mask edge detector.
7. Average Filtering using Convolution for smoothing the ridges
8. Enhanced Fingerprint Image

Through intensity mapping in our experimental work we used the intensity stretching technique using the gamma operator. Intensity mapping does not affect on the original structure of the fingerprint image as shown in figure 3.



(a) (b)

*Figure 3: Intensity mapping (a) original image (b) Intensity mapped image.*

Figure 4 shows how to remove regular patterns from images. In the frequency spectrum regular pattern found on the shows as vertical line segment spikes. Filtering removes the peaks by setting the magnitude at those locations to zero. The filtered Fourier transform image power spectrum show in figure 4 by line segment black spots where filtering was performed.

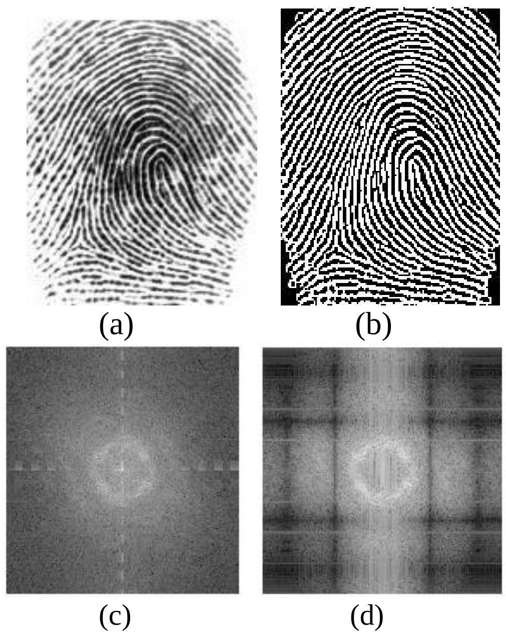



*Figure 4: (a) original Image (b) enhanced Image (c) and (d) Fourier Spectrum of (a) and (b) respectively*.

In the experiment of this paper the quick mask of size 3-by-3 is used to connect broken, cut and weak ridges of all eight directions within only one convolution. Where as to do this using conventional mask we have to convolve eight times. This seems that quick mask reduce the computational efforts. For smoothing the convolved image here we have used 5-by-5 average filter. We got good smoothing result by this average filter. The experimental result of composed algorithm also use to connect the broken, cut and weak ridges as shown in figure 5 (a) & (c). The resultant connected ridges are shown in corresponding rectangles in figure 5 (b). In figure 5 (d) the corresponding rectangles shows the maximum cut area has also been connected whereas distance between the high cut is minimized. Figure 6 shows the composite algorithm not only enhance the dry fingerprint images but also can enhance the oily images.

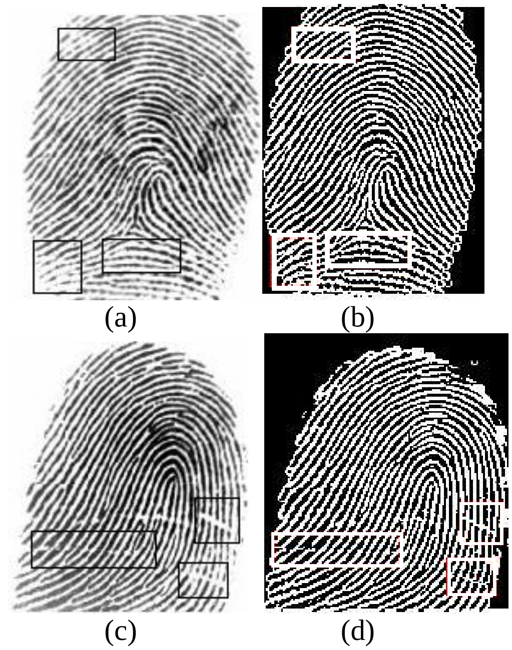



*Figure 5: (a) and (c) original images and (b) and (d) output images of composed algorithm*.

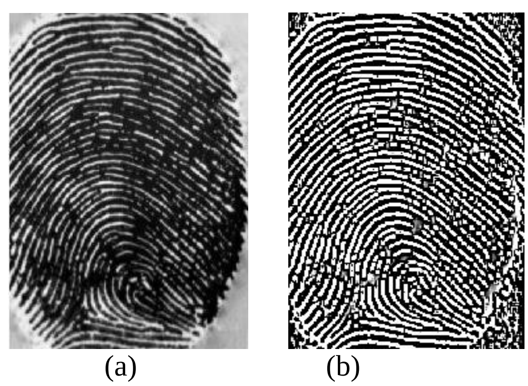



*Figure 6: (a) Oily fingerprint image (b) enhanced image.*

## 4. Conclusion:

In this paper we used the composite algorithm for noisy or corrupted fingerprint image enhancement in three terms namely intensity mapping, Fourier spectrum analysis, and connecting broken ridges. Intensity mapping function map the intensities from low to high and high to low, due to this we just increase the contrast of the image and it doesn't affect on structure of the fingerprint image. Fast Fourier Transform (FFT) in frequency spectrum shows prominent features of fingerprint that could not be extracted by other enhancement techniques. Frequency spectral analysis techniques use to highlight very weak fingerprint information from variety of background patters. Where as, because of applying of quick mask broken ridges of fingerprint has been connected. This mask connects broken ridges of all eight direction within one convolution operation, hence its saves computational efforts. This proposed composite algorithms shows the batter performance for enhancement and connecting the broken ridges in noisy images. However it may not show the desired result where the broken or cut ridges are at very high level.

Our future work is to extend the work of this area by using the wavelet and wavelet packets rather than FFT and redesign quick mask to connect the high broken and cut ridges.

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