Jurnal
Teknologi

Full Paper

FINGERPRINT IMAGE ENHANCEMENT USING MEDIAN SIGMOID FILTER

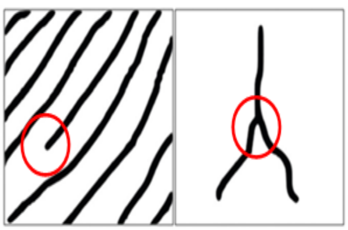
Ainul Azura Abdul Hamid[a], Rosely Kumoi[a], Mohd Shafry Mohd Rahim[b]*, Nur Zuraifah Syazrah[a]

[a]ViCubeLab, Faculty of Computing, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]UTM-IRDA DMC, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

Article history
Received
3 December 2013
Received in revised form
2 July 2014
Accepted
25 November 2014

*Corresponding author
shafry@utm.my

Graphical abstract



Abstract

Quality of fingerprint image is most essential to ensure good performance of minutiae extraction result since it depends heavily on the quality of fingerprint images. Fingerprint image with noise usually will produce spurious minutiae. In this paper, new combination filter called Median Sigmoid (MS) filter is introduced to remove the unwanted noise created during the acquisition process and hence increasing the accuracy of minutiae extraction result. The result shows that MS filter is an effective filter in enhancing the quality of a noisy image.

Keywords: Enhancement, filtering, median sigmoid, distance vector

1.0 INTRODUCTION

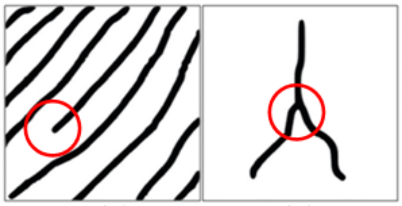
Biometrics is an accepted and dependable answer to solve identity verification dilemma by identifying individuals based on the physiological or behavioral traits that are inherent to the person [1]. Physiological and behavioral traits that are normally utilized for biometric recognition are face, fingerprint, iris, retina, DNA, signature, palm print, ear, voice, keystroke dynamics, hand-geometry and gait. Automated Fingerprint Identification System (AFIS) is recognized and acknowledged world-wide [2]. It is moreover turned out to be one of the significance in security field which by numerous researchers have attended to persist in carrying out research on it.

A lot of researches on fingerprint recognition are based on minutiae matching approach. This approach requires an accurate minutiae extraction result to be able to identify the owner of the fingerprint image. This is one of the challenges in fingerprint identification system. It is challenging because of noise presence in the fingerprint image during data acquisition process.

A noise can be defined as a process that affects the original image since it is not a part of the original image. Noise in an image can be caused by use of scanner, sensor or digital camera [3]. There are a variety types of noises that can corrupt the image such as salt-and-pepper and random valued noise. For better image processing, an image that is free from any noise is essential [4]. Hence, it is necessary to apply noise removal algorithm to enhance the quality of the degraded image. The noise removal algorithms reduce or remove the visibility of noise by smoothing the entire image leaving areas near contrast boundaries. By removing the unwanted noise in the fingerprint image, the quality of the image is increased thus the accuracy of minutiae extraction results.

A fingerprint is the pattern of ridges and valleys known as furrows, on the surface of a fingertip [5]. Generally, there are three main criteria about fingerprint: (i) Unchangeable; (ii) Unique; and (iii) Limited classification.

Basically, in the fingerprint images, there are global and local features. Global features are characteristics that can be seen by the naked eye such as ridge pattern, core and delta areas. Local features are known as minutiae points [6]. The two most important local ridge characteristics called minutiae are ridge ending and ridge bifurcation (Figure 1). Ridge ending is defined as the point where a ridge ends while a ridge bifurcation is defined as the point where a ridge forks or diverges into branch ridges [2].



(a) (b)

Figure 1 Fingerprint local feature: (a) Ridge ending; (b) Ridge bifurcation

Automated fingerprint identification system highly depends on these local ridge characteristics for successful fingerprint matching. Ideally, the ridge structure in a fingerprint image should be well-defined and has high contrast; a poor quality fingerprint is marked by low contrast and do not have well defined boundaries between the ridges [7].

Minutiae can be accurately located from the thinned ridges and it can be easily detected. On the other hand, in some cases, due to variations in impression conditions, ridge configuration, skin condition, acquisition devices and non-cooperative attitude of subjects, a significant percentage of acquired fingerprint images is of poor quality image. These will lead to some problems especially in the performance of minutiae extraction and fingerprint recognition phases. Thus, to make sure the performance of the recognition is more accurate, there is a need to do an enhancement method to increase the clearness of the ridge structures.

This paper is organized as follows. Section 2 describes proposed method for removing the noise. Section 3 explains the way an experiment being set-up. Section 4 presents experimental result. Discussion regarding the result is described in Section 5. Lastly, the findings of this paper will be summarized in Section 6.

2.0 PROPOSED METHODOLOGY

Digital images are prone to a variety of noise types. Noise is the effect of errors in the image acquisition process that cause in pixel values that do not reflect the true intensities of the real scene. There are several ways that noise can be introduced into an image, depending on how the image is created.

Apart from the image that is free from noise, contrast of the image plays an important role in determining the quality of the image. Contrast of any image is a very important characteristic which decides the quality of image [11]. Contrast is an important factor in any individual estimation of image quality [12]. Low contrast image contain details which are not clearly visible and by applying the contrast enhancement, one can make these details more clearly visible. Contrast enhancement techniques are able to produce output images with better appearance and high detailing as compare to the input images by increasing the gray-level differences among objects and background.

This paper is proposing a new combination filter called Median Sigmoid (MS) filter. This filter is a combination of median filter and sigmoid function. The reason to propose this filter is to remove salt-and-pepper and Gaussian noise from the acquired image as well to enhance the image to the suitable level of contrast. Reducing noises, healing broken up ridges, cleaning up ridge valleys and increasing the contrast between ridges and valleys in the gray scale fingerprint images are major tasks of enhancement and restoration techniques [13]. A good quality image is free from noise and has a good contrast. Hence, this study has come out with this new combination filter to achieve this goal.

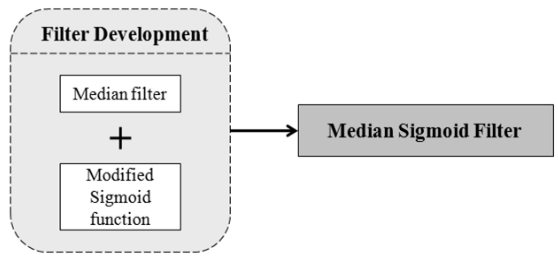


Figure 2 Framework of MS filter development

MS filter is developed by combining median filter and modified sigmoid function (Figure 2). In order to come out with a new formula of MS filter, a modification will be done towards median filter and sigmoid function formula.

Below is the formula for the median filtering implementation. A filter mask (3 x 3) that consist of 8-neighbourhood with the centre of *(x,y)* is used. Let say, *I* is the input image obtained after pre-processing, *F* is the 3 x 3 moving filter mask, and *M* is the output image. The pixel values in the 8-neighbourhood filter mask are sorted in ascending order by using Equation 1. Then, median value is determined by using Equation 2. The value of *M*(x,y) is then replaced by the obtained median value. This action is done by using Equation 3

$$OrderSet = F_{(0)} \leq F_{(1)} \leq F_{(2)} \leq \ldots \leq F_{(N-2)} \leq F_{(N-1)} \quad (1)$$

$$F_{median} = \{ \frac{F_{(N/2)} + F_{(N/2-1)}}{2} F_{((N-1)/2)} \quad (2)$$

Where

N – Number of pixels in neighborhood

$F_{(0)}$ – Minimum value

$F_{(N-1)}$ – Maximum value

$$M(x,y) = median\{I(x,y);(x,y) \in F\} \quad (3)$$

The operation of obtaining the median means those very large or very small values (noisy values) will end up at the top or bottom of the sorted list. Thus, the median will in general replace a noisy value with one closer to its surroundings. Now, the modified sigmoid function says *S(x)* is given as,

$$S(x) = \frac{1}{(1+e^{c*(th)})} \quad (4)$$

where
S(x) - Sigmoid function
c - Contrast factor
th - Threshold value

The contrast factor is used to determine the most wanted degree of the contrast depending on the degree of darkness or brightness of the input image. For the c value in Equation 4, a value of about 5 is neutral which is it gives little changes to the enhanced image. On the other hand, a value of 1 will reduce contrast to about 20% of the input image and value of 10 will increase the contrast 2.5 times. For effective contrast enhancement, the value of c should lie in range of 10 to 25. Therefore, this paper will use c value of 12.

By using and modifying both equations of median filter and modified sigmoid function as one, MS filter formula is given as,

$$Mask = c*(th - M(x,y)) \quad (5)$$

$$MS(x,y) = \frac{1}{(1+e^{Mask})} \quad (6)$$

where
MS(x,y) - Enhanced pixel value
c - Contrast factor
th - Threshold value
M(x,y) - Input image

As stated before, c is the contrast factor that determines the degree of contrast needed by the input image. Threshold value *th* in Equation 5 is another control parameter to represent the normalized gray value about which contrast is increased or decreased. Initially, the value of *th* is 0.5 which is the midpoint value of gray scale. However, different images might require different points of the gray scale to be enhanced. Thus, this paper used the value of 0.05 for *th* value for better enhancement.

This new combination filter by using Equation 6 is a process that performs directly towards each pixel of an image. The mask passed over the image pixel by pixel starting from the upper right corner. Each intensity value of pixel in the output image is equal to its intensity value in the input image added to the value of this mask. This formula operates upon the input target image pixel by pixel.

3.0 TESTING

3.1 Dataset

Prior to 1993, most researches used NIST Database 14 fingerprints for development and testing of fingerprint classification systems [8]. Later, in 1993, NIST released a new version of fingerprints database well suited for development and testing of fingerprints classification systems. This upgraded version is called NIST Special Database 14, Mated Fingerprint Cards Pairs 2, and version 2, hereinafter named DB14 in its short form [9]. The dataset is considered as de facto standard fingerprints database that is used for developing and testing of automated fingerprint classification systems [9-10].

The DB14 is made up of 54,000 8-bit grayscale fingerprint images obtained by rolled method of fingerprint acquisitions. The fingerprints were scanned from two types of prints. The first type was fingerprint patterns created by rolling the individual's ink-covered finger on the fingerprint card. The second type was patterns taken with a live scanning device and printed onto a fingerprint card. These cards were then scanned at 500 dpi resolution by a standard grayscale scanner. The dataset consists of mated fingerprint cards pairs, which are two cards from the same individual. The prints are 832 (W) x 768 (H) pixels. Each fingerprint was acquired two times. The first acquisition denotes the fingerprints from f0000001 to f0027000 is called file cards, the second acquisition denotes the fingerprints from s0000001 to s0027000 is called search cards.

3.2 Experimental Setup

Quality of each image which has gone through median filter, sigmoid function and MS filter was measured by distance vector calculation. For this experiment, 100 samples of fingerprint images in file cards starting from f0000001 to f0000100 will be used to measure the quality of fingerprint images for each median filter, sigmoid function and MS filter as the comparison of quality among them.

For the training dataset, 100 original images were categorized into 10 categories. Each category refers to each finger. In one category, there are 10 images from 10 different persons. MS filter was applied to these images to obtain filtered images from the original images. On the other hand, for testing dataset, Gaussian noise is added (different variance values from 0.01 to 0.05) to the 100 images. Then, MS filter was applied to remove the noise. The filtered images produced will be used as the test dataset. For better understanding, Figure 3 shows the way effectiveness measurement is being implemented.

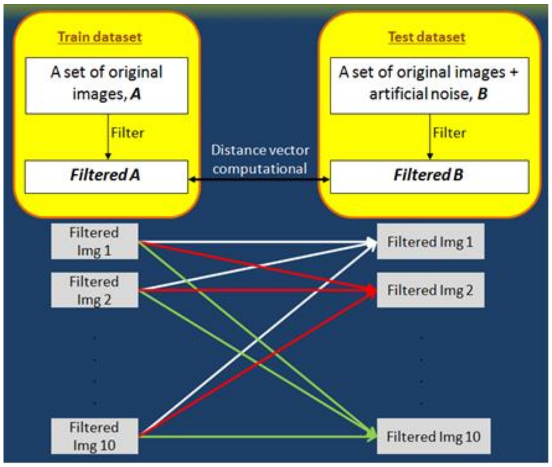


Figure 3 Framework of effectiveness measurement computation of MS filter

The computation was implemented by using the following equations:

For training dataset:

$$NormalizedVector, a' = \frac{a}{|a|} \tag{7}$$

For testing dataset:

$$NormalizedVector, b' = \frac{b}{|b|} \tag{8}$$

Distance vector between two images:

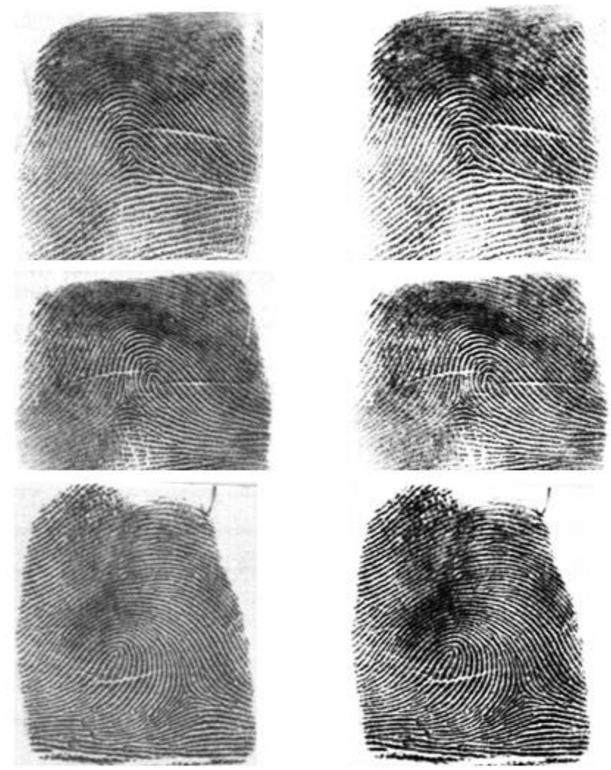
$$\text{Distance,d} = \sqrt{(a' - b')^2}$$
$$= \sqrt{(a' - b')^T - (a' - b')} \tag{9}$$

where ^{T} is transpose function.

In this experiment, two types of images are compared. First comparison is between identical images and second comparison is between different images. The ratio between average values for the same images and average values for the different images will determine the effectiveness of those filters. The hypothesis for this experiment is the larger the ratio value is for the particular filter, the better the recognition performance would be, and the more effective the filter is.

4.0 RESULTS

The performance of the proposed filter in terms of visual inspection was measured. Figure 4 and Figure 5 show the transformation of the image quality by using MS filter in removing the noise in the image.



(a) (b)

Figure 4 MS filter output: (a) Input image; (b) Image after MS filtering

(a) (b)

Figure 5 Comparison of the thinned images: (a) Image before MS filtering; (b) Image after MS filtering

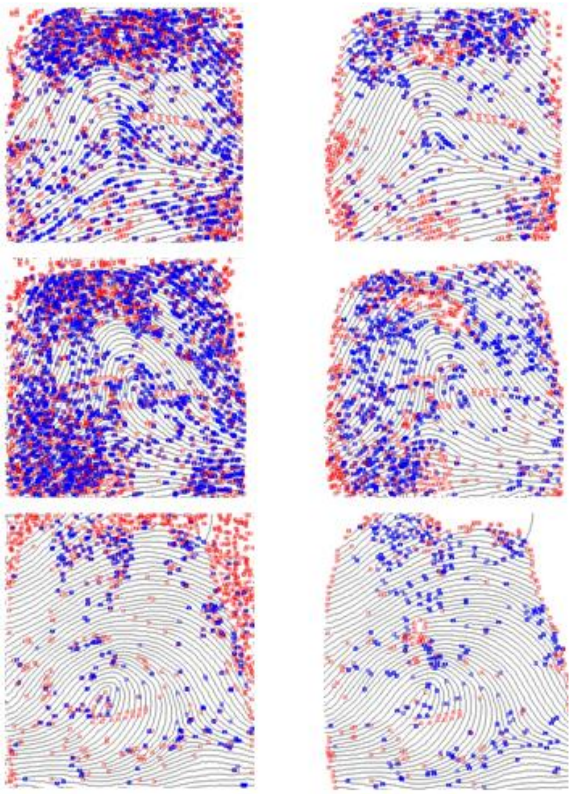


Figure 6 Comparison of the extracted minutiae: (a) Before enhancement; (b) After enhancement

Figure 6 shows the extracted minutiae before and after an enhancement using MS filter is being applied.

Table 1 Ratio values between two same images being compared and different images being compared for right thumb category

Gaussian noise, mean = 0	MS filter		Median filter		Sigmoid function	
Variance = 0.01	0.237	0.796	0.086	0.350	0.307	1.054
Variance = 0.02	0.247	0.795	0.114	0.357	0.341	1.051
Variance = 0.03	0.256	0.794	0.136	0.364	0.377	1.048
Variance = 0.04	0.265	0.794	0.155	0.371	0.410	1.045
Variance = 0.05	0.271	0.794	0.166	0.375	0.434	1.043
Total	1.276	3.973	0.657	1.817	1.869	5.241
Ratio	1 : 3.114		1 : 2.766		1 : 2.804	

Same images being compared
Different images being compared

Table 2 Ratio values between two same images being compared and different images being compared for each category

Category	MS filter	Median filter	Sigmoid Function
Right thumb	1 : 3.114	1 : 2.766	1 : 2.804
Right index	1 : 3.398	1 : 3.078	1 : 3.108
Right middle	1 : 3.281	1 : 2.885	1 : 2.979
Right ring	1 : 3.210	1 : 2.891	1 : 2.990
Right little	1 : 3.189	1 : 2.816	1 : 2.855
Left thumb	1 : 3.291	1 : 2.763	1 : 2.937
Left index	1 : 3.359	1 : 2.984	1 : 3.015
Left middle	1 : 3.369	1 : 2.886	1 : 2.968
Left ring	1 : 3.231	1 : 2.716	1 : 2.839
Left little	1 : 3.073	1 : 2.993	1 : 2.921

5.0 DISCUSSION

As can be seen in the Figure 3 and Figure 4, noise in the background of the images was successfully reduced and had cleaner background (white). On top of that, the ridge structures were clearer after MS filter had been applied onto the images. This is important in order to reduce the number of spurious minutiae during features extraction. In Figure 6, it can clearly be seen that the number of detected minutiae before the enhancement is larger than the number of detected minutiae after the enhancement. This result shows that MS filter improved the image by removing the unwanted noise and at the same time improved the contrast to the suitable level.

The effectiveness measurement of this filter was computed based on the distance vector principle. Table 1 shows the ratio values between same images and different images being compared of each filter for first category, right thumb. Ratio value of MS filter is larger compared to median filter and sigmoid function.

Based on Table 2, the ratio value between same images and different images for MS filter of each category is the largest compare to the ratio values of median filter and sigmoid function. Hence, it is proved that MS filter is an effective filter in order to enhance the quality of a noisy image as it can recognize the same fingerprint even though Gaussian noise has been added into the images.

6.0 CONCLUSION

Image quality plays an important role in determining a good result of identification. There were several of noises that damage the quality of those images. This is the reason that it is so important to remove those unwanted noise and proceed to the next process with noise free fingerprint images. In this paper, MS filter as a combination filter between median filter and modified sigmoid function were combined to produce better image quality with clear ridges structure and background. This kind of image is very suitable for Fingerprint Identification System as the input to obtain good minutiae extraction result.

Acknowledgement

This research is supported by the Malaysia Ministry of Higher Education (MOHE). This paper is financial supported by Fundamental Research Grant Scheme (FRGS), Vot No.: R.J130000.7828.4F299.

References

[1] Bhowmik, P., *et al.* 2012. Fingerprint Image Enhancement and Its Feature Extraction for Recognition. *International Journal of Scientific and Technology Research (IJSTR)*. 1(5): 117-121.

[2] Asif, I. K. and Arif, M. W. 2014. Strategy to Extract Reliable Minutiae Points for Fingerprint Recognition. *IEEE International Advance Computing Conference (IACC)*. 1071-1075.

[3] Gupta, A. and Kaushik, Y. 2014. Comparative Study of Noise Removal Techniques. *International Journal of Current Engineering and Technology*. 4(6): 3904-3907.

[4] Kumar, J. and Abhilasha. 2014. Survey on Non Linear Noise Removal Techniques for Salt Pepper Noise in Digital Images. *An International Journal of Engineering Sciences*. 3(2014): 90-95.

[5] Moorthy, M.S., Jayaraj, R., and Jagadeesan, J. 2014. Fingerprint Authentication System using Minutiae Matching and Application. *International Journal of Computer Science and Mobile Computing (IJCSMC)*. 3(3): 616-622.

[6] Babatunde, I. G., Charles, A., and Olatunbosun, O. 2013. Uniformity Level Approach to Fingerprint Ridge Frequency Estimation. *International Journal of Computer Applications*. 61(22): 26-32.

[7] Misra, D .K. and Tripathi, S. P. 2012. A Study Report on Finger Print Image Enhancement Methods. *International Journal of Computer Science and Communication*. 3(1): 163-170.

[8] Watson, C. I. and Wilson, C. L. 1992. *NIST Special Database 4. Database: National Institute of Standards and Technology*. [Internet] From: http://www.nist.gov/srd/nistsd4.cfm.

[9] Watson, C. I. 1993. *NIST Special Database 14, Mated Fingerprint Card Pairs 2 (MFCP2). Database: National Institute of Standards and Technology* [Internet] From: http://www.nist.gov/srd/nistsd14.cfm.

[10] Maltoni, D., Maio, D., Jain, A. K., and Prabhakar, S. 2009. *Handbook of Fingerprint Recognition*. 2nd ed. New York: Springer. 59-74.

[11] Kanan, P., Deepa, S., and Ramakrishnan, R. 2012. Contrast Enhancement of Sports Images using Two Comparative Approaches. *American Journal of Intelligent Systems*. 2(6): 141-147.

[12] Hassan, N. and Akamatsu, N. 2004. A New Approach for Contrast Enhancement using Sigmoid Function. *The International Arab Journal of Information Technology*. 1(2): 221-226.

[13] Balaji, S. and Venkatram, N. 2008. Filtering of Noise in Fingerprint Images. *International Journal of Systems and Technologies*. 1(1): 87-94.