# The Enhancement of Fingerprint Images using Gabor Filter

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# The Enhancement of Fingerprint Images using Gabor Filter

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**Abstract**   Fingerprint is used as an object of the image that can be characteristic of every human being. Fingerprint images that have noise, blur and are not clearly a major problem in image processing. Enhancement of fingerprint image quality is proposed with the Gabor Filter method. The steps taken begin by increasing the local image contrast by applying the adaptive histogram equalization (AHE) method, then, corrected by the Gabor Filter and binarization methods. Image quality improvement was measured by peak signal to noise ratio (PNSR) and mean square error (MSE). The results of the experiment using the NIST dataset resulted in the best value of PNSR of 18.2692 and MSE of 159.3449.

## 1. Introduction

In human organ detection, software technology is widely developed through image processing. Several studies of organ detection systems have been developed, such as the detection of ears, face, tongue and iris [1], [2], [3], [4]. The fingerprint is one of the objects in the field of biometrics that is part or characteristic of the identity that is inherent in human beings. Fingerprint identification is one of the oldest biometric techniques and has proven its value in a variety of applications [5] [6]. Fingerprints have a prominent part on one side called a hill or ridge. While on the other side that is not prominent is called valley. Sulong, Ghazali [5] distinguishes fingerprints from the number and position of the singular point, into five basic forms, namely: arch, tented-arch, left-loop, right-loop, and whorl. Fingerprint image capture often experiences problem with image quality such as being exposed to noise, blur and so on. For this reason, it is necessary to improve the quality of the fingerprint image. Fingerprint Enhancement is a process of forming a new image quality using various techniques and methods as needed to obtain images that are more easily interpreted by the human eye. In this process, certain characteristics contained in the image are more clearly defined [7][8].

Lin Hong[9] proposed the technique of improving the quality of fingerprint images starting with normalization which aims to take the mean and variance of the input image which is then applied to local orientation estimation in order to obtain the orientation. The use of local frequency estimation that aims to align the results of local orientation estimation. Then, a region mask estimation is performed which is obtained from the classification of each block in the normalized fingerprint image into blocks that can be repaired or that cannot be repaired. This step aims to determine whether the area executed has a value that is smaller or greater than the threshold. This stage determines the input image to enter the next stage or even rejected. If the area value is greater then enter the stage where filtering is done. This stage aims to determine the value so that it can be filtered or not, which will later affect the noise filtering. But this method requires another step, which is to increase the level of precision in the region mask.

Based on the above problems, an additional Adaptive Histogram Equalization (AHE) was proposed with the aim of adjusting the contrast of the image. The implementation of the algorithm starts with normalizing the image using AHE, then filtering the image with Gabor then after that, the binary transformation is performed.

## 2. Fingerprint Enhancement

In work of [10], image enhancement comes from the problem solutions that often being seriously involved at the time of such as intensity, transmission data corrupt, blur or shaken lens. Image enhancement way is manipulation of gray level and the brightness level of the image that it will be useful in image analysis or extraction [11]. They also said that image enhancement is used to clarify image's edge and also known as an edge sharpening. In their work, they use three image enhancement methods, i.e. Histogram Equalization, Sharpening and Noise Removal with Standard Median Filter.

In this work, the enhancement process that was carried out for the first time was by acquiring image input data. The image used is an image from NIST's database. The image tested in the experiment was 10 images. After that, the image will be processed to increase the Adaptive Histogram Equalization(AHE). Next, the image in the filter uses a Gabor filter. Then, a binary transformation is performed so that the black and white image of the fingerprint is more clearly visible. The complete process is presented in the block diagram in Figure 1.
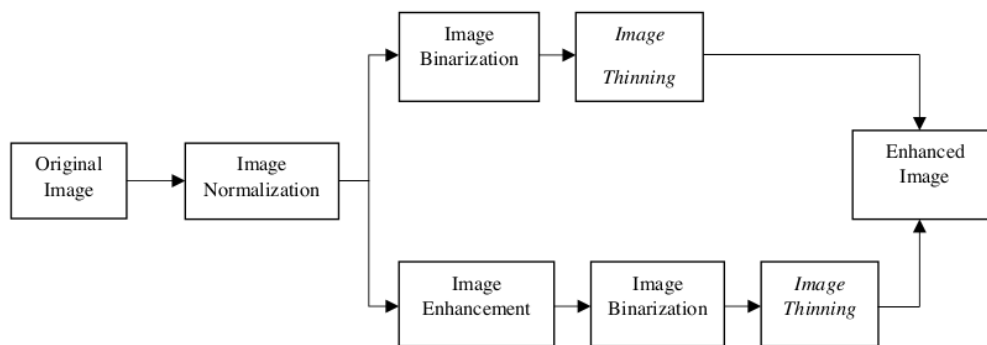


**Figure 1.** Fingerprint Image Enhancement Process Block Diagram

### 2.1 *Normalization*

The normalization process is carried out to uniformed the intensity value of the fingerprint image by adjusting the gray level coverage so that it is within the expected value range. The normalization process does not change the clarity of the ridge and valley structures. The main purpose of normalization is to reduce the variation of gray values along the ridges and valleys. With normalization, gray level values are made to be in a certain range that is good enough to increase the contrast and brightness of the image which will facilitate the next processing steps [9][12].

Image conditions such as dim, balanced, or too bright images will be generated in the form of a histogram. The technique often used for processing histograms is the Adaptive Histogram Equalization. AHE produces a uniform histogram and is evenly distributed so that it is often called the histogram alignment term.

The original image histogram is shown in Table 1 (c) describes a low contrast image where all pixel values are not evenly distributed at 0-255 image intensity, which looks to have a main peak with most pixel intensity values clustered tightly around it. When viewed from the x-axis histogram, this main peak tends to the left, and right. This condition causes the image to be too dark and too bright in certain parts.

After going through the normalization process, the image has a good contrast that is the image that has the distribution of the intensity of the width and flat shown in Table 1 (d). The histogram does not show a dominant peak. So the image looks better and the object is clearer.

Therefore, image normalization is needed to increase the contrast between ridge and valley in fingerprint images, where the normalization process will help the process of improving fingerprint images.

**Table 1.** Image Normalization Results; (a) Original Image; (b) Normalized Result Images; (c) Original Image Histogram; (d) Normalized Result Image Histogram



|   a   |   b   |   c   |   d   |
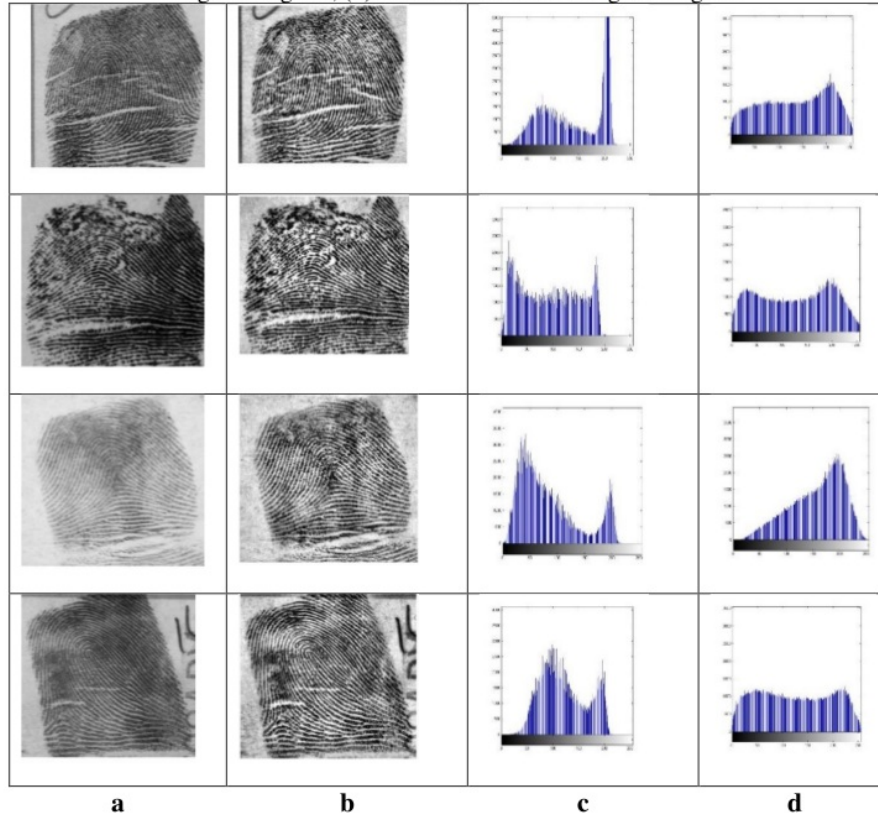
### 2.2 Filtering

Gabor filters are formed from two components, sinusoidal and Gaussian. The Gabor filter method is able to connect the optimal representation of orientation direction and the spatial domain (frequency). The Gabor function was discovered by Gabor in 1946, where the function was defined in 1-D with t stating time and then developed into 2-D in the spatial domain formulated the following equation (1):

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

where

$$x_{\theta} = x \cos\theta - y \sin\theta$$
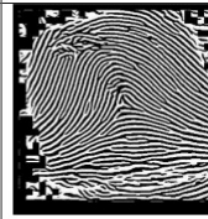
$$y_{\theta} = x \sin\theta + y \cos\theta$$
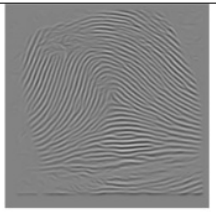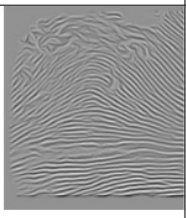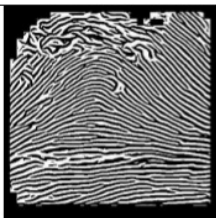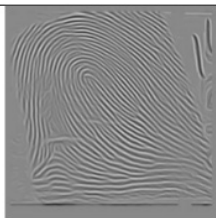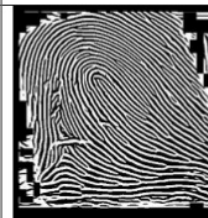
$\theta$ is the orientation direction, $f$ is the cosine wave frequency $\sigma_x$ and $\sigma_y$ is a fixed distance from the Gaussian properties respectively along the x and y-axes.

### 2.3 Image Binary Transformation

Binary Transformation is the process of converting gray level images into binary images [13]. In binary imagery, there are only two levels in it, namely, black pixels and white pixels where the pixels show

ridges and valleys in the fingerprint image. The pixel value of 0 is set to the black area of the fingerprint image that represents the ridges line, and the pixel value 1 identifies the white area in the image that represents the valleys [7]. The Binary Transformation approach is used to keep the fingerprint characteristics of the ridges structure and to remove some cohesion between patterns. The final result of Binary Transformation is presented in Table 2.

**Table 2.** Results of Gabor Filter and Binary Transformation

| No | *Gabor Filter* | Binary Transformation | No | *Gabor Filter* | Binary Transformation |
|----|----------------|------------------------|----|----------------|------------------------|
| 1  |                |                        | 3  |                |                        |
| 2  |                |                        | 4  |                |                        |

## 2  Result and Discuss

The Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) values are used to show the performance of the image quality improvement process presented in Table2. PSNR value on contrast stretching is intended for noise information on the image quality improvement. MSE in the stretching contrast information on the mean square error value, if the MSE value is smaller, the better the image quality improvement results, it can be formulated as follows with equation (2) and equation (3):

$$PSNR = 20 log_{10}\left(\frac{255}{RMSE}\right) \tag{2}$$

$$MSE = \frac{\sum_{i=1}^{ro}\sum_{j=1}^{co}(I_0^c(i,j) - I_{th}^c(i,j))}{row \; x \; col} \tag{3}$$

Where:
$I_0^c$          = original image
$I_{th}$         = segmented image
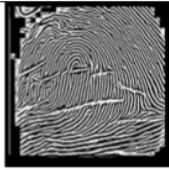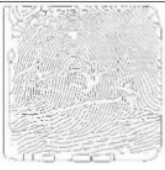row x col = Total amount of image rows and columns
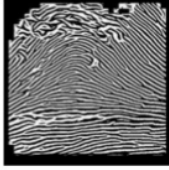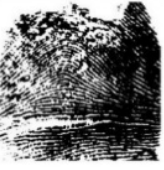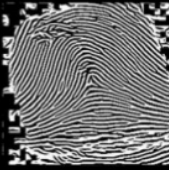
From the results of the calculation of the MSE value, and PSNR in Table 3 shows that in the normalization process there is a change in the input image and result image (output image).

**Table 3.** PSNR and MSE results from Image Normalization

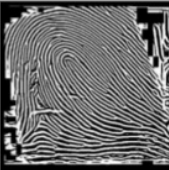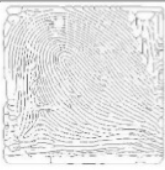| Images | Results of PSNR | Results of MSE |
|---|---|---|
| 1. | 17.9272 | 95.0488 |
| 2. | 16.2420 | 78.4870 |
| 3. | 16.2685 | 90.2696 |
| 4. | 18.0951 | 80.3449 |
| 5. | 16.1891 | 74.0728 |
| 6. | 15.0853 | 66.5585 |
| 7. | 14.8973 | 62.5868 |
| 8. | 17.6584 | 96.4326 |
| 9. | 18.2692 | 82.0024 |
| 10. | 18.0898 | 80.4210 |
| Average | 16.8721 | 87.2782 |

The greater the MSE and PSNR values of an image enhancement process, the greater the changes that occur between the input image and the resulting image. These changes indicate an image that is initially of poor quality to be a better image (input image) as presented in Table 4.

**Table 4.** Comparison of results of binarization and thinning before and after the enhancement process

| No | Binarization Image after Image Enhancement | Binarization Image before Image Enhancement | Thinning Image after Image Enhancement | Thinning Image before Image Enhancement |
|---|---|---|---|---|
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |
| 4 |  |  |  |  |

## 4. Conclusion

Contrast setting on the image by applying the Adaptive Histogram Equalization (AHE) method successfully improves the image. After filtering with Gabor functions and binary transformations, the image enhancement process gets better. The greater the MSE and PSNR values of an image enhancement process, the greater the changes that occur between the input image and the resulting image. The results of the experiment using the NIST dataset resulted in the best value of PNSR of 18.2692 and MSE of 159.3449.

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## Hardware Implementation For Fingerprint Image Enhancement Using Anisotropic Gaussian Filter", IEEE Transactions on Image Processing, 2017

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