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ORIENTATION FIELD ESTIMATION FOR LATENT FINGERPRINT ENHANCEMENT

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Short Profile

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ABSTRACT:
Fingerprints have been the most accepted tool for personal identification since many decades. It is also an invaluable tool for law enforcement and forensics for over a century, motivating the research in automated fingerprint-based identification, an application of biometric system. The matching or identification accuracy using fingerprints has been shown to be very high. The theory on the uniqueness of fingerprint minutiae leads to the steps in studying the statistics of extracting the minutiae features reliably. Identifying latent fingerprints (refers to the impressions unintentionally left on items handled or touched by fingers) is of vital importance for law enforcement agencies to apprehend criminals and terrorists. Compared to live-scan and inked fingerprints, the image quality of latent fingerprints is much lower, with complex image background, unclear ridge structure, and even overlapping patterns. A robust orientation field estimation algorithm is required for enhancing and recognizing poor quality latents.

However, conventional orientation field estimation algorithms, which can satisfactorily process most live-scan and inked fingerprints, do not provide acceptable results for most latents. The major limitation of conventional algorithms is that they do not utilize prior knowledge of the ridge structure in fingerprints. Inspired by spelling correction techniques in natural language processing, this project propose a novel fingerprint orientation field estimation algorithm based on prior knowledge of fingerprint structure. It uses prior knowledge of fingerprints using a dictionary of reference orientation patches, which is constructed using a set of true orientation fields, and the compatibility constraint between neighboring orientation patches.

Orientation field estimation for latents is posed as an energy minimization problem, which is solved by loopy belief propagation. Experimental results on NIST SD27 latent fingerprint database, FVC2002 latent fingerprint database and an overlapped latent fingerprint database demonstrate the advantages of the proposed

orientation field estimation algorithm over conventional algorithms.

KEYWORDS
Latent Fingerprint, Decomposition, segmentation, ridge frequency, minutiae, orientation feature, algorithmic parameters

RELATED WORK

For orientation field estimation, algorithms are broadly classified into three categories.

Local Estimation

Local estimation approach compute a local ridge orientation at pixel X = (x, y) using only the neighborhood around X, which is typically 32 × 32 pixels for 500 ppi fingerprints. The most well-known local estimation approach is gradient-based [13], [14], [41], and [42]. Since gradient operators, such as Prewitt or Sobel operators [43], are sensitive to noise and pores (regularly placed on the ridges), a dominant orientation is computed using the gradients in the local neighborhood.

Slit-based approach is another widely used orientation field estimation method [30]. This approach explicitly utilizes the fact that the variation of intensity is the smallest along the ridge orientation and largest along the orthogonal orientation. By testing such a hypothesis along a number of different orientations, the best orientation is chosen. Ridge pattern in a local area of a finger can be approximated by a 2D sine wave [44]. Thus, the magnitude Spectrum of the Fourier transform of a local fingerprint image will contain a pair of peaks whose location corresponds to the parameters of the sine wave. The magnitude spectrum can be mapped to the polar coordinate system. The normalized magnitude spectrum can be viewed as a probability distribution [11]. The best orientation can be estimated as the most probable orientation or the mean.

Orientation fields obtained by local estimation approaches for poor quality fingerprints are usually very noisy. To deal with this problem, two types of algorithms have been adopted to regularize the noisy orientation field, namely, orientation field smoothing and global parametric model fitting. Typically, some constraints or knowledge about the fingerprint orientation field are utilized in the regularization algorithm.

Smoothing

Many orientation field regularization techniques have been proposed to deal with noise present in the fingerprint. The most commonly used smoothing method is based on low-pass filtering [14]. Although the low-pass filtering method is simple and effective, the size of the filtering window is a critical parameter. A large window can suppress the noise better while a small window can preserve the true orientation in a high curvature region. Several authors have suggested using multiresolution orientation fields to address this problem [9], [21], [30], [45]. However, when the noise is severe, as in latents, smoothing techniques are not able to recover the true orientation field. Several researchers have implemented orientation field smoothing by using the Markov Random Field (MRF) model or energy minimization approach [16], [19], [31]

A well-known limitation of these algorithms is that the orientation variable corresponds to a very small image region so that it can be represented by a single dominant orientation. However, an MRF model with small neighborhood or context is able to exploit only limited prior knowledge about fingerprint structure [46], [47] and thus cannot deal with fingerprints of very poor quality.

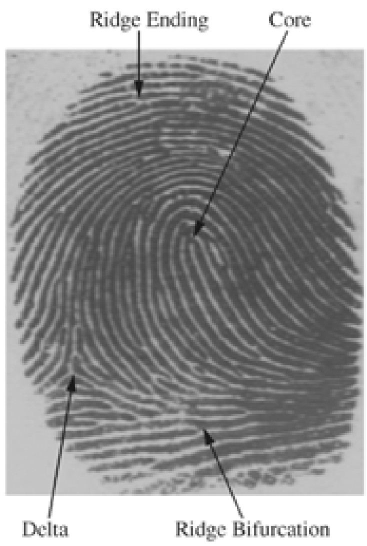
Global Parametric Models

Researchers have proposed several mathematical models to represent the whole fingerprint orientation field. Some of the models are quite general, such as polynomials [22] and Fourier series [25], while the others are more specific to fingerprints [12], [20], and [29]. Without invoking constraints on the parameters [22], [25], general models tend to have over fitting (e.g., if the order of the polynomial is high) or under fitting problems (e.g., if the order of the polynomial is low), especially when the initial orientation field is very noisy. Models which explicitly consider singular points rely on reliable extraction of singular points. However, extracting singular points [12], in latents is a very challenging problem itself. That is why the orientation field estimation approaches in require manually marked singular points as input.

INTRODUCTION

Fingerprint

Fingerprints are the patterns formed on the epidermies of the fingertips. It is composed of Ridges & Valleys.The interleaved pattern of ridges & valleys are the most evident structural characterstics of a Fingerprint.



Various levels in fingerprint

(a) Grayscale image (b) orientation field (c) ridge skeleton (d) ridge contour, pore and dot

A fingerprint image contains regions of different quality.

Well formed region, Recoverable region & Unrecoverable region. These regions may be identified according to image contrast, orientation consistency, ridge frequency & other local features.

Three main fingerprint features are Global ridge pattern, Local ridge detail (not adopted in AFIS) & Intra ridge detail (adopted in AFIS).

Local ridge details are the discontuities of local ridge structure referred to as Minutiae.

They are used for Forensic experts to match two Fingerprints. There are about 150 different types of Minutiae. Among these Minutiae types ridge ending & ridge bifurcation are the commonly used as all the other types of Minutiae are combination of ridge endings & ridge bifurcation.

The steps in Image Enhancement (in general or conventional method)

Segmentation : Separates the foreground regions (have high variance value) from the Background regions(have low variance values) for extraction of Minutiae.
Normalization : It allows to standardize the distorted levels of variation in the grayscale values.

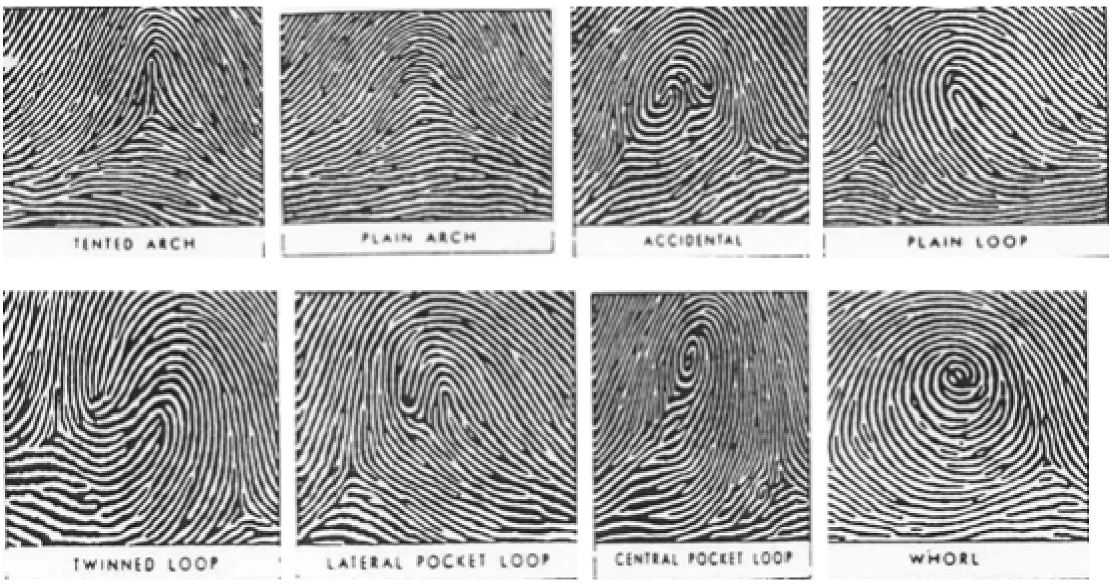
Orientation estimation : Orientation image represents the local orientation of the Ridges & is a matrix of direction vectors(Gabor filtering depends on the proper orientation)

Ridge frequency estimation : Important parameter used in the construction of the Gabor filter.

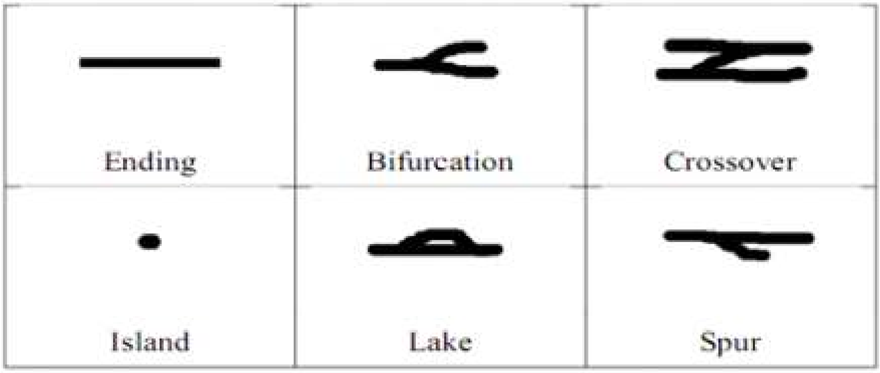
Minutiae extraction : After the enhancement of the finger print image , the image is ready for minutiae estimation. For proper extraction, a thinning algorithm Is applied to the enhanced image. It produces a skeletonized representation of the image.

Thinning is a morphological operation used to remove selected foreground pixels from binary images. It is used to eliminate the redundant pixels till the ridges are just one pixel wide.
Improving Minutiae extraction & recognition rate are the main goals in enhancing finger print images.

Fingerprint Patterns



Common Minutia types



Types of Fingerprints

Three types of impressions of the same finger.

(a) Rolled fingerprint (b) plain fingerprint (c) latent fingerprint.

Latent Fingerprints

Latent fingerprints refer to the impressions unintentionally left on items handled or touched by fingers.

Latent fingerprints are often not directly visible unless some physical or chemical technique is applied to enhance them.

Need for fingerprint enhancement :

- Latent fingerprints, or simply latents, have been considered as cardinal evidence for identifying and convicting criminals.
- The amount of information available for identification from latents is often limited due to their poor quality.
- Unclear ridge structure with complex background or even other latent prints.

•It is obvious that fingerprints are the most widely applied biometric identifiers.
•With the help of high performance computers, Automatic Fingerprint Identification Systems (AFIS) have gradually replaced human experts in fingerprint recognition as well as classification.
•However, fingerprint images contain noises caused by factors such as dirt, grease, moisture, and poor quality of input devices and are one of the noisiest image types.
•Therefore, fingerprint enhancement has become a necessary and common step after image acquisition in the AFIS.

Latent Fingerprint Enhancement

Estimating orientation field of a fingerprint is a crucial stage in most fingerprint matching algorithms. Orientation field, ?(x, y), represents the ridge flow of a fingerprint at each location. To reduce computational and storage complexity, fingerprint orientation field is generally defined at the block level rather than at the pixel level. The dominant ridge orientations in a block are called orientation elements and defined in the interval [0,π). Quality of fingerprint ridges can be improved by enhancing the local ridge clarity along the ridge orientation and suppressing noise in other directions. The proposed latent fingerprint enhancement algorithm consists of the following four steps:

1. Manual markup of ROI and singular points.
2. Orientation element computation using the Short-Time Fourier Transform (STFT).
3. Orientation field estimation using R-RANSAC.
4. Fingerprint enhancement using Gabor filters

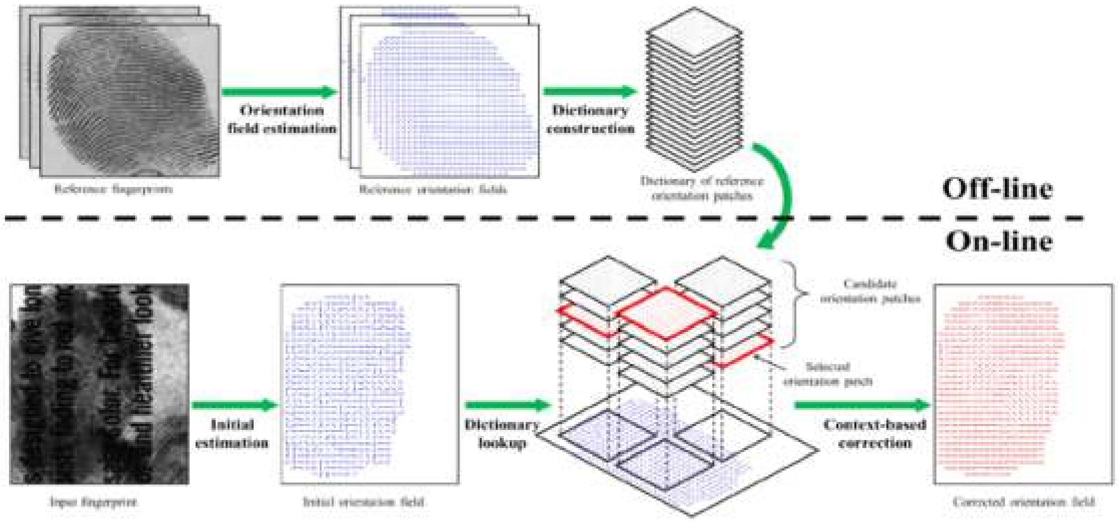
Proposed Orientation Field Estimation Based Enhancement

A reliable extraction algorithm is a critical step for a general fingerprint identification system. This performance is relatively dependent on the fingerprint image quality and enhancement step that can improve the clarity of the ridge structures. An Orientation Field Estimation based image enhancement algorithm is proposed. Orientation Filed Estimation is the representative method for contrast enhancement, specifically global contrast. Along with Orientation Filed Estimation a pyramid based Gabor filtering is applied. The reconstruction of the final out image which is a combination of both processing, aims to get the resultant image, enhanced with local information, such as local contrast and fine edges in the image. The proposed scheme is based on the following equation as,

$$I_0 = I_N + \sum_{m=1}^{N} Dn$$

Where I_0 =input grayscale image,
I_N = decomposed images with Gaussian low pass filter
N = the highest decomposition layer D_n = Laplacian images

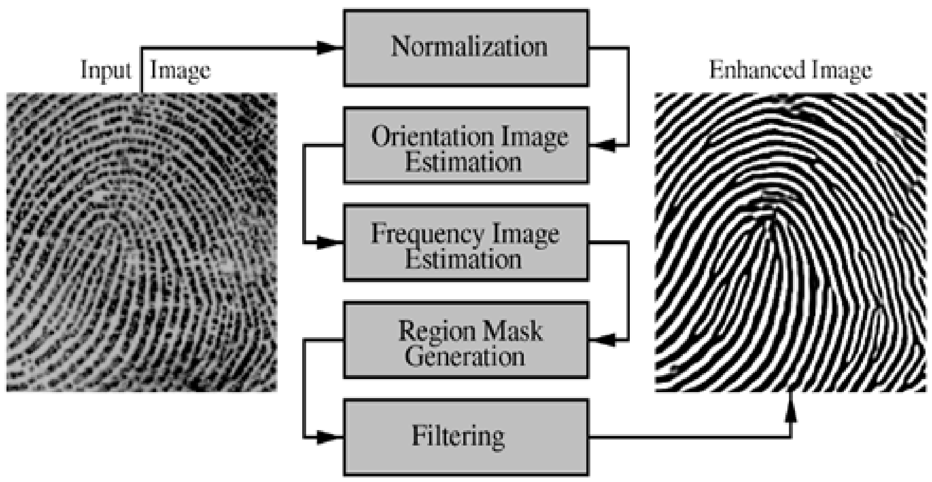
Proposed Algorithm



Greedy Algorithm

1.The first orientation patch is added into the dictionary, which is initially empty.
2.Then we test whether the next orientation patch is sufficiently different from all the orientation patches in the dictionary. If yes, it is also added into the dictionary; otherwise, the next orientation patch is tested.
3.Here, the similarity measure between two orientation patches of b × b blocks is computed as ns/b2, where ns denotes the number of orientation elements whose difference is less than 10 degrees.
4.Repeat step 2 until all orientation patches have been tested. The number of reference orientation patches in the dictionary depends on the number of reference orientation fields and the size of the patch.

Steps for fingerprint enhancement



A flowchart of the proposed fingerprint enhancement algorithm

The following steps (in no particular order) are the basic steps that may be utilized before a template can be created.

• Image binarization • Thinning • Finding Minutia • Remove False Minutia

The built-in Morphological thinning function in MATLAB to do the thinning and after that an enhanced thinning algorithm is applied to obtain an accurately thinned image.

Orientation field (or ridge flow) estimation:

Various methods:

1) Gradient-based 2) Gabor filters 3) STFT

Improvement

The proposed algorithm is still inferior to manual marking, especially on low-quality latents, and its speed is slow. The following aspects should be considered to improve the current algorithm.

1.Developing an automatic region segmentation algorithm.
2.Conducting a comprehensive study of various algorithmic parameters using large latent fingerprint databases.

Performance Evaluation

The main goal of an orientation field estimation algorithm is to obtain an accurate estimation of fingerprint orientation field, while its final goal is to improve the fingerprint matching accuracy. Thus, we conducted experiments to evaluate the accuracy of orientation field estimation and the accuracy of fingerprint matching, respectively.

In addition to the proposed orientation field estimation algorithm, two other approaches were included:

1.Combination of gradient-based local estimation and FOMFE-based global model[25].
2.Combination of STFT-based local estimation and low-pass filtering [11].

The accuracy of orientation field estimation algorithm is measured using the average Root Mean Square Deviation (RMSD) [37]. The ground truth was established based on the manual marking of the orientation field by one of the authors. Average RMSD of the proposed algorithm and FOMFE and STFT are computed on all the latents in the Fingerprint database and also on the subsets of NIST SD27 belonging to three quality levels (Good, Bad, and Ugly).

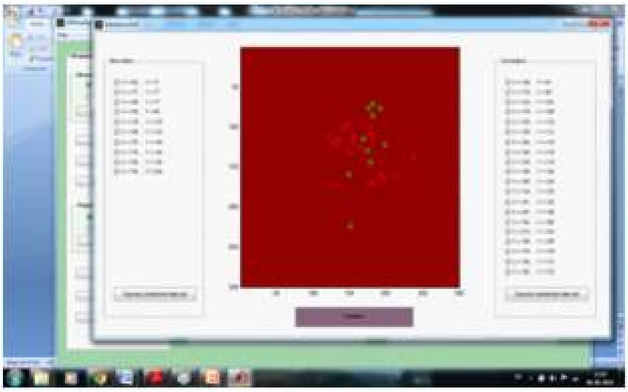
To evaluate the matching accuracy, we need to integrate an orientation field estimation approach with the other modules in the matching system, namely, fingerprint enhancement, feature extraction, and matching. Latent fingerprints are enhanced using a Gabor filter whose frequency parameter is fixed at 1=9 cycles per pixel, standard deviations of the Gaussian envelope are fixed as 4, and the orientation parameter is tuned to the estimated orientation field [10]. VeriFinger SDK 6.2 [40] is used to extract features from enhanced latents and original full fingerprints. The same SDK is then used to compute the match scores between latents and full fingerprints.

EXPERIMENTAL RESULTS

Our experiments were conducted on two latent databases: NIST SD27 database and West Virginia University (WVU). NIST SD27 and the WVU DB, respectively, contain 258 and 192 latent ?ngerprints with their corresponding rolled prints. NIST SD27 contains latents and mated full prints from operational settings whereas WVU DB was collected in a laboratory. The characteristics of these two databases are quite different with NIST SD27 being a better representative of type of images processed by AFIS. The proposed method provides satisfactory results as far as visual inspection is concerned.

RESULTS

Automatic region segmentation validation of Minutia points



Various algorithmic parameters

CONCLUSION

• In this project orientation estimation and Gabor filter is used for latent fingerprint enhancement.
• Because of its frequency selective and orientation selective properties it is very effective for fingerprint enhancement.

Experiments are conducted using proposed algorithm & Improvement algorithm(Automatic region segmentation algorithm) & measured various algorithm parameters(i.e MSE,PSNR,NK,SSIM) are measured & got satisfactory results.

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