Latent FingerprintEnhancement Technique

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Abstract:

Latent fingerprints are fingerprints which are smudged, overlapped, and distorted. They are poor quality images with unclear ridge structure. Latent fingerprints are seen at crime scene, so it plays a vital role in identifying and declaration of criminal in law enforcement. Therefore it is important to enhance the latent finger prints which are distorted by most of the non-finger print patterns. By enhancing the latent fingerprints it becomes easy to match with the large database of know persons fingerprints.By seeing the advances of sparse representation in image denoising, the work proposes the method of enhancement using sparse representation. In Sparse representation initially total variation model will be used for latent fingerprint image, where image is disintegrated into cartoon and texture components. Cartoon component contains noise, which will be discarded while texture component contains main information. Second sparse representation method is applied on texture component. Experimental results are carried on NIST SD4 to show the effectiveness of the proposed algorithms.

Index Terms: Gabor filter, Latent fingerprints, Sparse representation.

I. INTRODUCTION

FINGERPRINTS falls into following categories a) Roll b) Plain c) Latent. Roll finger print is obtained by turning the finger from one end to another i.e. nail-to nail so that all ridges are captured. Plain finger prints are obtained by pressing the finger onto a flat surface. And latent fingerprints are the finger skin impression left at the crime scene. These fingerprints are not visible to human eyes; some physical or chemical techniques are used to process and enhance them to make them visible by naked eyes. Latent fingerprints are used as a significant evidence to recognize the criminals in law enforcement agency for more than a century.

Before the introduction of automated fingerprint identification system (AFIS), fingerprints were manually matched against previously enrolled (rolled or plain) fingerprints to identify the suspects. The introduction of AFIS improved the speed of fingerprint matching and latent fingerprint identification against huge fingerprint database available.

Since latent fingerprints are of inferior quality caused due to uneven image contrast, various overlapping of printed letters, handwriting or different fingerprints. Due to this low quality latent fingerprint AFIS is undesirable and features like singular points and minutiae have to be mark manually by the latent examiner [10]. However manual marking up of minutiae features takes long time and along with that it has short of repeatability and compatibility. Thus this is not the best solution of manually marking minutiae features for identifying the latent fingerprint. Hence before giving input to AFIS, the latent fingerprint image should be enhanced to remove the overlapping images and reconstruct the broken ridges and separate joined ridges [5]. Hence the objectives of latent finger print enhancement are 1) improve matching performance of latent finger print 2) provide with a visually enhanced image of latent fingerprint to make latent examiner easier to mark features of fingerprint. Therefore in proposed work the latent fingerprint is enhanced using sparse method, which mainly consists of two stages. Firstly the TV model is used for image decomposition into texture component and cartoon component. Out of which texture component is of great interest because it contains more information of ridges and it is use for further enhancement of the image. Whereas cartoon component is discarded because it contains most of the irrelevant contents along with structured noise. Secondly dictionaries are constructed with a set of Gabor elementary function to capture the characteristics of fingerprint ridge structure, and sparse representation is applied to construct high quality fingerprint image.

II. EXISTING METHODOLOGY

The minutiae extraction can be made better by involving an enhancement stage before minutiae extraction stage. The enhancement stage is usually involved to get best results by taking away the degradations in finger print image. Enhancement techniques can dismiss the structure noise and overall contrast from finger print. However this technique does not work well for the damages caused due to broken ridges and scars. Therefore to enhance the images suffered by scars and broken ridges, directional contextual filtering shows the best results [1]. Bad quality finger print image can affect recognition algorithms, because it can alter the information of reference and minutiae points. Hence it becomes mandatory to enhance the poor quality image before giving it to identification process. Various enhancement method is been proposed in literature. Directional Fourier domain filtering is the method for finger print image enhancement which is based on filtering the finger print image by the filter banks which are pre-computed. The orientation of these pre-computed filter banks are in eight different directions placed at every 22.5degree. This method assumes the ridge frequency is constant all over the finger print therefore the effects of enhancement is undesirable [2]. “Anil K. Jain, Fellow, IEEE, and Jianjiang Feng” [4], proposed method which works on the ―”Latent Fingerprint Matching” this method deals with Automated Fingerprint Identification Systems (AFIS) which has a very important part in various applications of forensics. A lot of changes have been done in flat and rolled types of fingerprint matching, but latent impressions are very difficult for matching because they are of very less visibility ridges, very small area of impression, broken ridges and large distortion i.e. noise are present in the image which makes it difficult for matching compared to other types of fingerprints.Another interesting technique based on Short Time Fourier Transform (STFT) analysis was proposed to perform contextual filtering in the Fourier domain for fingerprint enhancement [6].The another method is finger print segmentation in which the fingerprint is decomposed into two layers one is known as foreground and another one is known as background. The foreground layer is also known as region of interest (ROI) which has desirable details of fingerprint while the background has structured noise and content which is irrelevant hence it is discarded in immediate step i.e. in processing step. Segmentation is important because without segmentation plenty of fake features will be extracted due to noisy background which will ultimately result in mismatch in proceeding step. So the main aim of finger print segmentation is to remove the background noise and decrease the generation of fake features [3]. A robust method was proposed for orientation field estimation to improve the performance of latent fingerprint enhancement with Gabor filters [7]. This method applied STFT method to obtain multiple orientation elements in each image block, and a set of hypothesized orientation fields were generated with a hypothesize-and-test paradigm based on randomized RANSAC. The above enhancement methods were fully formed for roll and plain finger prints. They show undesirable results for latent finger prints because of two issues. First latent finger prints are left by accident which are blurred and have broken ridges. And second the latent finger prints are over lapped with handwriting, stain, character which is called as structured noise.

The total variation model was introduced to minimize the total variation of an image which is extensively used in image decomposition. Zhang et al. [3] proposed an adaptive TV model (ADTV) to remove undesirable noise for latent fingerprint segmentation. They further proposed the method adaptive directional total variation model (ADTV) by integrating the local orientation and scale for fingerprint segmentation and enhancement [8].In this method the image was decomposed into two components cartoon and texture component. Out of which cartoon component is a smooth image which has less information about the ridges of finger print. And texture component has oscillatory ridge patterns of finger print. Now the segmentation and enhancement of latent finger print is performed on texture component from which structured noise is removed. But it is not a simple task to estimate ridge orientation and frequency of ADTV model of latent finger print which is of very poor quality, which in turn degrades the execution of latent finger print identification.

Therefore the dictionary based method was proposed for perfect estimation of ridge details of latent finger prints which helps in automatic segmentation and enhancement of latent finger print [11]. Even though proper estimation of ridge orientation and frequency can improve the performance of latent finger print enhancement still it has limitation in region of high curvature and restoration of ridge orientation and frequency highly corrupted by structured noise.A dictionary-based method was proposed to enable reliable estimation of ridge orientation and frequency fields and facilitate the automatic segmentation and enhancement of latent fingerprints [9].The main problem to tackle in latent finger print enhancement to remove various structured noise with restoration of corrupted regions and at the same time enhancing those regions. So the sparse method along with the over completed dictionary is desirable for image enhancement.

III. PROPOSED METHODOLOGY

The proposed work is enhancement of latent fingerprint using sparse method. It consists of two stages: image decomposition by TV model and use of Gabor elementary function to build the dictionary. In TV model image is decomposed into texture component and cartoon component. Out of which texture component is of great interest because it contains more information of ridges and it is use for further enhancement of the image. Whereas cartoon component contains majority of irrelevant contents along with noise, so it is discarded. Then a set of Gabor elementary function with various parameters are used to build the basic atoms of dictionary, with help of it texture components are reconstructed. Fig. 1 shows the flow chart of the proposed method.

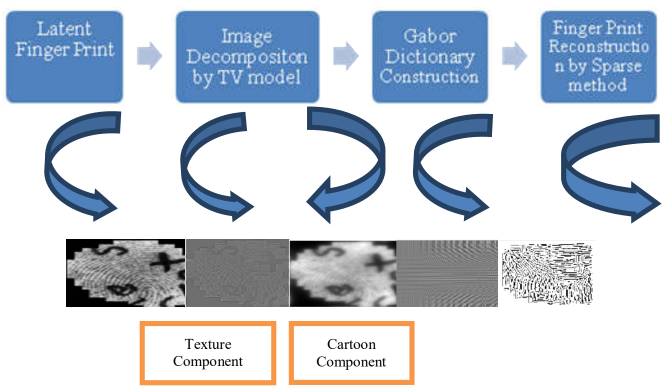


Fig.1. Flow chart of the proposed method.

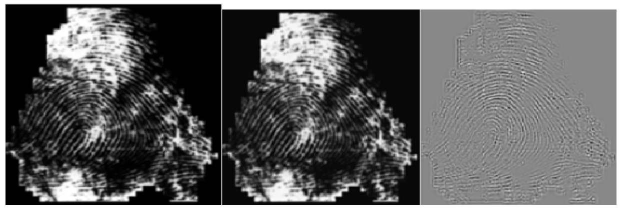
1. Latent Finger Print Decomposition Using TV Model

The input image i.e. latent finger print y, is decomposed which can be modelled as k = u + v, where u denotes cartoon component and v denotes texture component. The general way to get above decomposition the following minimization equation has to be solved

$\min\{y|Du| \ | \ ||u\text{-}k||_B \leq \sigma\}$ (1)

Where *Du* denotes generalize derivation of u and $||.||_B$. The total variation of u, which is $\int|Du|$, is minimized to regularize the image u without smoothing the edge of k in u. the fidelity term $||t(u,k)||_B \leq \sigma$ forces u to be close to f [12],[13].

Fig. 2, shows the original image decomposed into two components: Cartoon image and Texture image.



(a) (b) (c)

Fig. 2 (a) Original Image (b) Cartoon Image and (c) Texture image.

2. Gabor Dictionary Construction

The mandatory step for enhancement of image using sparse method is construction of redundant dictionary. To get good quality of enhancement the dictionary should possess all kind of details and structure. Finger print usually has 2D sinusoidal wave shape along with frequency and orientation. The gabor faction also possess the same both frequency and orientation with add on advantage of good joint resolution in both the domain i.e. spatial and frequency domains [14]. Generalize equation of gabor function can be given as [14].

$$G(x,y,\theta,f) = \exp\{-\tfrac{1}{2}[x^2_\theta/\delta^2_x + y^2_\theta/\delta^2_y]\}\, \mathrm{Cos}(2\pi f x^2_\theta + \phi 0) \quad (2)$$

$$y_\theta = -\ x \sin\theta + y\cos\theta \quad (3)$$

$$x_\theta = x\cos\theta + y\sin\theta \quad (4)$$

Where θdenotes the orientation, f denotes the frequency and$\phi 0$denotes the phase offset. To construct the dictionary we have used 16 different orientation, 9 different frequencies and 6 different phase offsets. Finally this gives 864 atoms dictionary for sparse representation. Fig. 3 shows Gabor dictionary.

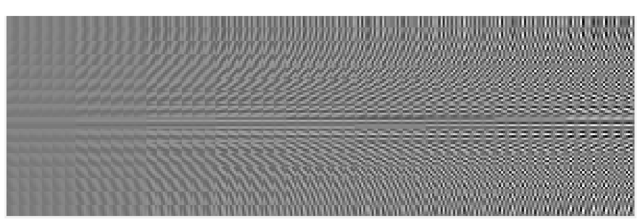


Fig. 3 Gabor dictionary.

3. Sparse Representation

A signal can be represented as $k \in \Re^N$. The fundamental idea of sparse representation is to transform $k \in \Re^N$ into $\alpha \in \Re^d$ where $d > N$. This transform is semi-linear, to transform from α to k is given by $k = D\alpha$, where $D\alpha \in \Re^{N*d}$ is a matrix which is referred to as dictionary. The dictionary D can be constructed with a set of basic functions of images to incorporate ridge structure with various frequency and orientation. Now the latent finger print has specific orientation and frequency of ridges therefore the coefficients are expected to be sparse i.e. having very few non-zero values. The transform is highly nonlinear, searching for sparsest explanation for signal k. The cost function l^0 counts the non-zero entries in this vector, and we expect a sparse outcome $||\alpha||_0 = x << N$. This $x << N$ is the tuning parameter to control the fidelity of the model approximation to k.

$$(P_0)\ \hat{a} = \text{argmin}^{\alpha}\ ||\alpha||_0 \text{ s.t } \quad x = D\alpha \qquad (5)$$

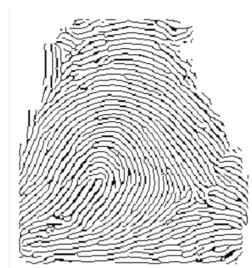
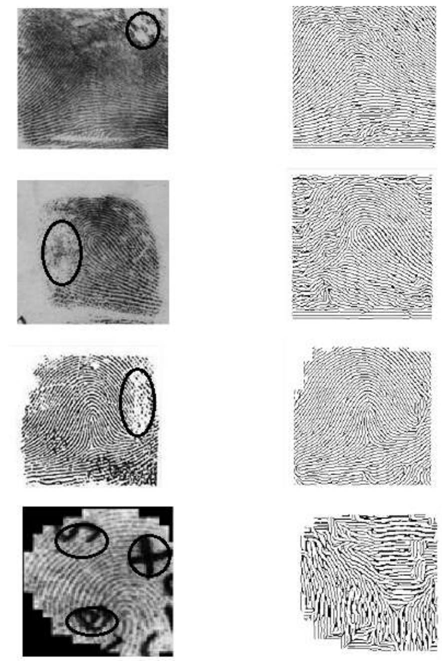


Fig. 4 Enhanced image

The Fig. 5 below shows the enhanced image for various latent fingerprints. The databased use for enhancement algorithm is NIST special database 4 Gray scale images of FIGS.



(a) (b)

Fig.5(a) Latent fingerprint and (b) Enhanced image.

The region corrupted by heavy noise is marked by circle. The enhancement algorithm reconstructs well the region corrupted by heavy noise.

IV. CONCLUSION

This paper presents a simple technique for enhancing latent finger print, which effectively combines total variation (TV) model and sparse representation for removing noise and enhancing the clarity of latent finger print image. Every latent finger print is disintegrated into texture and cartoon component takin the help of TV model and over texture component which has fine details of fingerprint, sparse representation method is implemented to obtain high quality of finger print image. This method ensures appropriate working of automatic fingerprint identification. The results of above method show significant improvement in latent finger print enhancement.

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