An Efficient Fingerprint Denoiser for Fingerprint Recognition

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ABSTRACT

Fingerprint identification is one of the oldest and popularly used forms of biometric identification system. Fingerprint image quality is of much importance to achieve high performance in Automatic Fingerprint Identification System (AFIS). Most of the fingerprint Recognition system relies on fingerprint ridges to extract the features. The fingerprint images which are corrupted due to variations in skin and impression conditions may reduce the efficiency of the feature extraction module. Therefore an efficient and a robust fingerprint image denoiser is necessary to overcome the challenges faced by the existing techniques. In this paper a new fingerprint image denoiser based on wavelets and contrast based grouping is proposed. The proposed model is compared with the existing algorithms. Experimental results proved that the proposed model is efficient in denoising the fingerprint image.

Keywords

Fingerprint quality, ridges, AFIS, wavelets, contrast based grouping.

1. INTRODUCTION

Fingerprints are widely used in a variety of security applications .Fingerprints are unique to each person and do not change overtime. Hence it is considered to be a more reliable approach in solving personal identification problems. Fingerprints are graphical patterns present on human fingers which are called ridges. A ridge is defined as a single curved segment and a valley is the region between two adjacent ridges [6].A fingerprint recognition system usually consists of four processes beginning with ridge enhancement, feature extraction, classification and matching. A fingerprint is captured either by scanning an inked expression of a finger or using live scan fingerprint scanners. The quality of the fingerprint plays a major role in an automatic fingerprint recognition system. There are several types of degradation associated with fingerprint images [6]:

1. The ridges are not strictly continuous; that is, the ridges have small breaks (gaps).

2. Parallel ridges are not well separated. This is due to the presence of noise which links parallel ridges, resulting in their poor separation.

3. Cuts, creases, and bruises.

Therefore a good enhancement technique is necessary to improve the quality of the fingerprint image so that the resulting enhanced image becomes appropriate for feature extraction and matching process which leads to a recognition system with high accuracy.

The paper is organized as follows; Section 2 presents a Background study on the different fingerprint enhancement techniques. Section 3 presents the proposed method for enhancement of fingerprint image. Experimental results are shown in section 4, and finally a brief conclusion section will summarize the paper.

2. PREVIOUS WORK

Several methods have been proposed to enhance the quality of the fingerprint images. Fingerprint enhancement algorithms can be classified into two groups [13] spatial domain filtering enhancement techniques [3],[1],[14] and transformed domain enhancement techniques [11],[12],[9] such as Fourier domain and wavelet domain, filtering. Spatial domain techniques are computationally expensive since it involves spatial convolution of the image with filters. Gabor filter have been widely [2], [8], [10], [17] used to facilitate various fingerprint applications such as fingerprint matching and classification. Gabor filters are band-pass filters that have both frequency-selective and orientation-selective properties [4].In practice, there are three typical methods to enhance the fingerprint images: Gabor filter, anisotropic filter and topographic analysis. However, all of them are time-consuming and complicated. As an alternative to the above mentioned filters, [4] and [15] used a Gaussian-shape mask or low pass filter to filter the selected section in every tracing step. Wavelet transform (WT) [5] has proved to be effective in noise removal. Although WT has demonstrated its efficiency in denoising, it uses a fixed wavelet basis (with dilation and translation) to represent the image. For fingerprint images, however, there is a rich amount of different local structural patterns, which cannot be well represented by using only one fixed wavelet basis. Therefore, WT-based methods can introduce many visual artifacts in the denoising output. PCA is a classical de- correlation technique in statistical signal processing and it is pervasively used in pattern recognition and dimensionality reduction, etc. By transforming the original dataset into PCA domain and preserving only the several most significant principal components, the noise and trivial information can be removed. Generally, in PCA-based schemes [7] a moving window is used to calculate the local statistics, from which the local PCA transformation matrix is estimated. However, as PCA is directly applied to the noisy image without data selection, many noise residual and visual artifacts appears in the denoised outputs

In NLM, [16], each pixel is estimated as the weighted average of all the pixels in the image, and the weights are determined by the similarity between the pixels. However, the algorithm has high complexity because of the average distance calculation of similar image pixels. To solve the problem of PCA-based model, [19] proposed a two stage image denoising that combined Principal Component Analysis (PCA) with Local Pixel Grouping (LPG).Here, pixel and its nearest neighbors is modeled as a vector variable. The training samples of this variable are selected by grouping the pixels with similar local spatial structures to the underlying one in the local window. With such a procedure, the local statistics of the variables are accurately computed so that the image edge structures are well preserved after shrinkage in the PCA domain for noise removal. This model is referred to as LPG-PCA Model. This method has the disadvantage that while performing efficient denoising, in some cases, it introduced ‘staircase’ artifacts and blurring edges. Moreover, time complexity of the algorithm is high

In this paper we present an efficient fingerprint denoising model which combine wavelets with LPG-PCA to remove the unwanted staircase and blurring effect caused by the model. And also an enhanced k-means clustering algorithm with a contrast based segmentation method is proposed to reduce the time complexity.

3. PROPOSED MODEL

The proposed model as shown in fig.1 has four steps. Initially the model uses an enhanced kmeans clustering algorithm to extract the fingerprint. Then discrete Wavelet transformation is applied on the noisy region. As step 3 a contrast based grouping method is used to model a noisy pixel and its nearest neighbors. This is stored as a vector variable and denoising is done by converting the noisy pixel into estimation. The estimation is performed using Principal component analysis technique. An important property of PCA is that it fully de-correlates the original dataset X. Generally speaking, the energy of a signal will concentrate on a small subset of the PCA transformed dataset, while the energy of noise will evenly spread over the whole dataset. Therefore, the signal and noise can be better distinguished in the PCA domain. Finally the inverse Discrete Wavelet Transformation is applied to get the denoised fingerprint Image.

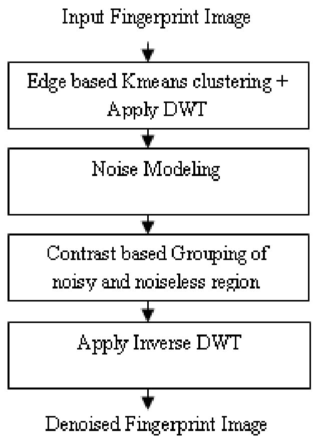


Fig1.Block Diagram of the fingerprint denoising model

3.1 Edge based Kmeans clustering

K means clustering is one of the simplest unsupervised learning algorithms that solve the well known clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (assume k clusters) fixed a priori. The main idea is to define k centroids, one for each cluster. The drawback lies in the assumption of K and the setting the cluster centers. These two drawbacks are solved in the proposed method by setting number of clusters ‘K’ to 2 since fingerprint image has Background and Foreground region and for initializing the seed points(Cluster Centers) a histogram is constructed and the first two highest peak location of the histogram is taken as cluster centers. The steps for the enhanced K-means algorithm are

1. Convert the fingerprint image into its binary form.
2. Detect edge of the fingerprint image.
    - Apply a linear smoothening to enhance the edges
    - Perform modified K Means segmentation, K =2 and initial seed selected through histograms
3. Perform enhanced dyadic wavelet based edge detection for automatic thresholding
4. Subtract Input from edge.
5. Extract the fingerprint and apply Discrete Wavelet Transformation on the noisy region.

3.2 Noise Modeling

An image pixel is described by two quantities, the spatial location and its intensity, while the image local structure is represented as a set of neighboring pixels at different intensity levels. In this paper, a pixel and its nearest neighbors are modeled as a vector variable and noise reduction is performed on the vector instead of the single pixel in the extracted fingerprint image. For an underlying pixel to be denoised, a KxK window centered on noisy pixel is set (denoted as set x) containing all components within the window. In order to identify the noise, PCA is used where a set of training samples is needed. For training, consider all L x L blocks inside the KxK window as shown in fig.2 centered on the noisy pixel that are similar to x. Therefore, there will be a total of $(L-K+1)^2$ blocks which will be fed for contrast based grouping process.

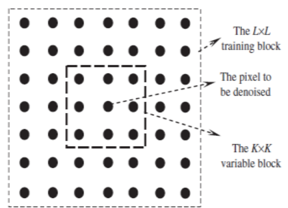


Fig.2 Modeling of noise

3.3 Contrast Based Segmentation (CBS)

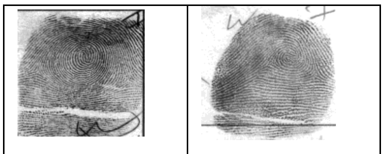
The main task is to group similar training samples together. Simple contrast based segmentation is performed to group pixels as noisy and noiseless region Grouping the training samples similar to the central KxK block in the LxL training window is indeed a classification problem and thus different grouping methods, such as block matching, correlation-based matching, K-means clustering, etc., can be employed based on different criteria. Among them, the block matching method may be the simplest yet very efficient one. Hence in order to group the pixels as noisy and noiseless region, two adjacent blocks say A and B is considered. For each pixel in the blocks, a Block Map is constructed that maps each pixel to either 0 or 1 according to the local contrast value as in eq.1.

$$I_{iA}(x,y) = \begin{cases} 1 & LC_{iA} - LC_{iB} > 0 \\ 0 & LC_{iA} - LC_{iB} < 0 \end{cases} \quad (1)$$

In all the blocks, Block Map having zeros or negative values is considered as blur region and the others are considered as sharp regions. Finally the Inverse Discrete Wavelet Transformation is applied to obtain the denoised fingerprint Image.

4. EXPERIMENTAL RESULTS

Several experiments were conducted to analyze the performance of the proposed fingerprint denoising model. The experiments were conducted on a dataset containing 1000 fingerprint images. The denoising model was developed in MATLAB 2009a and was tested on a Pentium IV machine with 4 GB RAM. The proposed algorithm was evaluated using four test images shown in Fig.3 that were selected randomly



FP1	FP2

Fig.3 Test Images

The performance metrics used are (i) Peak Signal to Noise Ratio (PSNR) (ii) Figure of Merit (FoM) and (iii) Denoising time. Random noise and Salt and pepper noise are the Impulse noise considered. Further, the results of the proposed model were compared with the Median Filter which is a traditional filter and the LPG-PCA Model. To compare the edge preservation performances, we adopt the Pratt's figure of merit [18] as in eq.2 defined by

$$FOM = \frac{1}{I_m}\sum_{i=1}^{I_a}\frac{1}{1+wd^2}$$

(2)

where $I_m = max\{I_i, I_a\}$. I_i w is the scaling constant adjusted to penalize the edge points that are detected and d is the Euclidean distance between the detected edge pixel and the nearest ideal edge pixel. *FOM* ranges between *0* and *1*, with unity for ideal edge detection. The comparison results of the Peak Signal to Noise Ratio and Figure of Merit for the proposed model are tabulated in Table 1.

Table1 . AssessmentParameters

Algorithm	Image	PSNR		FOM	
		Random Noise	Salt & Pepper	Random Noise	Salt & Pepper
Median Filter	FP1	13.61	14.92	0.7399	0.7001
	FP2	14.20	15.33	0.7199	0.7200
LPG-PCA	FP1	16.22	17.43	0.7690	0.7653
	FP2	17.38	17.95	0.7652	0.7610
Proposed	FP1	17.21	18.66	0.7990	0.7892
	FP2	18.99	19.17	0.7877	0.7813

From the Table it is evident that the proposed method is efficient in image quality when compared to the traditional filters. The high PSNR obtained by the proposed model indicates that it is the best choice for denoising fingerprint images and at the same time edges can also be preserved which is evident from the high FOM value. The time taken for denoising is shown in fig.4.From the results projected, it is clear that the proposed system outperforms the traditional models compared in terms of quality and time.

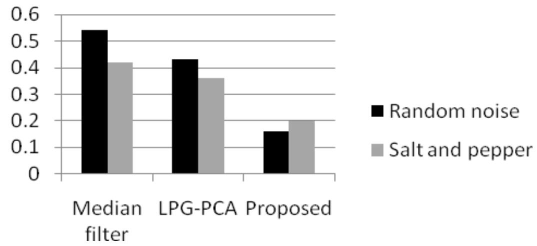


Fig. 4. Performance in terms of time(seconds)

5. CONCLUSION

We have presented a new fingerprint denoiser based on wavelets and a contrast based grouping method. The proposed model uses an edge based k-means clustering algorithm in an enhanced manner to reduce the time complexity To model a noisy pixel and its nearest neighbors a Contrast-based grouping method was used. This was stored as a vector variable and denoising was done by converting the noisy pixel into estimation. The PCA technique was used for such estimation. Performance evaluation of the proposed model is computationally efficient and fast when compared with the existing methods. In future, this algorithm will be combined with a fingerprint recognition system.

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