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A NEW FINGERPRINT IMAGE ENHANCEMENT TECHNIQUE WITH APPLICATION OF FILTERS

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ABSTRACT

This research paper is a new design techniques in which different kind of filters are added for fingerprint image enhancement. The images acquired from acquisition devices are not good quality and in turn it has large impact on quality and performance of feature extraction and recognition devices. To have better quality image for further processing and applications, it is necessary to enhance acquired fingerprint image by some method. In open literature study it is found some methods of enhancement either in spatial, frequency and some methods based on fuzzy logic concepts. In this research paper a new method applying different filter in frequency domain is devised and outcome of method is very good result comparative to other methods.

KEYWORDS: Acquisition Device, Fingerprint Image, Fuzzy Filter, Image Enhancement, Image Quality, Ridge and Valley, Spatial and Frequency Domain

INTRODUCTION

Fingertip epidermis depicted on smooth surface form spiral curve like pattern denoted as fingerprint. In defining other way, fingerprint is the friction ridge trace or part of finger on smooth surface. Friction ridges are made of two layers: epidermis and dermis and they are formed during fetal or embryonic development stage of human [1]. Fingerprint image can be acquired by historical conventional ink impression method or new digitalized inkless sensor method. In conventional ink impression method images are obtained by keeping, depressing the finger against tough stratum or on paper but this method is cumbersome and socially un-acceptable in present era of computer society. Due to advent of inkless sensors (e.g. optical, capacitive, thermal and ultrasonic), it has become easy to acquire image in digital form and even acquisition is much more convenient, faster and data storage take very less space [2].But any acquisition method puts up to anomalous (non-linear) deformation in ridges as well as in minutiae point endemic location [3]. The contortion is caused by many factors, some are: Finger orientation towards the sensor, quantum of pressure germane by the object, flair of object, motion of finger, skin moisture and elasticity of the skin etc [3]. The distortion may create prominent quantity of fictitious minutiae and actual minutiae are being disregarded.

Fingerprint image enhancement though pre-processing technique but it suffers a lot with noise caused above. Such acquired poor quality images have low dissimilarity, poorly-defined and indistinct enclosure among ridge and valley [4] and degrades effectiveness of fingerprint image applications. Thus it becomes necessary to enhance image at significant level to eradicate noise in acquired images, improve the quality of image, illuminate parallel ridges and valleys and reconstruct actual image to the possible instant of true image.

Fingerprint enhancement can be applied on either gray-scale or binary image. Binarization process ahead to enhancement [4] proliferate fictitious minutiae and loose precious finger image information. In open literature some techniques with the use of gray-scale image have been found out. Spatial domain enhancement method e.g. histogram equalization [4], Hong's mean and variance normalization method [5], Shlomo .Greenberg et al wiener filter [6] improve the legibility and lucibility of images but have not made any change in ridge structure. Majority of the techniques apply contextual filter having ridge frequency and orientation dependent parameter. L.O'Gorman et al. [7] applied anisotropic smoothening kernel. This kernel has its major axis oriented parallel toward the ridges. Greenberg et al. [6] applied adaptive filter given by Yang et al. [8]. Hong et al. [5] applied frequency and orientation tuned Gabor kernel for enhancement. A. Sherstinsky and R.W.Picard [9] applied joint time-frequency based algorithm. Che-Yen Wen and Chiu-Chung Yu proposed algorithm based on reaction diffusion techniques [10]. Monro et al [11] comply with contextual filter in the frequency domain. D.Bennet & Dr. S. Arumuga Perumal [12] and K. Srinivasan and C. Chandrasekar [13] proposed fingerprint image enhancement applying fuzzy approach.

The paper is re-organized as follows: First part of paper provides information and introduction about fingerprint image and brief history of fingerprint image enhancement. Second part describes filters used in fingerprint image enhancement. Third section brought detail about design block diagram and each filter output. Fourth section is result discussion and fifth section conclusion on design work. Limitation of design and acknowledgement is briefly put for perusal.

Fingerprint Enhancement Domain

In frequency domain filter [4] transfer function is convolved first with Fourier transform of input image and we take reverse Fourier transform to get back enhanced image:

$$g'(x, y) = f^{-1}[H(u,v)\, F(u,v)] \ldots\ldots \quad (1)$$

Where f^{-1} is inverse discrete Fourier transform, F (u, v) is input image discrete Fourier transform and H (u,v) is filter transfer function

In spatial domain filter does operation on image plane and pixels. It can be manifested by: [4]

$$g'(x,y) = T\{f'(x,y)\} \ldots.. \quad (2)$$

Where g'(x, y) is spatial enhanced image, f'(x, y) is input image and T is filter transfer function.

Fingerprint Enhancement Filter

In design and coding shown in figure 1, there are several filters applied. Brief about each filter is put for ready perusal:

- **Edge Filter**

In finger print edges are significance of local change of intensity and they are found normally on the boundary of image between two different regions. In low quality image edges have contrast very low compare to actual image and in grey image foreground and background level are quite similar. To remove this artifact Z.C.Shi et al [14] has proposed grey based algorithm and same is applied to segment and enhance the corners, lines and curves.

- **Gabor Filter**

Gabor filter being a band pass filter applied for edge detection, noise removal, preserving ridge and valley structure in fingerprint image processing. Gabor filters [5] having frequency and orientation selective properties, tuned to match local ridge orientation and frequency enhances ridges in local orientation direction and decreases contrast for others. Even-symmetric spatial 2-D Gabor filter can be re-written as [5]:

$$g(x,y) = \exp\{-\frac{1}{2}[\frac{x^2}{\delta x^2} + \frac{y^2}{\delta y^2}]\} \cos(2\pi u_0 x) \ldots\ldots \quad (3)$$

Where u_0 is the frequency, δx and δy are Gaussian envelope space constants w.r.t. x and y axis respectively. In this design eight number of Gabor filter in form of Gabor kernel is applied. Gabor kernel is defined as:

$$\text{Gabor}(\sigma, \omega, \theta) = \text{Gaussian}(\sigma) * \text{Fourier}(\omega, \theta) \ldots \quad ..(4)$$

Where σ is standard deviation, ω is frequency and θ is orientation.

- **Intensity Calculation**

In the design image intensity cum-enhancement is done with the application of histogram processing and histogram equalization method. Histogram processing of fingerprint image is discrete function and defined as [4]:

$$H(r_p) = n_p \ldots\ldots \quad (5)$$

Where r_p is p^{th} intensity value and n_p is number of pixels in the image with intensity r_p.

Let us assume:

(a) T(r) is monotonically increasing function in the space $0 \le r \le L-1$.

(b) $0 \le T(r) \le L-1$ for $0 \le r \le L-1$

(a)’ T(r) is strictly monotonically rising function in the space $0 \le r \le L-1$.

Then Histogram equalization is defined as [4]:

$$s=T(r) \quad 0 \le r \le L-1 \ldots. \quad (6)$$

Here r denotes the intensity in the range of (0, L-1) to be processed. The condition (a) that T(r) be monotonically increasing and it provide guarantee for output intensity values to remain greater than input values and prevents intensity artifact reversal. Condition (b) satisfies that both output and input intensity range is same. Condition (a)’ provides guarantee of mapping s back to r with exactly same values and prevent ambiguities.

- **Frequency Filter**

Frequency filter is band pass filter and it is defined as $H_{radial}(\rho)$ [15]:

Frequency filter $H_{radial}(u|u_i, u_{min}, u_{max}, b_p, n)$

$$= \{1/X\, f(u|u_i\, b_p, n) \quad u_{min} < |u| < u_{max} \ldots\ldots \quad .(7)$$

0, otherwise

Here

$$f(u|\, u_i, b_p, n) = \frac{1}{(m+n)}\exp\left\{-\frac{(u-u_i)^2}{2b_p^2}\right\} \ldots.. \quad (8)$$

And

$$X = \int f(u|u_i, b_p, n)\, du \ldots \quad (9)$$

Whereas u_i is defined as centre frequency and b_p is Filter Bandwidth. u_{min} lower cut off frequency and it suppresses the effects of ink blotches. u_{max} is higher cut off frequency which suppresses high frequency noise effect. X is filter output normalization factor and 1/(m+n) is added component (factor) to suppress higher frequency noise.

- **Directional Filter**

After frequency, enhancing ridge direction, directional filter $H_{direction}(\phi)$ expressed as:[15]

$$H_{direction}(\phi|\phi_j, \sigma_\phi) = \exp\left[-\frac{\min(\phi-\phi_j+n\pi)^2}{2\sigma_\phi^2}\right] \ldots\ldots \quad (10)$$

Here ϕ_j is filter direction and σ_ϕ is direction bandwidth parameter.

Fingerprint Enhancement

Finger print image enhancement method as designed in figure 1 implemented using MATLAB Version R2013a on Laptop loaded with Windows 7 Home Basic 64 bit OS (operating system). Laptop has been configured with Pentium 4, Intel (R) Core i3 processor @ 2.20 GHz CPU speed with 2GB RAM and used to carry out experiment and simulation. Input image acquired by any sort of acquisition device is made input. In first instance image is normalized to remove imperfection acquired during acquisition process to desired zero mean and variance value of one. Normalized image obtained in figure b reveals that intensity values of ridges are adjusted and equally shifted along-with x-axis by positioning skeleton of ridges and valleys. This step made images contrast very high. Normalization step shown output is shown in figure 2(a) input image and figure 2 (b) is normalized image respectively. This is to be given as input to edge filter.

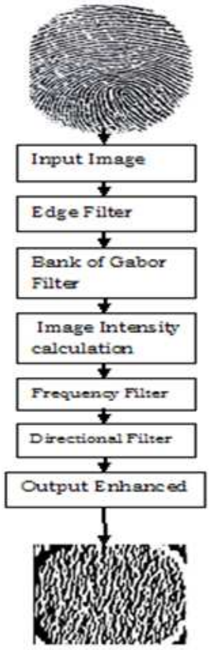

Figure 1: Finger Print Enhancement Block Diagram

Normalized image is cropped and reselected to the input of edge filter. This step select image of 200x200 pixels to remove false minutiae and edges available to the corner of normalized image and improves quality of image in terms of PSNR and MSE. Edges [4] are significant local change of intensity and available on the boundary between two different regions. In this design method and algorithm given by Z. C. Shi et al [14] algorithm for edge enhancement and to segment the image.

Figure 2: (a) Input Image 2(b) Normalized Image

By selecting variance threshold of 100, we can get a very good segmentation result between the foreground and background regions. Foreground regions contains ridges and valleys while the background regions have noise or false minutiae information. In edge filtration corners, lines and curves are filtered from the edges of fingerprint image. The output of filter for input of figure 2(e) is shown in figure 2 (f).

Figure 2: (c) Normalized Image 2(d) Cropped Image

Binarization operations which convert grey scale image into binary image by applying adaptive thresholding [4].This process differentiate between black ridge and white valley pixels. The result of the binarization operation is shown in figure 2(g). The MATLAB’s ‘bwmorph’ operation applying ‘thin’ option generates thinned images. Operation result shown in figure 2 (h) signifies that both ridge thickness and connectivity of ridge structure is well preserved.

Figure 2: (e) Input Image 2(f) Edge Filtered Image for (E)

After binarization process image is transformed and desired image is extracted. The orientation estimation, ridge frequency estimation is done to generate oriented output image. In the enhanced image all blocks and regions may have different denseness. Out of all some block or region may contain high disparateness whereas others low disparateness.

Figure 2: (g) Binarised Result of (2f) 2(h) Thinned Image of (2g)

Binarized and thinned image is given to input of Gabor filter bank (8 no of Gabor kernel) having different orientation. Details of Gabor kernel are: g1(2,0.5,0.7584), g2(2,2,0.7584), g3(2,0.5,1.5708), g4(2,2,1.5708), g5(5,0.5,0.7584),g6(5,2,0.7584), g7(5,0.5,1.5708) and g8(5,2,1.5708). Output response of Gabor kernel is shown in figure 2 (i). Output response of Gabor kernel has two options, it can be made either output or by selecting ‘no option’ in code, it can be made input to next stage for intensity calculation.

For intensity calculation, histogram processing and histogram equalization [4] method applied in the design.Output of Gabor filter have eight image, so we get eight intensity enhanced image as shown in figure 2(j) and figure 2(k) respectively.

Intensity calculation-cum- filtering process enhance and increas the intensity of image.The intense image is fed to frequency filter i.e.band pass filter [15].In this process image is first Fourier tranformed, convolved with frequency filter and again inverse Fourier transformed to get back enhanced image as shown in figure 2(l)

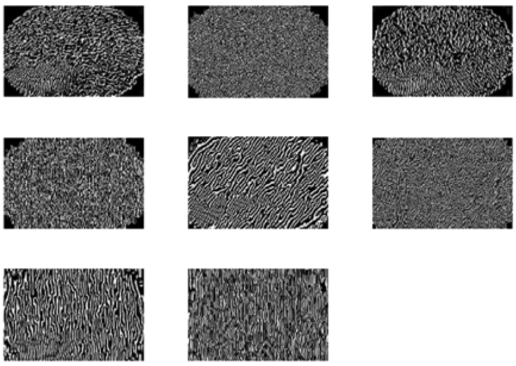

Figure 2: (i) Gabor Filter Output

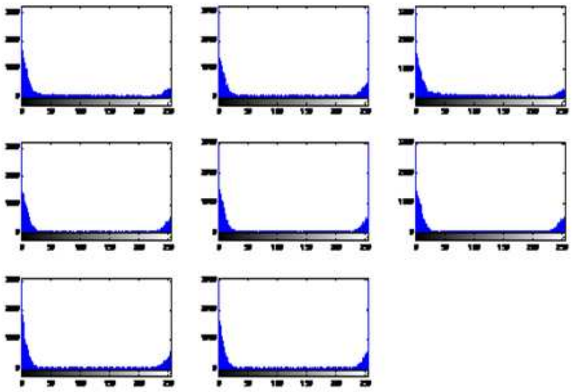

Figure 2: (j) Histogram Processed Image

Frequency filter propitiates unevenness effect in low frequency like ink blackhead and high frequency detonation like perspiration kink, slits and excoriation in the ridges. Frequency filtered image is made input to Direction filter to cover entire region of image to enhance ridge direction. Output of filter is again eight different enhanced images as shown in figure 2 (m).

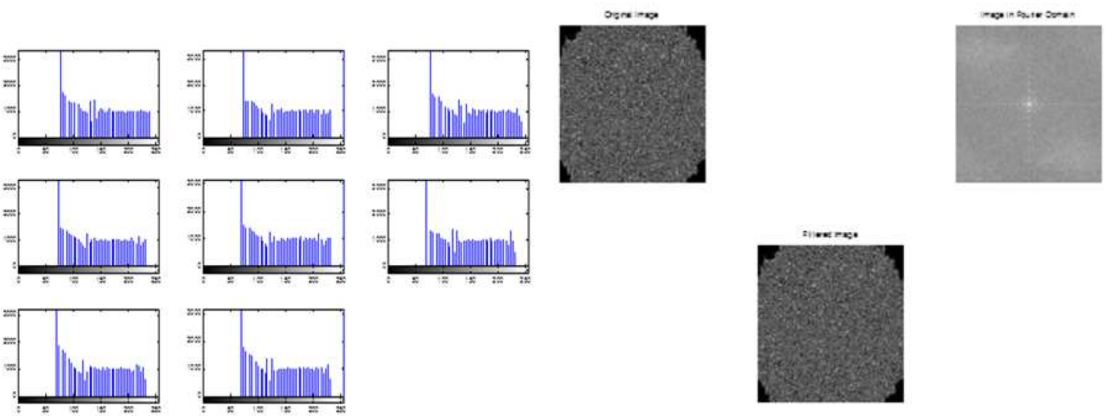

Figure 2: (k) Histogram Equalized Image

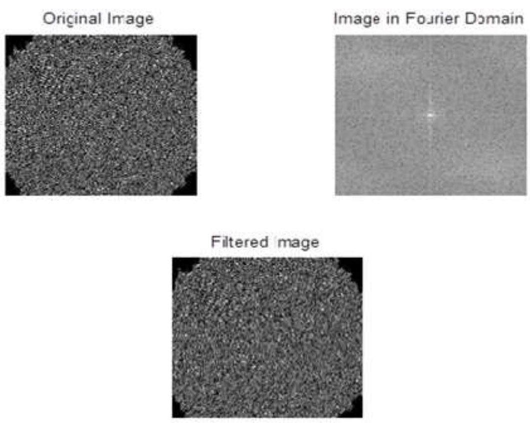

Figure 2: (l)Frequency Filtered Image(1…8)

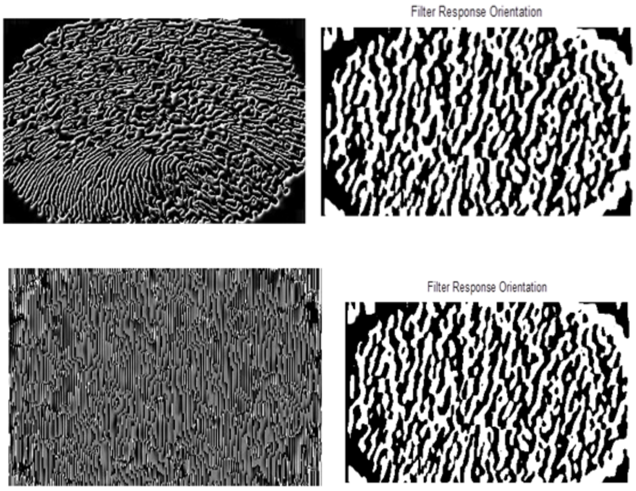

Figure 2: (m) Directional Filtered Image (1…8)

RESULT S

Result of design described in figure 1 provides output result for each filter. They are presented in figure 2(a) to 2(m) for each filter stage. The outcome result is very good enhanced image. In the last we get eight frequency as well as direction filtered output image because of in design eight number of Gabor kernel is applied for orientation enhancement. Provision through coding is done to either one output result or all eight can be obtained as per requirement.

CONCLUSIONS

In this paper a fingerprint enhancement technique with the use of different filter is designed and coded. Though in spatial domain filtering ridge orientation and ridge detection can be performed on one by one pixel basis, but in this design frequency domain method is used which cover complete image during enhancement. First complete image is Fourier transformed, convolved with filter function and then inverse Fourier transformed to get back enhanced image. It is very complex design and output of each filter is made available for further processing and analysis purpose. In the design both ridge direction and ridge frequency enhancement is done simultaneously by two different filter and net outcome result is very good comparative to other methods.

Limitation

Due to complexity in design in frequency domain fingerprint enhancement method has not been much successful. But due to invention of high clock rate, speed processor computational complexity problem is overcome some extent, operation becomes faster and result obtained is useful to industry. Still in obtaining result in each stage of design take much more time (complete enhancement process take approximately 90 second) than it was expected. Final result obtained through frequency and directional filter has eight outputs and based on their requirement user has to take decision to select correct output.

Future Work

Design presented and coding done above (refer figure 1) have much complexity, so obtaining final output is more time consuming. It suffers processing speed problem due to addition of many filters in enhancement process (complete enhancement process take approximately 90 second). Though advent of high clock rate/speed processing computer process is completing faster but still in near future course of action faster processing operation has to be worked out (may be coding/language platform e.g. SQL, RDBMS, Dotnet or some other programming platform which can give fastest output) seeing need of industry and society perspective. User always has apprehension of getting desired output only, so a method has to be incorporated not to provide all output but to get demanded one.

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