An Efficient Fingerprint Enhancement System using Fuzzy Based Filtering Technique

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Abstract

Fingerprint identification is one of the salient areas in biometric identification system. The quality of the fingerprint image is imperative for a veracious matching process. Normally, the contrast of the image is improved during the preprocessing phase of fingerprint matching. Contrast refers to the difference between two contiguous pixels. There are several enhancement techniques available for fingerprint identification. But, these existing techniques are very complex and inefficacious. Hence, in order to conquer the drawbacks of existing techniques, we proposed an efficient and robust fingerprint enhancement technique via fuzzy based filtering. In this paper, a fuzzy modeling approach is employed for removing the noise as well as for improving the luminosity of the ridges. Moreover, the fuzzy filter values are evaluated and superior results are produced in the image domain. The probabilities of gray values are measured from the position of the input image pixel. Finally, the result shows the enhanced performance of the proposed fuzzy filtering technique.

Keywords: Image processing, fuzzy filters, membership functions, noise reduction, morphological operation, High pass filtering.

1. Introduction

Biometrics is the measurement of biological data. Nowadays, the term biometrics is often employed to verify the certification of an individual by examining the corporeal characteristics, such as fingerprints, handprints, eyes and voice, or the behavioral characteristics, such as signatures. Fingerprints are said to be the ridge and furrow patterns on the tip of the finger and are widely used for personal identification of people. Huge numbers of fingerprints are captured and stored each day in a wide range of applications such as forensics, access control, and driver license registration [3]. One of the most leading biometric technologies is fingerprint-based identification, which have received a large amount of attention in recent years. For more than a century, humans are utilizing fingerprints for personal identification and the potency of fingerprint identification has been well established. Today, fingerprint technology is the most widely used technique in personal identification and it has almost become the synonym of biometrics [1].

When compared with token-based or password-based techniques, biometric identification and authentication techniques have provided a considerable handiness as well as some security benefits. These comprise theft detection, cross matching and exposure, trace-ability of individuals and have inspired research about the security of stored biometric data in recent years, mainly focusing on evasion of information seepage [2]. Generally, a ‘better’ featured fingerprint image contains high contrast between ridges and valleys, whereas a poor quality fingerprint has low contrast and indistinct boundaries between ridges and valleys [5]. The performance of any fingerprint recognizer mainly relies on the fingerprint image quality. As well, different forms of noises in the longer print images cause a greater trouble for recognizers. Most of the Automatic Fingerprint Identification Systems (AFIS) have utilized several types of image enhancement techniques. Although numerous techniques are available in the literature, still there is a possibility for proposing better techniques for biometric identification system [17].

The commonly collected fingerprint images based on inked impressions often be affected due to the occurrence of some types of noises such as 1) over inked areas; creating smudgy areas, 2) under inked areas; creating breaks in ridges, and 3) skin being stretchy in nature; changing the positional characteristics of fingerprint features [4]. In an investigation of the related works, we have found many modus operandi for enhancement. The image enhancement algorithm can enhance the transparency of ridges and valleys and the singular point region is the region, wherein the ridge position is higher than the normal structure. Mainly, filter estimation is performed for improving the image quality and linear filters are employed for noise removal, edge recognition, segmentation etc [3]. The main goal of an enhancement technique is to minimize the superfluous noise in the image as much as possible, to increase the transparency of ridge structures of fingerprint images in recoverable regions as well as to remove the irrecoverable regions. Almost all the algorithm can efficiently improve the ridge of the fingerprint, when the fingerprint image is at quite high quality, but the effectiveness of the algorithm is damaged when the fingerprint image is of inferior quality such as: arid, wet or damp, smudge, scars, blurred and wrinkle [4].

To authorize the personal identification of people, an automatic fingerprint image matching process is performed, which efficiently depends on the evaluation of the minutiae points of interest (MPOI) and their associations. A reliable automatic extraction of the MPOI is an important process in fingerprint classification [15]. Both the spatial domain and frequency domain contains merits and demerits. Gabor filter enhances the image on its point of reference, but it is difficult to be precise at the ridge position. Chikkerur *et al*. have proposed an efficient implementation of contextual filtering based on short-time Fourier transform (STFT) [6], where the image was partitioned into small overlapping blocks and Fourier analysis was performed individually on each block. The orientation, frequency and mask region of the image are all estimated at the same time [7]. Majority of these techniques, initially convert the fingerprint images into binary images, and then a thinning process is applied to the obtained images, where the ridge line thickness is reduced to one pixel and finally, the pixels that correspond to minutiae are found by a simple image scan [8]-[9].

A directional filter bank (DFB) has been developed by Bamberger [Bam90] for image analysis in order to enhance the quality of fingerprint image. The algorithm along with DFB has decomposed a fingerprint image into several directional subband images and produced an enhanced output image by combining the filtered outputs, which are blocks with the utmost energy among the subband images. Park [San99] has presented a DFB based enhancement system, where visualizable subbands are created to facilitate pixel processing. When an input image is splitted based on its directionality, the pixels in the local block of the subband image that has the maximum energy and those in the two blocks of the contiguous subband images were taken and combined to increase the local linear attribute [10]. The pixel oriented augmentation techniques such as histogram equalization [11], mean and variance normalization [12], Wiener filtering [13] increases the lucidity of the fingerprint, but does not change the ridge structure. Moreover, the definition of noise in a normal image and a fingerprint are broadly unlike.

In some binarization-based techniques, the binarization and thinning process are preceded by a smoothing operation, based on intricacy with a Gaussian mask [14], to standardize the preliminary image. Shlomo Greenberg et al. [15] have proposed a scheme via a unique anisotropic filter for direct gray-scale enhancement. Whereas, Muna F. Hanoon has created an optimal quantization codebook iteratively for a given unique quantization codebook that was created based on the transmitter's quantization codebook. Algorithm executed in fingerprint compression using VQ codebook was calculated from many prior training images [16]. In the existing research done using Traditional Gabor Filter (TGF) technique, there is an assumption that the parallel ridges and valleys show some perfect sinusoidal-shaped plane waves related with some noises, and then the TGF was extended to Modified Gabor filter (MGF) by rejecting the imprecise former sinusoidal plane wave assumption. Here, the MGF's parameters were purposely represented by some principles rather than experience and an image independent parameter selection scheme was applied [12].

The rest of the paper is structured as follows: section 2 describes some of the recent related works. Section 3 discusses about the fingerprint enhancement techniques. Section 4 describes about the proposed fuzzy based filtering technique for fingerprint enhancement. Section 5 illustrates the experimental results and analysis of the proposed methodology. Finally, Section 6 concludes the paper.

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2. Related Work

A handful of researches present in the literature deals about the fingerprint enhancement and filtering techniques. Today, Gabor filtering is playing an essential role in fingerprint enhancement. A concise review of some recent researches is portrayed here:

Abdullah Bal *et al.* [13] have proposed a supervised filtering technique based on a dynamic neural-network approach for constructing an efficient fingerprint enhancement algorithm. Here, a joint transform correlation (JTC) algorithm has been used for pattern matching, which has offered a high processing speed for real-time applications. They have mainly utilized this fringe-adjusted JTC algorithm for recognition purpose because it has ability to produce a better correlation output than the alternate JTCs.

Sharat Chikkerur *et al.* [14] have proposed a Short Time Fourier Transforms (STFT) Analysis based approach for fingerprint enhancement. STFT is an eminent technique in signal processing employed for analyzing the non-stationary signals. Here, they have extended its application to 2D fingerprint images. All the essential properties of the fingerprints namely the foreground region mask, local ridge orientation and local ridge frequency have been evaluated simultaneously by the algorithm. Moreover, a probabilistic approach has been employed for effectively evaluating the parameters.

Majority of the fingerprint identification approaches are based on minutiae matching and have been widely investigated. But, these technologies still undergo many problems such as the handling of bad (poor quality) impressions and so on. Distortion is one of the main problem occur while fingerprint matching. Distortion alters both the geometric position as well as orientation, and cause difficulties in determining a match between several impressions obtained from the same finger tip. Specifying all the minutiae precisely and removing fake minutiae is another important problem, which is still under research. Manvjeet Kaur *et al*.[15] have constructed a minutia extractor and a minutia matcher by integrating several techniques. The amalgamation of multiple techniques comes from a wide investigation into research papers. Furthermore, in their research work, they have used segmentation using Morphological operations, enhanced thinning, false minutiae removal techniques, minutia marking with special considering the triple branch counting, minutia amalgamation by dividing a branch into three terminations, and matching in the unified x-y coordinate system after a two-step transformation.

Wei Wang *et al*. [16] have developed two techniques for fingerprint image enhancement. The first technique has been done using local histogram equalization and noise reduction filters, whereas in the second, a wavelet transform and a contourlet transform which was an extension of the wavelet transform in two dimensions has been applied. Moreover, a technique has been introduced to identify the fingerprints using artificial neural network (ANN), which has been trained by means of Finger Code dataset obtained from a filter bank. A fixed length feature vectors have been acquired for each fingerprint, and these vectors have been applied to a matching process via ANN.

Extensive research of automatic fingerprint identification system (AFIS), although started in the early 1960s, no satisfactory solution has been found till now for reliable fingerprint identification problem. A reliable extraction of features (mostly minutiae) from the input fingerprint image is the salient step for AFIS precision. However, the efficacy of a feature extraction is chiefly based on the quality of the input fingerprint images. Hence, the fingerprint enhancement module in fingerprint recognition system has been combined to create the system more efficient with respect to the quality of input fingerprint images. Andelija M. Raicevic *et al.* [17] have proposed an adaptive filtering in frequency domain for improving the fingerprint image quality.

Bashar Nema and Hamza Ali *et al*. [18] have proposed an approach for the creation of long and secure code for versatile applications, such as ATM, coded door locks and other safety purposes. Their technique includes two stages: the first stage has been performed using fingerprint image enhancement and thinning, whereas the second phase comprises extracting minutia, ridge ending, bifurcation and all other features to make the initial pattern. Finally, the one-way MD5 hash function has been applied on that pattern for producing multipurpose secure code.

P. Viswanathan and P. Venkata Krishna *et al.* [19] have addressed the fingerprint identification problem using their proposed Morlet wavelet based algorithm. This algorithm contains two phases. In the initial phase, the contextual information like frequency and orientation of the image has been analyzed by using wavelet analysis. And in the second phase, Gabor filtering has been utilized for smoothening and eliminating the noise. Good ridge continuity has been obtained with compression and the bogus minutia has been removed by Gabor filtering.

The main target of the fingerprint enhancement algorithm used in the fingerprint identification system is to diminish the noise present in the image. The occurrence of scars, variations of the pressure between the finger and acquisition sensor, damaged artifacts, and biological conditions during acquisition process are the factors that impinge the quality of the obtained fingerprint image. Hence, an input fingerprint image has been transformed by the enhancement algorithm in order to eradicate the noise present in the image. M. M. Kazi *et al.* [20] have performed the research using a new database of fingerprint images obtained with a 500dpi optical sensor. Here, three diverse enhancement algorithms have been applied on the images and the qualities of the renovated images have been compared in terms of mean-square error and peak signal to noise ratio.

One of the most salient areas in biometric identification is fingerprint recognition. The quality of the fingerprint image is very significant one for a faithful matching process. Generally, the contrast of the image has been increased on the preprocessing phase of fingerprint matching. Contrast refers to the difference between two contiguous pixels. Dr.S.Arumuga Perumal *et al.* [21] have proposed a fuzzy modeling approach for diminishing the noise as well as for improving the vividness of the ridges. Here, the fuzzy filter values have been evaluated and better results have been obtained in the image domain. Also, the probabilities of gray values have been measured from the position of the input image pixel.

Fingerprint identification is a propitious factor for the Biometric Identification and authentication process. Only the noise free image can obtain a high quality fingerprint. So, the preprocessing methods need to be applied on the image for obtaining a noise-free fingerprint image. Dr. E. Chandra *et al.* [22] have described the finger print classifications, characteristics and preprocessing techniques. Here, a histogram-equalized image has been obtained by applying the histogram on 256 gray scale fingerprint image with the default threshold value. Then, the binarization process has been performed on this histogram-equalized image. Finally, the binarized fingerprint image has been filtered by using Median filtering technique to create the noiseless image. Moreover, from the comparison of the median filtered image with the original noisy image, they have found the intensity of the noise spread in the original image.

3. Fingerprint Enhancement Techniques

Normally, fingerprints are the traces of an impression from the friction ridges of any part of a human hand. Fingerprint recognition is the most imperative area in biometric identification. The quality of the fingerprint image is very significant one for a faithful matching process. Images can be tainted by diverse types of noise, for several reasons. For instance, noise can arise due to the circumstances of recording, transmission, storage, copying, scanning and so on. The two most frequently found noises are impulse noise and additive noise. It is a great challenge for the researchers to propose efficient algorithms that can eradicate noise from the image without affecting its content. Consequently, fingerprint image enhancement is usually the initial step in most of the automatic fingerprint identification systems (AFIS). For fingerprint comparison, majority of the automatic systems are based on minutiae matching. Minutiae features are local discontinuities in the fingerprint pattern, which describe terminations and bifurcations. The main reason for performing enhancement is to eradicate the noise in the fingerprint images, illuminate the parallel ridges and valleys, and protect the true configuration of them. The efficiency of minutiae extraction algorithms is greatly depends on the quality of the fingerprint images. In order to obtain robust performance of a minutiae extraction algorithm, an enhancement algorithm that can improve the transparency of the ridge structures, is very essential. Fingerprint enhancement can be performed on either binary ridge images or gray-scale images. Sometimes, the binarization process may leads to information loss about the true ridge structure, and it has intrinsic limitations.

The accuracy of the fingerprint image is severely affected when a distortion occurs. There are two major reasons for the occurrence of fingerprint distortion. First, the acquisition of a fingerprint is a 2D or 3D warping process. The fingerprint collected from several contact centers often results in diverse warping mode. Second, fingerprint distortion will be happened due to the non-orthogonal pressure of people applied on the sensor. Normalization technique is utilized to avoid these types of distortions. Normalization is employed to eradicate the impact of sensor noise and finger pressure dissimilarity. Fuzzy image processing is not a unique theory. It is a compilation of several fuzzy approaches to image processing. Fuzzy image processing is the collection of all approaches that realize, represent and process the images, their segments and features as fuzzy sets. There are three main processes in fuzzy image processing: image fuzzification, modification of membership values and image defuzzification. The use of expert knowledge is indispensable in several image processing applications for overcoming the difficulties.

Fuzzy set theory and fuzzy logic provides robust tools to understand and process the human knowledge in form of fuzzy if-then rules, whereas, on the other hand, numerous difficulties have been occurred in image processing because the data/tasks/results are indecisive. However, this indecision is not only due to randomness but also due to the ambiguity and vagueness. In order to achieve the best image for the identification process, it is indispensable to preprocess the image before conducting meaningful pattern recognition exercises with the images. The recognition process becomes difficult when the original image might be contaminated with considerable noises. Processing, diminishing or eradicating those noises is a vital step in the recognition process. Frequency transformation decomposes an image from its spatial domain intensities into a frequency domain. The frequency transformation represents the frequency of pixel brightness variations, pattern change and the amplitude of the signal waveform. Moreover, frequency domains are performed for selective elimination of noise pattern from an input image. Filtering approach is a way of tracking the pixel values from its nearby locations. The mean and the standard deviations of such neighborhood are employed for contrast improvement.

4. Fingerprint Enhancement System Using Fuzzy Based Filtering

Today, fingerprint recognition technology is extensively applied in the personal identification for achieving higher level of security. Fingerprint image enhancement is an indispensable preprocessing step in fingerprint recognition applications. The quality of the input fingerprint image is very important for improving the effectiveness of a fingerprint feature extraction as well as matching algorithm. The Fuzzy statistical values are measured based on the gray intensity of the spatial domain. The image intensity is transformed by means of a specified Probability Density Function (PDF). The Cumulative Density Function (CDF) is utilized in accumulating pixel values in an ordered manner for increasing the contrast. The smooth fingerprint image with minute noise is formed in the output domain. The general structure of the proposed technique for fingerprint enhancement is shown in Fig. 1. The major processes that take place in our proposed technique are image fuzzification, membership modification and the image defuzzification. The fuzzification (coding of image data) and defuzzification (decoding of the results) are the steps, where the images are processed with fuzzy techniques. The modification of membership values is the main step in fuzzy image processing, which is performed after fuzzification. That is, after the image data are converted from gray level plane to the membership plane (fuzzification), the membership values are altered by suitable fuzzy techniques. This can be called as fuzzy clustering, a fuzzy rule based approach, a fuzzy integration approach and so on. The proposed technique to enhance the fingerprint has the following stages:

A. Preprocessing
B. Image Fuzzification
C. Membership Modification

D. Image Defuzzification
E. Morphological operation
F. High pass filtering

A. Preprocessing

The goal of fingerprint enhancement technique is to process an input image $I(x, y)$ and to produce more appropriate result for identification. The enhancement algorithm reduces the noises from the input image. The input image $I(x, y)$ is defined as a $M \times N$ matrix, where $I(i, j)$ represent the gray of the pixel at the i^{th} row and j^{th} column.

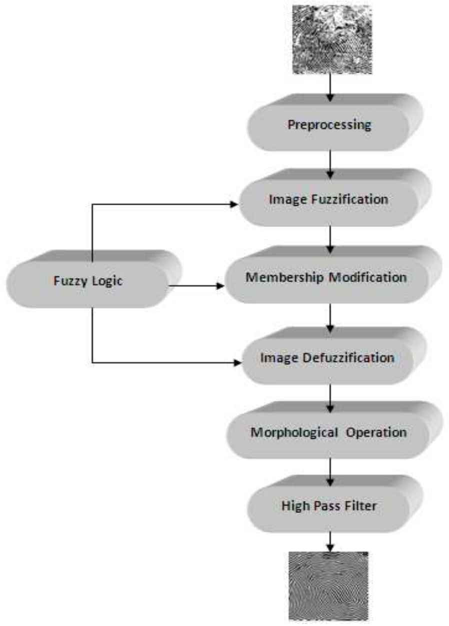


Fig. 1: Block diagram of the proposed work

To produce a better fingerprint image, the image must be preprocessed before the smoothing process starts. In this stage, the size of the image is reduced into 256 pixels for the convenient input to the process system. Then, each pixel value of the image is rearranged by decreasing the pixel density value by 255. In this preprocessing stage, the image density values are interchanged i.e., white regions to black and black regions to white. The preprocessed image is then subjected to the proposed method of fuzzy based enhancement.

B. Image Fuzzification

Fuzzification is a process of converting the crisp values into grades of membership for linguistic terms of fuzzy sets. Fuzzy sets represent the statistical value based on the theory of Fuzzy sets. A gray scale transformation may succeed in preserving edges in one image and it may fail in another one. Fuzzy statistical values can enhance the quality of the input image by eliminating noises and improving the intensity segments.

C. Membership Modification

Let us, consider the grayscale image be represented by a matrix I of size $M \times N$,

$$I = \{I(i, j) \in \{0,1,\cdots,255\}\} \tag{1}$$

Where $i = 1,2,\cdots,M$ and $j = 1,2,\cdots,N$. Then, the similarity function can be written as

$$\mu : [0;\infty \to R) \tag{2}$$

Consider the following assumptions for ζ:

1. ζ is decreasing in $\zeta[0;\infty)$,
2. ζ is convex in $\zeta[0;\infty)$,
3. $\zeta(0) = 1,\ \zeta(\infty) = 0$.

In this stage, the central pixel in the window W is replaced by that one, which maximizes the sum of similarities between all its neighbors. Basic assumption is that a new pixel must be taken from the window W. The Fig.2 represents the filtering window. *P(i,j)* represents the center pixel of the window W.

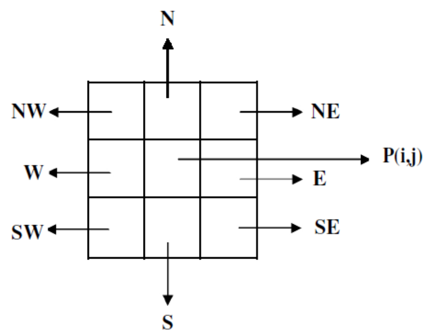


Fig. 2 Filtering window

For each pixel (i, j) of the image (that isn't a border pixel) use a 3×3 neighborhood window. Each neighbor with respect to (i, j) corresponds to one direction $\{NW = North\ West$, $N = North$, $NE = North\ East$, $W = West$, $E = East$, $SW = South\ West$, $S = South$, $SE = South\ East\}$. These directions relating to (i, j) can also be linked to a certain position. The table 1 represents the position of each direction and its corresponding gradient directions.

Table 1 Gradient directions of the pixel positions

Position	**Direction**	**Gradient Directions**
(i-1,j-1)	*NW*	SW,NE
(i-1,j)	*N*	*W,E*
(i-1,j+1)	*NE*	*NW,SE*
(i,j-1)	*W*	*N,S*
(i,j+1)	*E*	*N,S*
(i+1,j-1)	*SW*	*NW,SE*
(i+1,j)	*S*	*W,E*
(i+1,j+1)	*SE*	*SW,NE*

Each direction R corresponds to central position. In Table 1, the column 2 shows the basic gradient for each direction and column 3 shows the two related gradients. The fuzzy gradient value for direction R is calculated by using following fuzzy rule:

$IF\ \left|\nabla_R P(i,j)\right|\ is\ large\ AND\ \left|\nabla'_R P(i,j)\right|\ is\ small$

OR

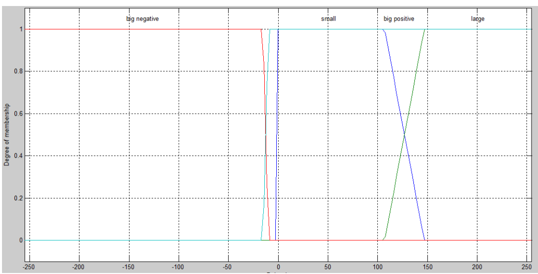
$\left|\nabla_R P(i,j)\right|\ is\ large\ AND\ \left|\nabla''_R P(i,j)\right|\ is\ small$

OR

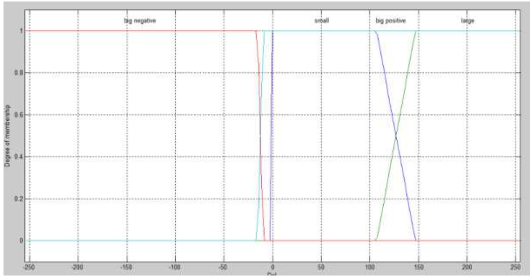
$\left|\nabla_R P(i,j)\right|\ is\ big\ positive\ AND$
$\left(\nabla'_R P(i,j)\ AND\ \nabla''_R P(i,j)\right)\ is\ small$

$THEN\ \left|\nabla_R^F P(i,j)\right|\ is\ large$

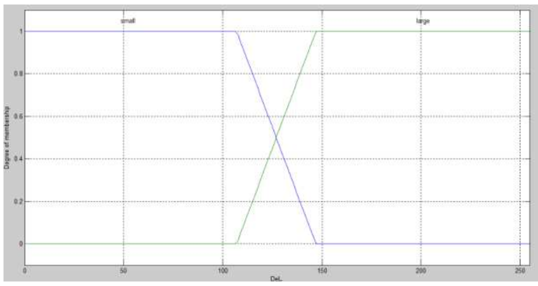
The membership functions are described by the following figures.



(a)



(b)



(c)

Fig. 3: Member ship functions used in the proposed system (a) and (b) represents the Big and small respectively c) represents Big positive and bid negative

The pixels of the image are arranged in these membership functions. The noisy pixels are then sort out. The noisy pixel values are then changed according to the following formula

$$I(i,j)=\frac{\sum_{k=-1}^{1}\sum_{l=-1}^{1}\left[1-\zeta(P(i+k,j+l))\right]P(i+k,j+l)}{\sum_{k=-1}^{1}\sum_{l=-1}^{1}1-\zeta(P(i+k,j+l))} \quad (3)$$

D. Image Defuzzification

De-fuzzification process is done using the fuzzy statistical value for obtaining an improved specification image. De-fuzzification is a process, which maps a fuzzy set to a crisp set. De-fuzzification is a reverse process of image fuzzification. When compared to other processes involved in fuzzy systems and technologies, the defuzzification has drawn not as much of attention. The simplest but least practical defuzzification technique is used to select the set with the highest membership. These will have a number of rules that convert a number of variables into a fuzzy result, which is described in terms of membership in fuzzy sets.

E. Morphological operation

Contemporary data and image processing includes more and more the analysis and processing of matrix-valued data. In this phase, the output gray scale image is converted into binary scale image. Morphology is a biological term that deals with the structure and shapes of approaches to find more appropriate for the fingerprint image enhancement. Morphology provides a unified and robust approach for the improvement of fingerprint structure. In mathematical morphology, the objects enclosed in an image are compared with known object called structuring element. Morphological operation is performed by comparing the output image with the original image. The error pixels are renovated by considering the neighborhood 3x3 pixels of the original image. The error pixel can be recovered by considering the neighborhood 3x3 pixels of the original image. The new pixel will be the average of the mean and the median of the neighborhood pixels. . In a morphological operation, the value of each pixel in the output image is based on a comparison of the corresponding pixel in the input image with its neighbors. By choosing the size and shape of the neighborhood, we can construct a morphological operation that is sensitive to specific shapes in the input image. Here we are taking a morphological operation area opening.

Area opening:

From a binary image **t**he filter that its connected components with area smaller than a parameter λ is called area opening. From a morphological perspective, this filter is an algebraic opening, and it can be extended to grayscale images. In particular, the area opening of parameter λ of an image I is the supremum of the grayscale images that are smaller than I and whose regional maxima are of area greater than or equal to λ.It can be defined as:

Let $X \subset M$ and $\lambda >= 0$. The area of opening of parameter λ of X is given by

$$\gamma_{\lambda}^{a}(X) = \{x \in X \mid Area(C_x(X)) >= \lambda\} \qquad (4)$$

Apparently, if $(X_i)_{i \in I}$ denote the connected components of $X, \gamma_{\lambda}^{a}(X)$ is equal to the union of X_i's with area greater than or equal to λ:

$$\gamma_{\lambda}^{a}(X) = \bigcup\{X_i \mid i \in I, Area(X_i) >=\} \qquad (5)$$

F. High pass filtering

High Pass filter is normally used to carry out the image modifications, improvements, noise diminution, etc., via the designs done in either the spatial domain or the frequency domain. The high-pass filter defines a small transfer function values sited around the origin or the low frequency side, whereas the large values are located outside this area. Sometimes, the output image has some dots or plane surface after the enhancement. We have applied a high-pass filter to eradicate the low frequency components that correspond to the background intensity and are immaterial to the identification process. Hence, the image is passed through a high pass filter to eradicate the low frequency components by comparing the original image.

5. Results And Discussion

In this section, we illustrate the effectiveness of the proposed fingerprint enhanced system by means of the results obtained from the experimentation. The proposed technique is implemented in MATLAB (Matlab 7.10). The quality of the reconstructed images is determined by measuring the PSNR. Here, a FVC2002 fingerprint database is used for enhancement.

DATABASE: FVC2002

Four diverse databases (DB1, DB2, DB3 and DB4) have been captured by using the following sensors/technologies:

DB1: optical sensor "TouchView II" by Identix

DB2: optical sensor "FX2000" by Biometrika

DB3: capacitive sensor "100 SC" by Precise Biometrics

DB4: synthetic fingerprint generation

Each database is 110 finger wide (w) and 8 impressions per finger deep (d) (880 fingerprints in all). The finger from 101 to 110 (set B) have been made available to the participants to allow parameter tuning before the submission of the algorithms. The benchmark is created by the fingers numbered from 1 to 100 (set A). The sample output obtained from the proposed technique is as follows.

Fig. 4: Sample images in the database.

Sample images in the fingerprint database are shown in Fig. 4. Then, by using fuzzy based filter, the fingerprint images are filtered. The quality of the pixels are improved by using fuzzy logic, which is illustrated in Fig. 5.

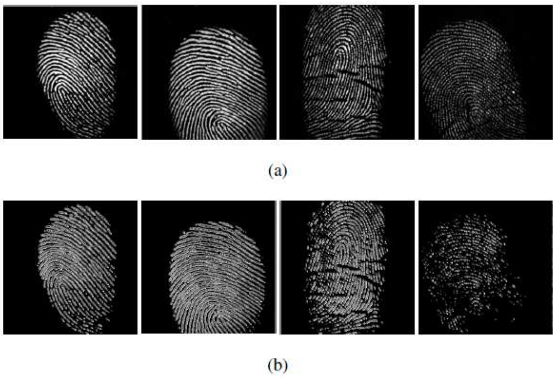


Fig. 5 The sample output obtained from the enhancement process using fuzzy logic a) original images b) enhanced images

After enhancing the quality of the pixels in the fingerprint image using the fuzzy logic, the thinning process is performed. This is described in Fig. 6. And, Fig.7 shows the final enhanced fingerprint images obtained by performing the morphological operations and high pass filtering.

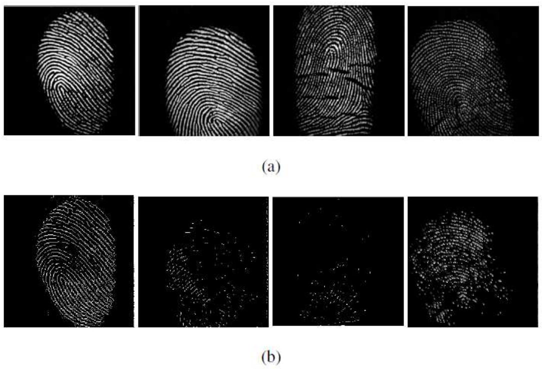


Fig. 6 The sample output obtained from the thinning process a) original images b) thinned images

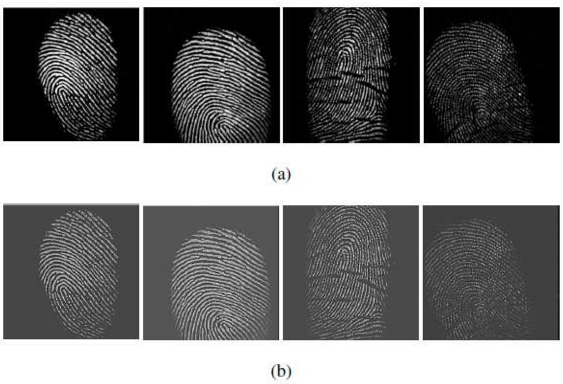


Fig. 7 The sample output obtained from the highpass filtering process a) original images b) filtered images

Comparative Analysis

To calculate the performance of the enhancement method in the proposed system, the Peak Signal to Noise Ratio (PSNR) based on the Mean Square Error (MSE) is used as a quality measure and its value can be determined using the following equation

$$PSNR = 20\log\left(\frac{(255)^2}{MSE}\right)dB \quad (4)$$

$$MSE = \frac{1}{MN}\sum\left(\hat{f}(x,y) - f(x,y)\right)^2 \quad (5)$$

Here MN is the total number of pixels in the image. $\hat{f}(x,y)$ is the decompressed image and $f(x,y)$ is the original image.

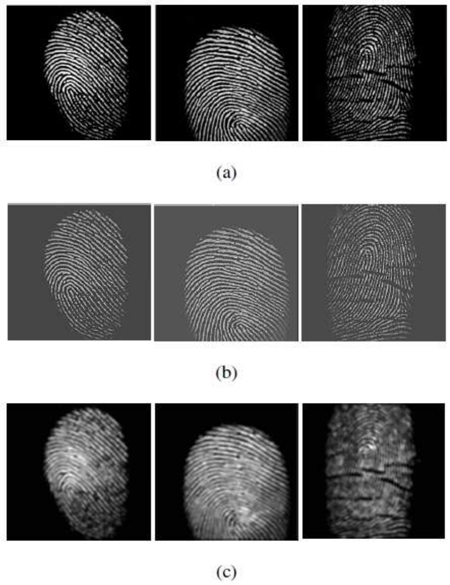


Fig. 8 Comparison of proposed method with other existing method a) original images b) enhanced images by using proposed method c) enhanced image by using Gabor filtering.

Fig. 8 illustrated that the proposed system gives better performance when compared to the Gabor filtering method. The visuality of the enhanced image of proposed method is high. The PSNR and SNR comparison are described as follows.

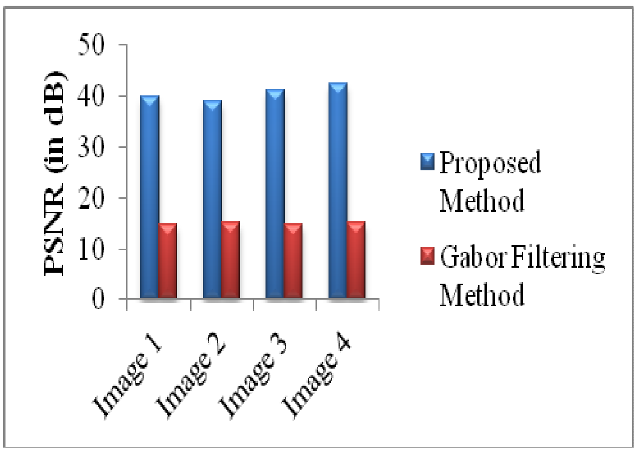


Fig. 9 PSNR comparison

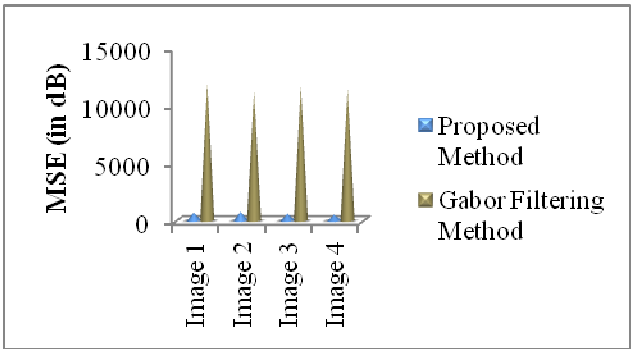


Fig. 10 SNR comparison

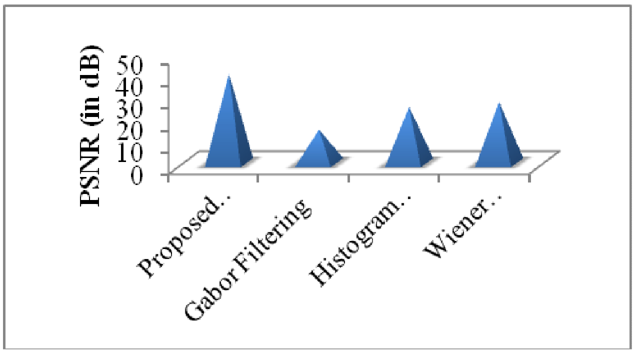


Fig. 11 PSNR comparison between proposed method and existing method.

From Fig. 9 and Fig. 10 we observed that the proposed method is better than the existing fingerprint enhancement system based on gabor filtering. The PSNR and SNR values for the existing as well the proposed method is given in table 2.

Table 2 Performance measure for sample images

Sample images	Performance Analysis			
	PSNR		MSE	
	Proposed Method	Existing Method	Proposed Method	Existing Method
Image 1	39.7477	14.8479	674.6792	1.19E+04
Image 2	38.7916	15.3799	753.1796	1.12E+04
Image 3	40.9302	15.0215	588.8058	1.16E+04
Image 4	42.4705	15.21	493.1217	1.14E+04

The proposed fingerprint enhancement system using fuzzy based filtering techniques gives high PSNR and low MSE when compared to the gabor filtering based fingerprint enhancement method. The proposed work is further compared with other existing enhancement techniques such as histogram equalization and wiener filtering etc. the results is described in the following table.

Table 3 Performance Analysis

Methods	Performance Analysis	
	PSNR	MSE
Proposed Method	40.485	6.27E+02
Gabor Filtering	15.11	1.15E+04
Histogram Equalization	25.54	5.34E+03
Wiener Filtering	27.69	4.51E+03

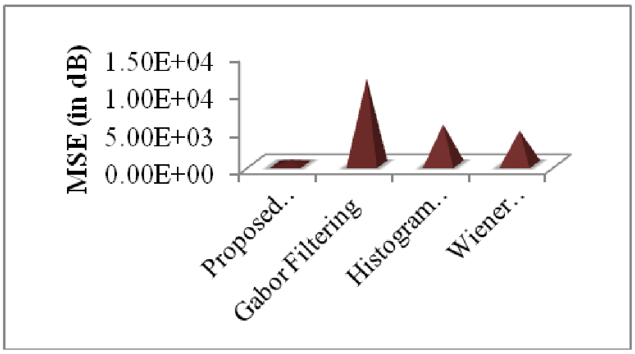


Fig. 12 MSE comparison between proposed method and existing method.

Histogram equalization, Gabor filtering and Wiener Filtering are the common methods used for fingerprint enhancement. Here we compare our proposed method with these existing method. From Fig. 11 and Fig. 12, we observe that our fuzzy based filtering technique for fingerprint enhancement gives better PSNR and lower MSE value when compared to the other existing methods. Hence the proposed fingerprint enhancement system effectively enhances the images and it will give better result in fingerprint recognition process.

6. Conclusion

In this paper, an efficient fingerprint enhancement technique via fuzzy based filtering was proposed for enhancing the contrast of fingerprint images. The proposed fingerprint enhancement algorithm has improved the transparency of ridges and valleys of the input fingerprint image. Fuzzy logic has provided a different approach on histogram specification for image enhancement. The intensity values generated by fuzzy histogram were used for increasing the contrast of the input image. The conventional filtering techniques cannot deal with the narrow intensity gray values. But, our proposed technique has solved the problem of narrow and wide gray range images. The proposed algorithm was tested with different types of fingerprint images and the result has shown that the quality of the generated images were very high with less noises.

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