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RECONSTRUCTION AND RECOGNITION OF LATENT FINGERPRINT USING IMAGE INPAINTING APPROACH

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ABSTRACT: Verifying latent fingerprints is important for law enforcement companies to capture criminals and terrorists. Compared to Live Scan and fingerprint inked, the picture quality of the latent fingerprints is much low with difficult picture environment, not clear ridge composition and even overlapped patterns. This kind of print can't be recycled in the law courtyard of rules straight to store an opinion if can be corresponding to recognized print. Physical latent fingerprint recognition is a dull, expensive & time overriding procedure, which is used to restore misplaced ridges. So, Researchers are continuously working to design an autonomous latent fingerprint recognition system. In this paper, a novel approach of image inpainting is used for the reconstruction and recognition of latent fingerprints. Image Inpainting is the process to recover/fill up the distorted and broken portion of image using the neighbour pixels. Image Inpainting based exemplar inpainting approach has been used for this work. The proposed concept has been experimented for the dataset of FVC 2002 database.

KEYWORDS: Latent Fingerprint, Image Inpainting, Ridges Reconstruction, Exemplar Inapinting, Minutiae Information

1. INTRODUCTION

A biometric system is considered as a pattern recognition system. In this, the features are extracted from the obtained data and then compared with the stored template to make a decision on the identity of human being. It is a feasible and a reliable way to identify and authenticate the person because the traditional methods include the knowledge based identification system. The knowledge based identification includes passwords, personal identification number or token based identification systems such as passport, driving license. These systems are not considered secured as they can be easily stolen, lost or shared but a biometric trait is always present on the body of authorised user. Therefore, Biometric Recognition can be defined as the use of different physiological and behavioural characteristics for identifying human beings. A biometric system works for the three fields i.e. Enrolment, Identification and Verification system. There exists a list of techniques for the recognition of fingerprints. But there exists several challenges in case of latent fingerprints

Latent fingerprints are by chance fingerprints which are left by criminal at a crime scene. These types of fingerprints are of very poor quality and highly distorted [1]. According to the noise level present in latent fingerprint, it can be classified into three types i.e. latent with background noise, partial latent and overlapping latent [2]. In current practice, the minutiae are marked manually in latent. Latent fingerprints can vary in the information content and quality level depending upon the presence of surface and skin type. It can be found with different background noise level, overlapping finger marks and quantity of latent presence. With all these challenges, manual recognition of latent fingerprints is not efficient approach [3]. There may be need to reconstruct the spoiled latent fingerprint (edges, ridge structure, minutiae information), enhancement in quality to reduce background noise and final recognition with quick approach. This paper presents an autonomous approach for the reconstruction and recognition of latent fingerprints. Image Inpainting based exemplar approach is considered for the reconstruction of spoiled latent fingerprint ridges, edges etc.

The entire process is divided into three section of latent fingerprint enhancement, reconstruction and recognition. For initial enhancement Sobel filter is used. For the latent fingerprint reconstruction exemplar inpainting is used. Then, final recognition of latent fingerprints is performed with minutiae based information.

For experimentation FVC 2002 fingerprint dataset is used. It consists of latent to rolled fingerprints [4]. These images are of approximate 500 PPI. These image are taken using capacitive and sensor dataset. Some sample images are shown in figure 1.

Figure 1: Dataset Images of FVC 2002

Other sections of the paper are discussed in the following manner: Section II presents the existing work for latent fingerprint reconstruction, enhancement and recognition. Section III represents the different types of fingerprint representation. Section IV discusses the basic concept of sobel filter and Exemplar inpainting. Section V describes the proposed concept for latent fingerprint recognition. Section VI presents the results and discussion section and Section VII concludes the paper.

2. FINGERPRINT REPRESENTATION

Fingerprint Representation influences system's accuracy and rest of the system. There are different kinds of fingerprint representation that are used for fingerprint recognition system. Each one of them has its own advantages and disadvantages.

Image Representation

In this representation, straightway fingerprint image is used as a template. There is no need for a feature extraction algorithm because the crude intensity pixel values are directly used. This representation holds most information about fingerprint but it requires a lot of storage space for fingerprints.

Global Ridge pattern

This representation depends on the ridge structure, orientation fields such as singular points and ridge frequency map. In this the quality of fingerprint should good. But it is not always good due to absence of singular points.

Local Ridge Detail

This representation is widely used in the fingerprint recognition system. Local ridge details are referred as minutiae. A minutia is defined as the points of interest in a fingerprint, such as bifurcations (a ridge splitting into two) and ridge endings. Sir Francis Galton discovered the structures of minutiae [5]. The forensic examiners use minutiae points to match the two fingerprints. There are around 150 different types of minutiae present in an individual fingerprint. Some minutiae are shown in Figure 2.

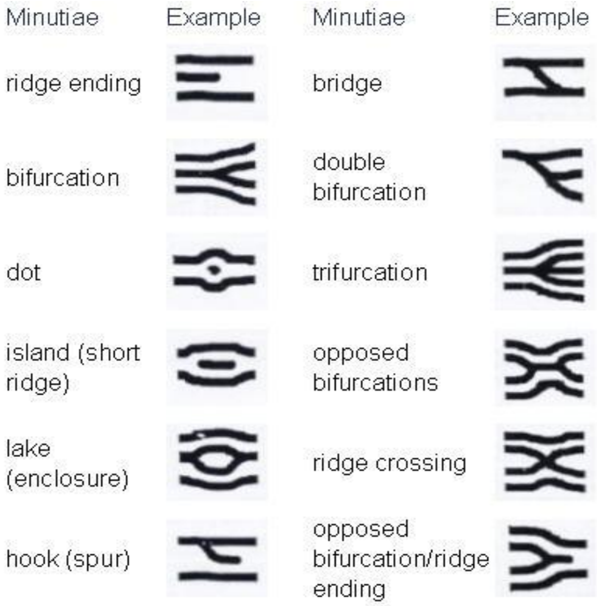

Figure 2: Different types of Minutiae in a Fingerprint

The main advantage of minutiae based fingerprint representation is that no one cannot reconstruct whole original image with only minutiae information. That's why most of the fingerprint recognition systems use local ridge detail representation [6].

A. Intra Ridge Detail

There are many ridges in one fingerprint of an individual. There are many sweat pores on the ridges. Pores are meant to be unique in terms of number, positions and shapes. But the issue with this representation is the extraction of pores possible in high resolution fingerprint images. This type of representation is not used for practical applications [7].

II. Related Work

There are lot of work for the latent fingerprint enhancement, reconstruction and recognition. Some of the existing work is presented here. Also a overall analysis is presented in table 1.

The paper of [Cao et al., 2014] proposed a dictionary approach for the enhancement of latent fingerprints. The author gives heavy discussion of latent fingerprint enhancement methods which have been explained in the literature [8]. The discussed method works on ridge structure dictionary which is used for latent segmentation and enhancement. The dictionary is learnt from high quality dictionary patches. The ridge quality of a patch is defined as the structural similarity between the patch and its reconstruction from the learnt ridge structure dictionary. For good performance and accuracy, the dictionary works at two levels i.e. coarse level and fine level. Dictionary approach consists of two types of stages i.e. off line and online dictionary stage. This method is fully automatic and reliable. However, the scheme still does not work well on poor quality partial latent fingerprints. The algorithm can be further improved by work on computational efficiency.

Liu et al. [9] have proposed the novel combined form of total variation model and multiscale path based sparse representation method. In this combined approach total variation model is used to decompose the latent fingerprints into texture & cartoon components. Here, cartoon components are removed and texture components having latent fingerprint impressions are further used for enhancement by using multiscale path based sparse representation method. The proposed algorithm also restores and enhances the corrupted fingerprints along with the removal of structured noise from images.

According to [Rahmes et al., 2007] partial fingerprints are enhanced and completed with Partial Differential Equation (PDE) Inpainting and Exemplar Inpainting approach [10]. The ridge lines are sharpened with anistropic filters. The discussed method is an automated reconstruction method and reduces manual mark-up. The objective of this algorithm is to connect the ridges pixel by pixel to minimize the interpolation error and to decrease its complexity. It has been reviewed that PDE does a good job in small damaged regions, but for the larger damaged regions the results are not good. Unlike the PDE Inpainting approaches which have limitations based on the size of the void to be filled in and the smoothness, the Exemplar method is aptly suited for replenishing larger voids and those containing high frequency data. In this paper, the voids are created manually.

An image enhancement method proposed by [Zhou et al., 2013], which is based on prior based knowledge concept and tried to implement 'Lights out identification' system [11]. The paper explains the three different reasons for the need of an AFIS. The author reviews published algorithms of orientation field estimation. The algorithms are coarsely defined into three categories i.e. Local Estimation, Smoothing and Global Parametric models. The algorithm also works in two stages i.e. offline stage and online stage. With a minor modification, the algorithm can also estimate the orientation field of overlapped latent fingerprints and its performance is comparable to the state-of art special purpose algorithm. However, the discussed algorithm is still inferior to manual marking, especially on low-quality latent, and its speed is slow. It requires manual mark-up of ROI and segmentation. The algorithm performance can be further improved by developing automatic region of segmentation and ROI.

Separation of overlapping fingerprints algorithm was proposed by [Shi Yuan et al., 2011]. The overlapping fingerprints are also lifted from the crime scene [12]. It is necessary to separate them for the identification of an individual. The challenge in overlapping fingerprints is accurate estimation of orientation fields of each fingerprint. This paper proposed a robust orientation field estimation algorithm. The first step to separate overlapped fingerprints is region segmentation. The image is segmented into three parts i.e. background region, overlapped region and two non overlapped region. An overlapped fingerprint image is segmented into non overlapping blocks of 16*16 pixels. Region mask, orientation field and frequency map are defined on blocks. The author calculates Discrete Fourier Transform in the window of 64*64 pixels around an overlapped block. After initial orientation field estimation, constrained relaxation labeling is used to determine the labels of overlapped blocks. The proposed algorithm also works on two component fingerprints which are from the same finger. This type of overlapping occurs when the same location of an object is touched by the same finger several times. Such overlapped fingerprints are common in weapons used by criminals, doorknobs, bottles, etc. The limitation of this paper is that it is not fully automatic yet.

A novel and efficient algorithm that combines the advantages of both texture synthesis and inpainting proposed by [Criminisi et al., 2004]. Texture synthesis means generation of large regions from available information present in an image and inpainting states fill gaps or void regions present in an image [13]. The patch which has highest priority will undergo for enhancement. The priority of patches is computed with confidence and data term. After priorities there is propagation of texture and structure information. The pixels of target region patches are filled with the help of source region. After filling the patches, the confidence values of patches are updated. The algorithm is applied on purely synthetic images to full-colour photographs that include complex textures. There is also side by side comparison to previously proposed methods. In all of the experiments, the patch size was set to be greater than the thickest structure (e.g., edges) in the source region.

The author [Yang et al., 2014] proposed a bio-cryptosystem based on fixed-length bit-string representations extracted from modified VNSs, which are rotation- and translation-invariant and distortion robust [14]. The author takes the full advantage of local Voronoi neighbour structures (VNSs), e.g. local structural stability and distortion insensitivity. The reviewed alignment-free bio-cryptosystem is able to provide strong security while achieving good recognition performance. Three performance indices are used for performance evaluation: (1) false reject rate (FRR), (2) false accept rate (FAR), and (3) equal error rate (EER), which is defined as the error rate when the FRR and FAR are equal. The experimental results proved the validity of proposed scheme. But it is also likely to introduce some fake Voronoi neighbour minutiae. The use of order 1 triangle algorithm can reduce the possibility of adding fake minutiae, but it is not 100% effective.

TABLE 1: LATENT FINGERPRINT RECONSTRUCTION AND RECOGNITION

Author and Year	Considered Approach	Key Features
Cao et al., 2014	Autonomous dictionary approach	• The discussed method works on ridge structure dictionary which is used for latent segmentation and enhancement. • For good performance and accuracy, the dictionary works at two levels i.e. coarse level and fine level. • This method is fully automatic and reliable. • The algorithm can be further improved by work on computational efficiency.
Liu et al. 2015	Total variation model and multiscale path based sparse representation method	• Combined total variation model is used to decompose the latent fingerprints into texture & cartoon components. • The proposed algorithm also restores and enhances the corrupted fingerprints along with the removal of structured noise from images
Rahmes et al., 2007	Exemplar Inpainting and Partial Differential Equation	• The objective of this algorithm is to connect the ridges pixel by pixel to minimize the interpolation error and to decrease its complexity. • The voids are created manually. • PDE approach is fit for small broken edges. Exemplar method is aptly suited for replenishing larger voids.
Zhou et al., 2013	Prior based knowledge concept	• With a minor modification, the algorithm can also estimate the orientation field of overlapped latent fingerprints and its performance is comparable to the state-of art special purpose algorithm. • The algorithm performance can be further improved by developing automatic region of segmentation and ROI.
Shi Yuan et al., 2011	Separation of overlapping fingerprints algorithm	• Proposed a robust orientation field estimation algorithm. • The proposed algorithm also works on two component fingerprints which are from the same finger. • Approach is not fully Autonomous yet.
Criminisi et al., 2004	Texture synthesis and inpainting Approach	• The priority of patches is computed with confidence and data term. • The algorithm is applied on purely synthetic images to full-colour photographs that include complex textures. • In all of the experiments, the patch size was set to be greater than the thickest structure (e.g., edges) in the source region.
Yang et al., 2014	Bio-Cryptosystem	• The author takes the full advantage of local Voronoi neighbour structures (VNSs), e.g. local structural stability and distortion insensitivity. • The experimental results proved the validity of proposed scheme.

III.BASIC CONCEPTS

This section presents the basic concepts of sobel filter and exemplar inpainting approach. These concepts are explained as below:

A. Exemplar Inpainting

Image Inpainting is the process to recover/fill up the distorted and broken portion of image using the neighbor pixels. Image Inpainting is one of the commonly used approaches in Photoshop for the image retouching. Exemplar Inpainting is a patch based texture synthesis approach used to reconstruct the missing portion of latent image [15]. Exemplar inpainting mainly works based on priority of the gradient scene [16]. Exemplar Inpainting is the combination of texture and inpainting approach where texture based available information is used to recover the distorted latent region using inpainting approach.

B. Sobel Filter

Sobel filter [17] is used in edge detection algorithms. It is very similar to Prewitt filter (used by the operator to calculate the gradient of image intensity at each point). The major difference in between two filters is the coefficients of covers are not fixed & they can be familiar according to our requirement.

IV.PROPOSED FRAMEWORK

This section presents the step wise explanation for the latent fingerprint enhancement, reconstruction and recognition. Initially, Image preprocessing steps of segmentation and enhancement is performed. Then Reconstruction is performed to recover the broken edges and curves. After reconstruction, post-processing steps of recognition based on Minutiae information is performed. Also a stepwise work flow is explained in figure 3. This stepwise explanation is below.

ALGORITHM

Step 1: Consider the FVC 2002 dataset images for the experimentation.
Step 2: Separate the background noisy part of image from the front image portion. This division is performed based on variance value of block wise divided image.
Step 3: Enhance the image using the Sobel filter based on the mask coefficient.
Step 4: This processed image is then reconstructed to restore the broken ridges, edges and curves.
Step 5: For reconstruction, exemplar inpainting approach is used. Exemplar Inpainting approach is used to recover the large distorted ridges and curves.
Step 6: This reconstructed image is further processed to extract the minutiae information so that it can be recognised with the original fingerprint.
Step 7: Further, thinning process is performed to reduce the overlapped minutiae and ridges.
Step 8: Then, minutiae based latent fingerprints are extracted.
Step 9: Further, minutiae information is aligned.
Step 10: Finally, matching of the processed latent fingerprints is performed to find the best match with the original fingerprints.

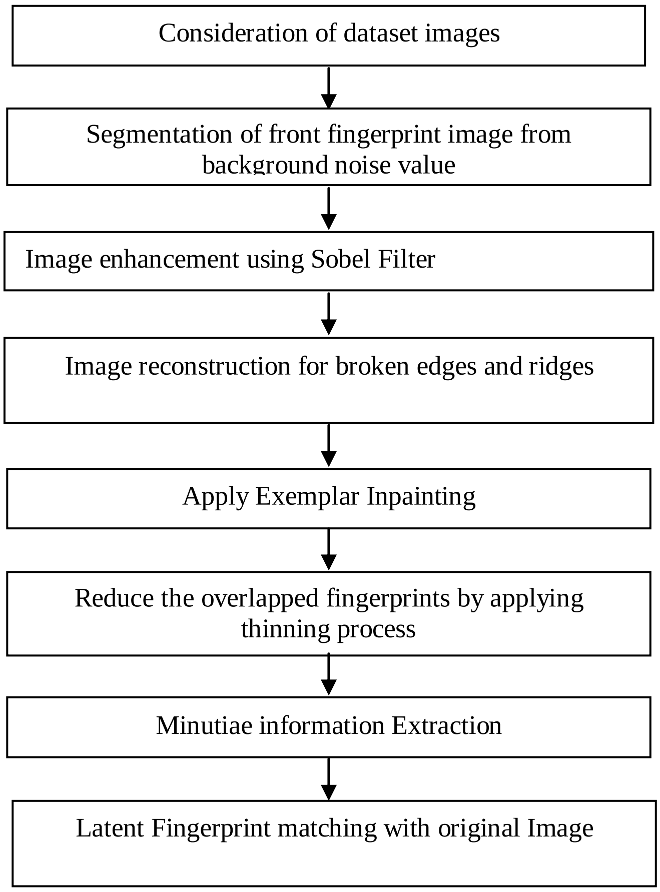

Figure 3: Latent Fingerprint Enhancement, Reconstruction and Recognition Using Exemplar Inpainting

V. RESULTS AND DISCUSSION

This section presents the experimental details with the functions and tolls considered for the evaluation. The considered concept of exemplar inpainting is used for the reconstruction and recognition of latent fingerprints. Here, MATLAB simulation software is used for the entire simulation of latent fingerprint recognition. Other software and hardware equipments include the Intel(R) Core(TM) i5 processor and 4GB RAM with Window based Operating System. The overall analysis steps with fingerprint sample are as mentioned.

Figure 4 shows the initial input image considered for the experimentation of latent fingerprint reconstruction and recognition. This image is taken from the FVC 2002 database. Further, segmentation function is performed to separate the front fingerprint information from the background noise value. This image is shown in figure 5 after the removal of background noise from the image.

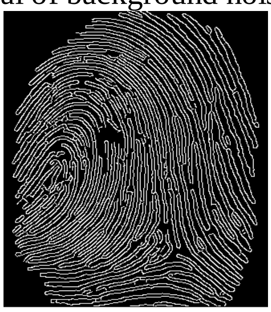

Figure 4: Fingerprint Considered from Dataset

Figure 5: Segmentation of Front Fingerprint portion from Background Noise

Further, Sobel filter is applied to enhance the image quality as shown in figure 6. This enhanced image is further used for the detection of broken edges and ridges as shown in figure 7. Then exemplar inpainting approach is applied to reconstruct the broken ridges as shown in figure 8.

Figure 6: Enhancement of Fingerprint Image using Sobel Filter

Figure 7: Detection of Broken Edges and Ridges

Figure 8: Apply Exemplar Inpainting to reconstruct broken Edges and Ridges

Further, minutiae based information is extracted from the image. This image is shown in figure 9. Based on this minutiae information, fingerprints are recognized from the ground-truth value.

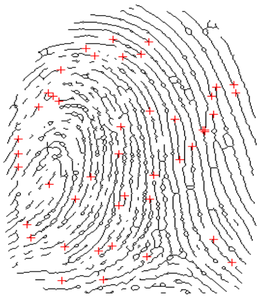

Figure 9: Minutiae Information Extraction

This figure 9 having the minutiae information is further used for the recognition of fingerprint of human. This can be performed by matching the detected fingerprints with the available dataset of FVC 2002.

VI. CONCLUSION

Partial latent fingerprints identification can become easy when an algorithm or software completes the gaps between ridges. In the research paper, Exemplar Inpainting is used for completion of the partial latent fingerprint. The Exemplar requires segmentation & ROI. The output image of Exemplar is enhanced with the sobel filter. Final recognition is performed with minutiae information extraction. This paper presents the proposed concept to resolve the challenges of latent fingerprint identification like spoiled ridges of latent fingerprints, higher value of background noise, lack of publicly availability of latent fingerprint dataset and non-availability of any specific method for fingerprint matching. Overall proposed approach optimizes the solution to identify the best possible match for latent fingerprints. Experimentation is performed based on the FVC 2002 dataset. In future, work can be further enhanced with some hybridization of concept with some evaluation parameters.

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