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Fingerprint Image Enhancement Using a Composite Algorithm Gaussian Mask and Sobel Convolution

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Abstract

The fingerprint image quality is very important for a fingerprint biometric authentication system. Therefore, the performance of the extraction of the minutiae of the fingerprint strongly depends on the biometric fingerprint image. As a result, the image enhancement stage of the recognition process has a significant impact on the biometric fingerprint verification system's performance. Image enhancement is a critical stage in biometric fingerprint recognition that improves image quality by reducing noise, repairing broken ridges, and smoothing the image. In this paper compare three methods like Canny algorithm, Sobel edge detection Laplacian edge detection with proposed composite algorithm that uses a Gaussian mask to smooth the image and two sobel convolutions to detect edges. The proposed research work is implemented using .net technology and with FingerDos database. The performance of proposed work is compared using parameter like PSNR, MSE, and execution time and quality of an image prove that proposed algorithm give better performance.

Keywords: *Fingerprint, Biometric, Authentication, Image Enhancement, Minutiae Extraction, Edge Detection*

1 Introduction

The quality of an image of a fingerprint would range from poor, medium or good. Ridges and valley patterns are frequently quite noisy and of poor quality. The quality of the fingerprint image has a significant impact on the performance of the

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fingerprint verification system. An enhanced fingerprint would give better results as compared to a poor and noisy fingerprint. Though, it is important to process the noisy image and convert it into an enhanced image so the resulting image can be used for better performance for a fingerprint recognition system [4,19].

It's nearly impossible to retrieve details from a low-quality fingerprint image. Preprocessing algorithms must be applied to enhance the quality of the image of the fingerprint [14-17][33]. Though genuine minutiae extraction can be carried out and proper identification and verification can be done for recognition. The basic objective of fingerprint image enhancement is to improve fingerprint's ridges and valley patterns through those more suitable features extraction [12] can be carried out from an enhanced image then the original poor-quality image [4] [20-21].

If a noisy, low-quality fingerprint image is available, fingerprint verification becomes an extreme problem for a biometric recognition system [1-3]. We are attempting to increase the quality of a fingerprint image by eliminating noise and obtaining an image with sharpened ridges as part of our research. The resulting image can be used for various subsequent processes like image binarization, image thinning and other subsequent steps of the fingerprint verification system.

2 Literature Review

An integration model for improving fingerprint images was put forth in the research publication [5]. They successfully connect the gap between the two ends of fractured ridges. This led to the removal of two erroneous ending details. Small and medium-sized valleys no longer have noise. The boundaries have also been improved, and the ridges holes have been fully eradicated. The suggested approach does not, however, account for all issues. It is challenging to estimate the orientation field in an image when there is a high level of noise present. Segmentation of the original image is needed as a result. The block directional difference and the Quality Index of the recovered minutiae through the clustering of image quality parameters are used to carry out the proposed work. The suggested approach is successful in enhancing block directional difference and quality index, and it also succeeds in enhancing the time needed is within a tolerable range. However, there is still room for improvement in the image characteristic aspects for the identification and verification system. The research's findings are still not good enough to match a fingerprint.

The researcher [6][33] is working on novel methods for fingerprint image minutiae verification. They claim that compared to conventional grey scale methodologies stated in the literature, the innovative characteristics for fingerprint picture verification provide greater accuracy. The methods are effective in terms of computation, and they can be utilized to create minutia detectors that can work directly on grayscale photos. To improve the image, it is still important to combine the results of the two classifiers and investigate the impact of minute verification on matching performance. This may be accomplished with the aid of picture improvement. Direct grayscale enhancement methods perform better than methods that call for binarization and thinning as intermediate stages. The proportion of errors that are abandoned, swapped, or false. The percentage of errors produced by the binarization strategy is significantly lower than the percentage of errors produced by other ways in terms of dropped, swapped, and false minutiae. Particularly for poor-quality images with problematic ridges and blocks with singular points, the modified Gabor filter performs best. Utilizing a special anisotropic filter eliminates the need for local frequency estimation using a Gabor-based filter. Speed and effectiveness are still necessary for the enhancement procedure.

The researcher [4] demonstrates the use of the well-known fingerprint enhancement algorithms O'Gorman and Gabor. Additionally, the O'Gorman filter is improved. Using MSE and PSNR values, the performances of these three algorithms are assessed. According on experimental findings, the improved O'Gorman filter provides superior outcomes to the other two algorithms. The researcher improved the algorithm to identify corrupt areas that are brought on by cuts, scars, dry skin, and sensor noise, eliminate them from the photos, and boost ridge and valley contrast. additionally join broken ridges.

The orientation vector was orthogonal to the gradient, thus the researcher [7][12-13][18][22][32] employed a gradient-based technique to determine the gradient. The gradient was first calculated for each pixel in the image, in the directions of x and y. The image was then divided into square blocks. Each block's orientation vector is computed. It is accomplished by performing an average operation on all of the vectors in the block that are orthogonal to the gradient pixels. A lowpass filter is employed to smooth down the image since chaotic images can often make it difficult to discern the direction of ridges precisely.

3 Proposed Work

Several segmentation techniques, including Sobel edge detection [8,29,30], Canny edge detection [9–10][23-25][30], and Laplacian edge detection [11][26-28][30], are employed for image augmentation. Following that, a variety of filters, like Gobor and Gaussian mask, can be used to remove noise. In proposed work, suggested a combined method that used two sobel convolutions to find edges while also using a Gaussian mask to smooth out the image. The Sobel operator is used in the image to measure the 2-D spatial gradient. The approximate absolute gradient magnitude at each position in a grayscale fingerprint image is determined using the Sobel Operator.

$\frac{1}{115}$

2	4	5	4	2
4	9	12	9	4
5	12	15	12	5
4	9	12	9	4
2	4	5	4	2

[Figure 1. Gaussian mask]

Two 3*3 convolution masks are being used. One is used to determine the gradient in the x direction (columns), and the other is used to determine the gradient in the y direction (rows). The image is substantially larger than the 3*3 mask. As a result, the mask is shifted over the fingerprint image, manipulating square pixels. Figure 1's x and y sobel mask directions are shown below.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

[Figure 2. x direction and y direction sobel mask]

The following equation is used to calculate an approximate magnitude

$$|G| = |Gx| + |Gy| \quad (1)$$ [10]

The mask is moved on the input image and it is going to change the current pixel value and then it slides on the right side and continues to change the pixel values on the right side until it reaches the end of rows. Then the same process is carried out for the next row. Figure-2 shows how the mask changes the values of each and every pixel. Each pixel value of the resulting fingerprint image is carried out by the formula. The mask center is placed over the pixel which is manipulating in the image.

X11	X12	X13	....	X1n
X21	X22	X23	......	X2n
X31	X32	X33	......	X3n
:	:	:		:
:	:	:		:
:	:	:		:

Input Image

M11	M12	M13
M21	M22	M23
M31	M32	M33

Mask

Y11	Y12	Y13	....	Y1n
Y21	Y22	Y23	......	Y2n
Y31	Y32	Y33	......	Y3n
:	:	:		:
:	:	:		:
:	:	:		:

Output Image

[Figure 3. Sobel edge detection example][9]

As shown in Figure 3. pixel Y22 can be calculated with the equation.

$$Y22 = (X11*M11) + (X12*M12) + (X13*M13) + (X21*M21) + (X22*M22) + (X23*M23) + (X31*M31) + (X32*M32) + (X33*M33) \quad (2)$$

It is also shows that corner pixels can't manipulated by 3*3 mask because of the boundary limitation of the mask.

4 Performance Measure and Result Discussion

The implementation work is done using .Net Framework. The FingerDOS [31] database was utilized to evaluate our study effort. It has 3600 finger images from 60 different people. Table 1 provides a summary of the FingerDOS database.

FingerDOS			
Types of Sensor	**Image Size**	**No. of Impression**	**Resolution**
optical sensor (SecuGen iD-USB SC)	260x300	3600=60x6x10 i.e. No. of subjects=60 No. of fingers=6 (index, middle and thumb of right and left hand) No.of impression=10	500 PPI

The following measurement standards are used to measure the performance of the research work.

(a) PSNR and MSE value

(b) Computational Time

(c) Fingerprint Image Quality

(a) PSNR and MSE value

The Table 2 below compares the MSE and PSNR values for a number of edge detection techniques, including Laplacian edge detection, Sobel edge detection, Canny Algorithm, and proposed Enhanced Composite algorithm using Gaussian mask and Two Sobel Convolution. The proposed method's high PSNR and low MSE values are compared, and the proposed strategy offers better results in terms of brightness and contrast.

Table 1. Comparison of MSE and PSNR value implemented edge detection methods

Images	Laplacian edge detection		Sobel edge detection		Canny algorithms		Proposed Algorithm	
	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
A_01	16.76	37.37	15.77	39.35	18.88	38.19	15.45	40.50
B_01	11.56	40.40	11.55	42.47	13.56	42.42	11.26	43.65
C_01	12.82	38.30	12.80	41.28	14.93	40.92	12.44	43.35
D_01	15.18	37.26	14.16	41.19	16.52	40.24	13.77	42.40
E_01	16.09	41.47	14.05	42.64	15.31	42.52	13.99	43.75
F_01	14.77	37.29	13.05	40.34	14.88	39.35	12.66	41.49

(b) Computational Time:

The comparison of processing time for image enhancement is carried out and shown in the following table. It claims that the suggested technique takes somewhat longer than Sobel and Canny edge detection algorithms, but is faster than the Laplacian edge detection method.

Table 2. Comparison of processing Time of various edge detection methods

Images	Laplacian edge detection	Sobel edge detection	Canny algorithms	Proposed Algorithm
A_01	36.55	35.09	35.07	35.13
B_01	35.57	35.46	35.20	35.50
C_01	35.16	35.10	35.05	35.15
D_01	35.19	34.90	35.08	34.93
E_01	35.68	35.57	35.44	35.60
F_01	36.88	35.90	35.79	35.93

(c) Quality of an image:

The quality of fingerprint image is improved after implementing an enhanced algorithm. The below table original image and enhanced image is shown.

Table 3. The proposed increased algorithm's image quality Using Sobel Convolution and the Gaussian Mask

Original Image	Enhanced Image	Original Image	Enhanced Image
			
A_01_Original Image	A_01_Enhanced Image	B_01_Original Image	B_01_Enhanced Image
			
C_01_Original Image	C_01_Enhanced Image	D_01_Original Image	D_01_Enhanced Image
			
E_01_Original Image	E_01_Enhanced	F_01_Original Image	F_01_Enhanced

Image Image

5 Conclusion

In this study, proposed a composite Gaussian mask and Sobel convolution technique. The image is smoothed using a gaussian mask, and edge detection can be done by Sobel convolution. The result of proposed technique is compared with the existing edge detection techniques like Sobel, Canny and Laplacian edge detection. The study prove that compared to existing edge detection technique the proposed technique give better result in terms of PSNR, MSE, computation time, and image quality .

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