Sparse based Latent Fingerprint Enhancement & Recognition using Minutiae Matching

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Abstract - *The fingerprints that are obtained from the crime scenes are normally smudged,overlapped and distorted in nature. These fingerprints are known as latent fingerprints. These fingerprints normally possess unclear ridge structures which makes them really difficult to be matched from the known database of fingerprints. It is vital to recognise the owner of these fingerprints inorder to establish a proper law enforcement. So it is very important to enhance these latent fingerprints inorder to identify them by the recognition algorithm. This enhancement or denoising can be achieved by using sparse representation. Initially the total variation model is used to disintegrate the fingerprint to texture component and cartoon component. Generally the texture component holds most of the relevant information and the cartoon component holds the noisy data. Thus the cartoon component can be discarded and the texture component is further enhanced by applying Gabor dictionary learning algorithm along with sparse reconstruction. This enhanced fingerprint is then passed to the minutiae matching algorithm. It searches for the similar fingerprint from the police database on the basis of the minutiae points and coordinates. If the minutiae points in the fingerprint matches with the minutiae points of a fingerprint from the database then it would show the details of the fingerprint from the datbase. Thus the owner of the latent fingerprint can be identified.*

***Key Words*: Latent Fingerprints, Sparse Representation, Total Variation model, Gabor Dictionary, Minutiae Matching, Recognition Algorithm**

1. INTRODUCTION

A simple fingerprint normally consists of ridges, furrows and whorls. The ridge structures and orientation varies from person to person. A minutiae can be defined as the ridge endings or the ridge bifurcations that are present in a fingerprint.There are mainly three types of fingerprints, namely - plain, roll and latent fingerprints.

Roll finger prints are the fingerprints that are attained from nail to nail which captures most of the ridges in the fingerprint. Plain finger prints are mostly the fingerprints that are obtained by using the fingerprint scanner devices which are mainly done by scanning the fingerprints on a flat surface. This leads to the loss of the ridges on the sides of the fingers. Latent fingerprints are the distorted or smudged fingerprints that are obtained from the crime scenes or public places like a library, train, bus and so on. They can be obtained by using chemicals such as iodine, cyanoacrylate, silver nitrate and ninhydrin. These chemicals react to substances such as oil and sweat, making it change the color so that the analysts can see the ridges better. Latent fingerprints are used as a significant evidence to recognize the criminals in law enforcement sector for more than a century.

The introduction of recognition algorithms such as minutiae matching, CNN based matching etc made the fingerprint analysis much more easier and reduced the time requirement for the recognition phase.

1.1 Objectives

The main objectives of this paper are:

- To enhance the obtained latent fingerprint which is noisy in nature by using the Gabor dictionary learning algorithm and sparse reconstruction.
- To identify the owner of the latent fingerprint from the database by using the minutiae matching algorithm.

1.2 Scopes

This technique can be implemented by the governments in law enforcement by identifying the criminals from their fingerprints that are obtained from the crime scene. Thus the criminals can be identified in an easer manner which improves the efficiency of the force.

2. EXISTING METHODOLOGY

The most widely used latent fingerprint enhancement[5] technique is the minutiae extraction method[7]. In this technique the available minutiae points are marked and extracted by using various pre-computed filter banks such as the Short Term Fourier Transform(STFT)[9], contextual filtering. This method applies STFT to obtain multiple orientation elements in each image block, and a set of hypothesized orientation fields. Then the obtained image blocks are analysed separately inorder to attain the minutiae points. Another technique is the Adaptive Directional Total Variation (ADTV) model[12] in which, the local orientation of the fingerprint is integrated by decomposing the image into texture component and cartoon component. The texture component holds the relevant information and cartoon component holds noisy data. Hence, texture component is further enhanced by using fiter banks.

There are mainly two types of fingerprint matching algorithms - CNN based fingerprint matching[4] algorithm and minutiae matching[3] algorithm. In the CNN based fingerprint matching, the neural network is trained to search in the database based on the minutiae orientation as well as their positions. The major disadvantage of this technique is the costlier and the much time consuming training phase. Once the training phase is done this method produces efficient and faster results. The minutiae matching method is much more cost effective and produces results with almost similar efficiency as compared with CNN based matching. In minutiae matching technique, the minutiae points are marked and positions are stored by representing them on an XY-plane. Then the recognition algorithm searches for similar fingerprints with same coordinate positions in the database. If the minutiae points of the latent fingerprint matches with any of the fingerprint in the database, then the ID number of the fingerprint would be revealed to the analysts. Using this ID number the owner of the fingerprint can easily be identified.

3. PROPOSED METHODOLOGY

The latent fingerprint obtained has to be enhanced inorder to improve the quality of the ridge structure and ridge orientations. This is vital since it can produce more accurate results in the recognition phase.

3.1 Pre-processing

Initially the RGB image is converted to a gray scale image for easy processing. Then the datatype is changed to double datatype. Then the fingerprint segmentation[8] is done. This is important as there will be a lot of fake features present in the latent fingerprints. These fake features are mainly caused due to overlapping fingerprints so it is crucial to get rid of these fake features. The removal of fake features are done in four steps :

- The first step is the feature extraction. The ridges and their orientation are the important features in a fingerprint. So in this step these ridge structures are identified and highlighted.
- The second step is local adaptive thresholding. Here a pre-defined threshold gray level value is set and the values below this are discarded. The ouput of this step will be a binary image.
- Then a morphological process of continuous dilation and erosion is applied to the obtained binary image. This will result in reducing the noisy background from the relevant data.
- Since, the fingerprint segmentation[8] is done in a roughly manner, it is essential to smoothen the binary image with a contour smoothening. In this step the smoothening is done by using the Fourier transformation domain.

3.2 Decomposition by TV Model

Total Variation (TV) model[11], which was introduced in 1992 played a crucial role in the capturing of first ever image of the black hole. Here the image is decomposed into texture component and cartoon component. the texture component holds the relevant data such as the edges(ridge patterns in the case of fingerprints). The cartoon component holds the noisy data such as the broken furrows or scarred whorls. Thus the texture component is used for further enhancement and the cartoon component will be discarded.

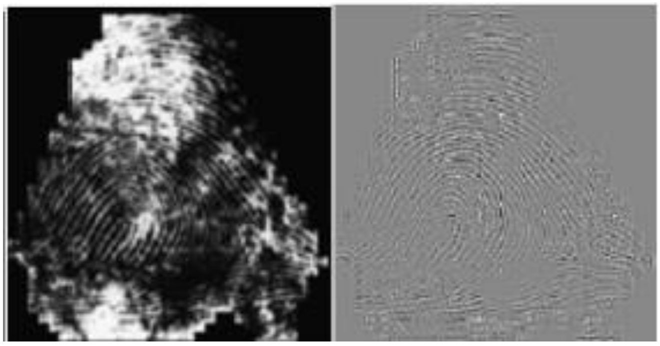

Fig 1 : TV Model decomposition of a latent fingerprint
(a) Cartoon component (b) Texture component

3.3 Gabor Dictionary Formation

In sparse reconstruction it is important to construct a redundant dictionary. To achieve a good representation, dictionary should characterize all kinds of image structures and details. The local fingerprint patch usually forms a 2D sinusoidal wave with a very well-defined orientation and frequency[9]. The Gabor functions have both frequency and orientation selective properties with optimal joint resolution in both spatial and frequency domains. They capture the periodic, yet non-stationary characteristics of fingerprint pattern and form a very intuitive representation of the fingerprint images. Thus, it is appropriate to use Gabor basis functions to model the local patch of fingerprint images. Normalisation is done to this image inorder to attain zero mean and unit standard deviation. The Gabor dictionary construction is mainly done in two steps , which are namely ridge segmentation and dictionary construction by Gabor functions.

In ridge segmentation[8], the image is broken into blocks of size 16x16 and the standard deviation(SD) in each block is analysed and blocks with SD greater than the threshold value are deemed to be a part of the figerprinnt. Then the ridge orientation(ϴ) and the ridge frequency(f) values of each block are calculated.

Then the dictionary is constructed by using the Gabor function G(x,y,θ,f), where θ is the ridge orientation and f is the ridge frequency.

$$G(X,Y,\theta,f) = \exp\{-1/2\,[\,X^2_\theta / Y^2_\theta\,]\}\cos(2\pi f X^2_\theta + \Phi_0), \text{ where}$$

$$X_\theta = -X\sin\theta + Y\cos\theta$$

$$Y_\theta = X\cos\theta + Y\sin\theta$$

3.4 Sparse Reconstruction

Now the image patches or blocks are reconstructed by using the sparse coefficient along with the image patches and the Gabor dictionary[10]. In this step the image is obtained by using a patch based refinement[2] based on sparse. This model of reconstruction using the sparse model provides enough information about the inherent features present in the unknown area such as the ridge dots, ridge bifurcations and so on. This patch based refinement process can replicate the structure and the natural texture from the available latent patch.

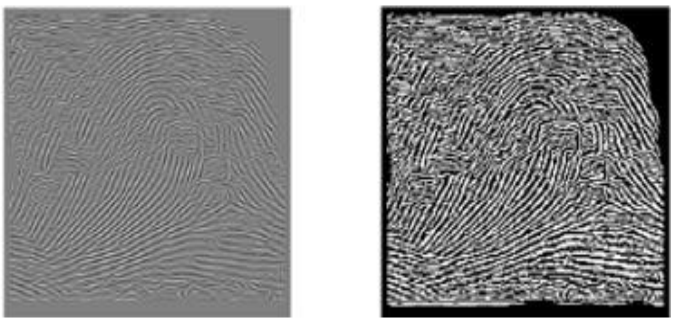

Fig 2 : (a)Reconstructed image (b)Binary form of reconstructed image

3.5 Minutiae Extraction

The reconstructed image is then applied with minutiae extraction process so that the minutiae points and their positions can be easily identified. This step further boosts the efficiency of the recognition or the matching algorithm. This is done in two steps :

- Thinning
- False minutiae removal.

In the thinning process fingerprint skeleton is obtained from the binary image. This is done by using the Canny Edge detection algorithm. The skeletonised image has clear ridge pattern and orientation as compared with the binary images. The skeleton image enables to mark the miunutiae points in the next step which is a vital detail for the matching of the fingerprint from the database. Here, the edges such as the ridges and minutiae are properly highlighted and thus gets enhanced by a sufficient margin.

Fig 3 : Skeleton image

In the false minutiae removal[7] step, the distances between each pair of minutiae are computed. Then, if the distance is less than the threshold distance then that pair is discarded. Thus the minutiae points with clear ridge patterns are obtained which makes the matching step easier.

3.6 Minutiae Matching

The enhanced image is now analysed and the spurious details such as the minutiae positions, ridge frequency and ridge orientation are calculated. The minutiae positions are then represented on an XY-plane for easier analysis.

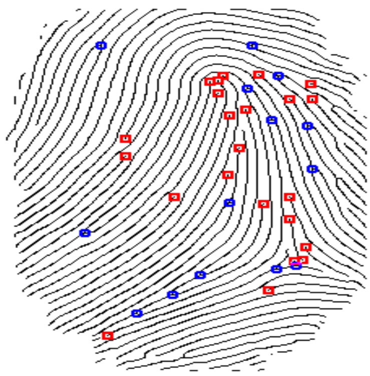

Fig 4 : Minutiae points marking - Ridge bifurcations in blue and Ridge endings in Red

After marking these coordinates and their patterns, the matching algorithm starts searching in the database for fingerprints with similar ridge frequency and ridge orientations. Once the fingerprints with similar ridge frequency and orientations are found each of them are scanned with the minutiae coordinates. Thus the analysis goes on until the fingerprint with the exact minutiae positions are found from the database. Thus the analysts can attain the details of that fingerprint inorder to identify the culprit. Eventhough the ridge frequency and orientation of people may be same, the minutiae points of each person is unique. So the algorithm naturally produces nearly complete accuracy.

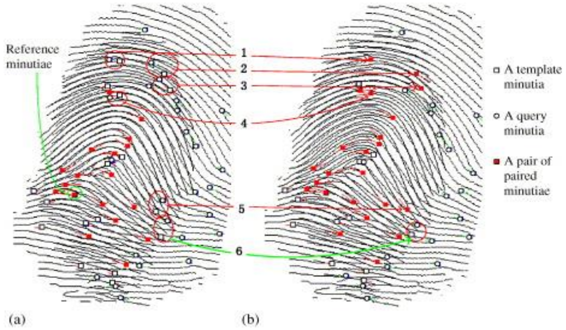

Fig 5 : Minutiae matching - (a) Minutiae in the database (b)Querry minutiae

4. RESULTS & ANALYSIS

The quality of the image after the enhanced phase and the image obtained can be compared inorder to see the difference in quality of the ridge patterns. Thus the enhaced image enables to mark the minutiae coordinates easier as compared with the obtained latent fingerprint. The minutiae points are represented on an XY-plane as below

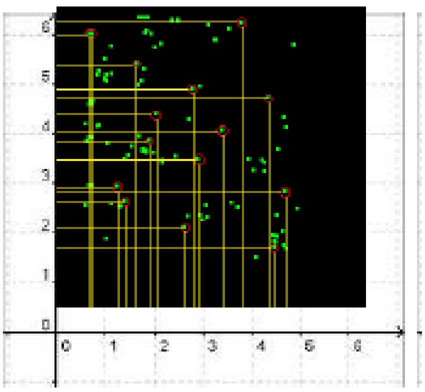

Fig 6 : Minutiae points in XY-plane

In the recognition phase these coordinates are analysed and the fingerprint with the exact coordinates is found. Thus the owner of the latent fingerprint can easily be identified with the details attached with the matching fingerprint from the database.

Fig 7 : Dialog box message showing matching fingerprint with its ID

The algorithm works with utmost precision since the matching is done on the basis of minutiae coordinate comparison. This also enables the analysts to keep a good quality image of the obtained fingerprints for future study rather than keeping the poor quality image obtained of the latent fingerprint.

5. CONCLUSIONS

This paper presents an effective algorithm to enhance the latent fingerprints and identify the person from a database easily. The obtained fingerprint is initially decomposed by TV model decomposition and later reconstructed by using the Gabor function and the sparse reconstruction technique. Thus a better quality ridge structure can be attained along with sufficient clarity in spurious details such as the minutiae points and ridge patterns. After the enhancing phase is done the matching algorithm is used to search for similar fingerprint in the available database. This is done by comparing the ridge orientation and ridge frequency with an initial search which returns some fingerprints with values in the same range. Later the minutiae coordinates obtained from the latent fingerprint is used to find the exact match from the obtained search results. So this algorithm can be easily used by the analysts to find the owner of the latent fingeerprint easily and efficiently with minimal time.

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