

FINGERPRINT MATCHING BASED ON PORE CENTROIDS

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Abstract

In recent years there has been exponential growth in the use of biometrics for user authentication applications. Automated Fingerprint Identification systems have become popular tool in many security and law enforcement applications. Most of these systems rely on minutiae (ridge ending and bifurcation) features. With the advancement in sensor technology, high resolution fingerprint images (1000 dpi) provide micro level of features (pores) that have proven to be useful features for identification. In this paper, we propose a new strategy for fingerprint matching based on pores by reliably extracting the pore features. The extraction of pores is done by Marker Controlled Watershed segmentation method and the centroids of each pore are considered as feature vectors for matching of two fingerprint images. Experimental results shows that the proposed method has better performance with lower false rates and higher accuracy.

Keywords:

High Resolution Fingerprint Image, Pore Extraction, Marker Controlled Watershed Segmentation, Pore Centroids, Pore Matching

1. INTRODUCTION

Fingerprint identification is a well-researched problem, and automatic fingerprint identification/verification techniques have been successfully adapted to both civilian and forensic applications for many years. Fingerprint features are divided into three categories: level – 1, level – 2, and level – 3 features [1]. Level – 1 feature represent the ridge-flow pattern and general morphological information. These features are not unique for establishing identity but are used for broad classification of fingerprints into different classes such as left loop, right loop, whorl, arch, and tented arch. Level-2 features represent the minutiae information such as ridge endings and bifurcations. Level-3 features are obtained from the sweat pores and ridges present in fingerprints. These features represent the intricate details of a fingerprint such as the dimensional attributes and structure of pores and ridges which are the most discriminating among all three levels of features. There are three types of fingerprint matching methods: minutiae-based, correlation-based, and image-based [1],[2]. In minutiae-based approaches, minutiae (i.e. endings and bifurcations of fingerprint ridges) are extracted and matched to measure the similarity between fingerprints [3]-[7]. These minutiae-based methods are now the most widely used ones [1],[8]. However, as people's desire for higher security levels keeps increasing, it is highly necessary to base the recognition of fingerprints on more features, but not merely minutiae. The recently developed high resolution fingerprint scanners make it possible to reliably extract level-3 features such as pores. Pores have been used as useful supplementary features for a long time in forensic applications [9],[10]. Using pores in Automatic Fingerprint Recognition System (AFRS) has two advantages. First, pores are more difficult to be damaged or mimicked than minutiae [11]. Second, pores are abundant on fingerprints. Even a small fingerprint fragment could have a number of pores as shown in Fig.1.

Therefore, pores are particularly useful in high resolution partial fingerprint recognition where the number of minutiae is very limited.



Fig.1. An example of high resolution partial fingerprint having hundreds of pores

Researchers have proposed algorithms for level-3 feature based fingerprint verification (1:1 matching) [12]-[14]. These algorithms extract level-3 features and fusion with level-2 information is performed hierarchically or at match score level. However, these algorithms are computationally expensive to be used for identification. Several identification approaches have been proposed by the researchers but none of them use level-3 features [15]-[19]. Further, identifying latent fingerprints is also a major challenge for law enforcement agencies [20].

In a single fingerprint image more than 1400 pores can be found. According to [12] only 20 to 40 pores are necessary for fingerprint identification. Therefore the pore's centroid based matching approach will effectively improve the accuracy of Fingerprint Identification System. To our knowledge, this is the first attempt to propose a matching technique based on pore centroids.

The rest of the paper is organized as follows. Section 2 gives a brief history of fingerprint pore extraction. Section 3 describes the proposed method of pore extraction and matching method. Section 4 provides the performance evaluation and finally conclusion is presented in Section 5.

2. BACKGROUND

2.1 FINGERPRINT PORE EXTRACTION AND MATCHING

In the earliest pore-based AFRS developed by Stosz and Alyea [21], fingerprints are first aligned by searching for the best alignment in a discretized transformation parameter space. The correlation between manually marked regions is used to choose the best alignment. Such correlation based method was later used by Kryszczuk et al. [22],[23] in their study of using pores to recognize fragmentary fingerprints. After aligning the fingerprints, the pores on them can be matched by simply comparing

their coordinates in the aligned fingerprint coordinate system. These pore matching methods are limited in the following factors. First, their accuracy highly depends on the way of discretizing the transformation parameters. Second, they have to search through all possible rotations and translations, which is computationally very expensive.

The state-of-the-art pore matching method was recently proposed by Jain et al.[24][25]. In the method, the fingerprint images were first aligned based on the minutiae features on them by using a string-matching algorithm. Minutiae on the fingerprints were then matched and paired. Pores lying in a rectangular neighborhood to each pair of matched minutiae were cropped and rotated according to the directions of the two minutiae. Afterwards, they were matched by using the iterative closest point (ICP) algorithm which is capable to handle sets of points with different numbers of points and can compensate for non-linear deformation between them. The average distance between matched pores was taken as the pore match score. This score was then fused with the minutiae match score by using the weighted summation scheme. Compared with previous pore matching methods, this method can cope with fingerprint transformation more efficiently. However, it matches pores based on the minutiae matching results. Consequently, the pore matching accuracy is limited by the minutiae matching accuracy and the match scores of minutiae and pores will be dependent. Such dependency will impair the effectiveness of the subsequent fusion of the match scores. In order to avoid the dependency of pore matching on minutiae matching this paper proposes a novel direct approach to matching pores on fingerprints based on centroid positions.

3. PROPOSED METHOD

3.1 PORE EXTRACTION METHOD

In this paper pores are extracted from fingerprint image by using Marker Controlled Watershed Segmentation method proposed by S. Malathi et al. [27]. Fig.2 shows an example of fingerprint image and the pores extracted from it. The algorithm created foreground and background markers using Morphological image reconstructions. The watershed transform of the gradient fingerprint image is computed without any other processing. The result is severely over segmented due in part to the large number of regional minima.

By computing the location of all regional minima in the fingerprint image, we found that most of the regional minima are very shallow and represent detail that is irrelevant to our segmentation problem. The extraneous minima is eliminated by computing the set of low spots in the image that are deeper (by a height threshold = 2) than their immediate surroundings. Then the markers are superimposed on the original fingerprint image.

Next, background markers are created. The approach followed here is to mark the background by finding pixels that are exactly midway between the internal markers. This is done by computing the watershed transform of the internal marker image. The resulting watershed ridgelines appear in midway between the pores and hence they serve as external markers.

The internal and external markers are then used to modify the gradient fingerprint image using a procedure called minima im-

position. The minima imposition technique modifies a fingerprint image so that regional minima occur only in marked locations. Other pixel values are pushed up as necessary to remove all other regional minima. The gradient fingerprint image is then modified by imposing regional minima at the locations of both the internal and the external markers. Finally watershed transform of the marker-modified gradient fingerprint image is computed. After superimposing the watershed ridgelines on the original fingerprint image, a much improved pore extraction is obtained as shown in Fig.2.

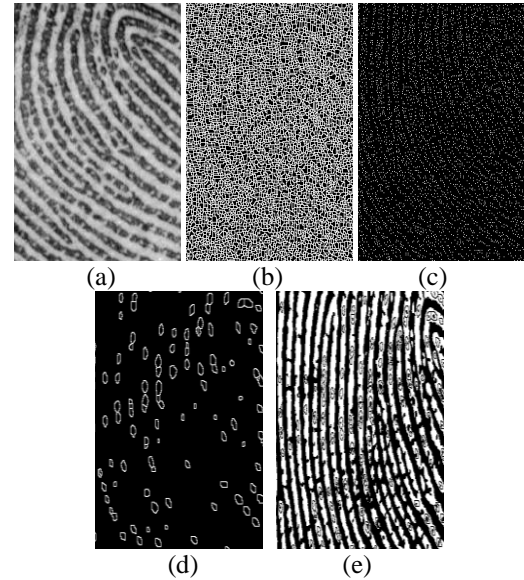


Fig.2. Pore extraction from fingerprint image (a) Original image (b) Over segmented image (c) Regional minima (d) Marker image (e) Extracted pores

3.2 PORE MATCHING

From a statistical perspective, the centroids of pores are events in point process [26]. With regard to the features of pores, usually only the locations (or centroids) of pores are stable enough for matching. In this paper the centroids of each pore is considered for matching two fingerprints. The configurations of pore centroids are usually non-homogeneous and form directional patterns. The centroid (ρ^x, ρ^y) is calculated as,

$$\rho^x = \frac{\sum_{cols} \sum_{rows} I_{ij} x_i}{\sum_{cols} \sum_{rows} I_{ij}}, \quad \rho^y = \frac{\sum_{cols} \sum_{rows} I_{ij} y_j}{\sum_{cols} \sum_{rows} I_{ij}}. \quad (1)$$

The matching phase typically defines the similarity (centroid) metric between two fingerprint representations and determines whether a given pair of representations is captured from the same finger (mated pair) based on whether this quantified similarity is greater (less) than a certain (predetermined) threshold. The similarity metric is based on the concept of correspondence in both fingerprint images. Therefore pore matching is accomplished by matching centroids of the fingerprint images. The x and y coordinates of the centroid positions are stored in a template file for both fingerprint images and taken for matching.

4. PERFORMANCE EVALUATION

In order to measure the performance, the matching algorithm is executed on images from Neurotechnology database. The database consists of 408 images (51 distinct fingers, 8 instances each). In order to obtain the performance characteristics such as False Rejection Rate (FRR), and False Acceptance Rate (FAR), total of 1428 genuine (each instance of a finger is compared with the rest of the instances resulting in $(8 \times 7)/2$ tests per finger) comparison and 1275 impostor comparisons (the first instance of each finger is compared against the first instance of all other fingers resulting in a total of $(51 \times 50)/2$ tests for the entire database).

Each sample in a database is matched against the remaining sample of the same finger to compute the False Rejection Rate (FRR). The FRR is the fraction of genuine fingerprints which are rejected and is calculated as follows,

$$FRR = \frac{\text{No. of genuine fingerprints rejected}}{\text{Total no. of genuine tests}}. \quad (2)$$

For all databases the first sample of each finger is matched against the first sample of the remaining fingers in the same database to compute the False Acceptance Rate (FAR). The FAR is the fraction of impostor fingerprints which are accepted and is calculated as follows,

$$FAR = \frac{\text{No. of impostor fingerprints accepted}}{\text{Total no. of impostor tests}}. \quad (3)$$

The results of employing the pore extraction method are very promising and the matching performance is high. Table.1 clearly shows the false rejection and false acceptance rate for different threshold values.

Table.1. Summary of experimental results

Threshold value	False Rejection Rate	False Acceptance Rate
80	0.064	0.026
75	0.046	0.065
70	0.048	0.096

5. CONCLUSION

This paper presents direct pore matching approach for fingerprint recognition. The proposed matching method is independent from the minutiae matching. First, pores are extracted using marker controlled watershed segmentation method. Then the x and y coordinates of the centroids of each pore are taken for matching. We have tested with various threshold values for matching process. By analyzing the matching scores, this method proves to be more effective in improving the fingerprint recognition accuracy. Our future work will concentrate on reducing the number of pores by introducing a better post processing method and better matching strategies.

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