A Hybrid System for Fingerprint Identification

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Abstract

F*ingerprint-based identification is one of the core methodologies for person identification. It remains a reliable, efficient and commonly accepted biometric. The most popular and extensively used method for fingerprint identification; the minutiae based, show poor performance for real time authentication. However, the performance of minutiae based approaches can be boosted by combining statistical information obtained from other image processing techniques (Wavelet transforms). This paper explores hybrid fingerprint matching system with the fusion of minutiae features and wavelet statistical features. The final matching score is calculated by fusing matching scores of the minutiae based method and wavelet based method. The performance of the proposed hybrid fingerprint recognition method can be evaluated by measuring its False Reject Rate (FRR) and False Accept Rate (FAR) as shown in the simulation results. The proposed method is more efficient than conventional minutiae based methods for real time authentication systems with large size databases.*

***Keywords*, of the Abstract**

Biometrics, fingerprint matching, Minutiae, Wavelet transform.

1. Introduction

Biometric is the science of verifying and establishing the identity of an individual through physiological features (Fingerprint, Hand-geometry, and Face) or behavioral traits (Handwriting, Speech, Signature, Gait). Biometrics is a rapidly evolving technology that has been widely used in forensics, such as criminal identification and prison security, and has the potential to be widely adopted in a very broad range of civilian applications such as Banking security, Physical access control, Information system security, Customs and immigration, National ID systems, Voter and driver registration. Fingerprint is the most reliable bio-metric for people identification [1]. According to Ross et al [2], it is extremely difficult to increase the accuracy of the system in a relevant way using just one form of representation or only one matching algorithm.

Minutiae based approach often gives satisfactory results for good quality images. But if, the quality of image is poor, then minutiae extraction is a very difficult task and often gives incorrect results that are not acceptable for real time authentication applications. However the performance of minutiae based approaches can be boosted by combining statistical information obtained from other image processing techniques. This paper explores hybrid fingerprint matching system with the fusion of minutiae features and wavelet statistical features and final matching score is calculated by fusing matching scores of the minutiae based method and wavelet based method. The performance of the proposed hybrid fingerprint recognition method can be evaluated by measuring its False Reject Rate (FRR) and False Accept Rate (FAR) as shown in the simulation results. The proposed method is more efficient than conventional minutiae based methods for real time authentication systems with large size databases.
The rest of the paper is organized as follows: Section 2 discusses fingerprint matching methods. Section 3 describes the proposed hybrid fingerprint matching method. Experimental results are discussed in section 4. Finally the conclusion and future directions are outlined in section 5.

2. Fingerprint Matching Methods

Following are the fingerprint matching methods:

1. Minutiae Based Method.
2. Wavelet Transform Based Method

2.1. Minutiae Based Method

Minutiae-based methods are the most popular ones being included in almost all contemporary fingerprint identification and verification systems [3]. This method represents the fingerprint by its local features like, terminations and bifurcations called as minutia. Minutiae are small points of interest in the fingerprint image. The minutiae-based method does the recognition in two stages that is minutiae extraction and minutiae matching. The minutiae extraction process can be shown below in figure 1:

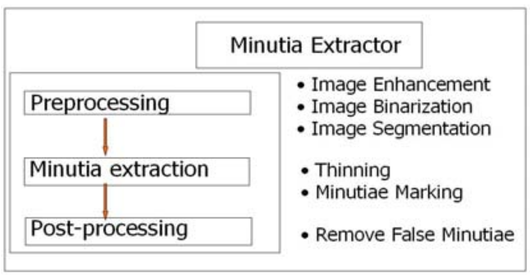

Fig. 1 Minutiae extraction process

The minutiae based method requires extensive preprocessing operations in order to reliably extract the minutiae features. The preprocessing operations include image enhancement, segmentation and thinning, false minutiae detection. Therefore this method requires lot of time to extract the minutiae for matching and has low computational efficiency [3-7]. After extracting the real minutiae points, the fingerprints are matched using the alignment based method. It aligns the two sets of minutiae points and determines the total number of matched minutiae. The minutiae based method is basically well suited for 1-many matching. It is a well-known and well researched method. People with no or few minutiae points (special skin conditions) cannot enroll or use the system effectively. This is exemplified by the fingerprint immigration programs where finger moistening peripherals are standard. Moreover, a low number of minutiae points can be a limiting factor for security of the algorithm. This can lead to false minutia points (areas of obfuscation that appear due to low-quality enrollment, imaging or fingerprint ridge detail). Moreover, the widely used minutiae – based representation does not utilize a significant component of the rich discriminatory information available in the fingerprints.

2.2. Wavelet Transform Based Method

This method uses image-based method of fingerprint recognition. It uses the wavelet transform. Wavelets provide rich techniques that can be applied to many tasks in signal processing, and therefore have numerous potential applications[8].The fingerprint patterns are matched based on their wavelet domain features which are directly extracted from the gray-scale fingerprint image without pre-processing (i.e. image enhancement, directional filtering, ridge segmentation, ridge thinning and minutiae extraction). The image-based approach do not use minutiae based features for fingerprint matching. As the method does not require pre-processing, the method achieves high computational efficiency and low computational complexity.

Fingerprint matching using wavelet transform is shown below in figure 2. Main steps are as follows:

I) Wavelet Statistical Feature Extraction.

II) Wavelet Statistical Feature Matching

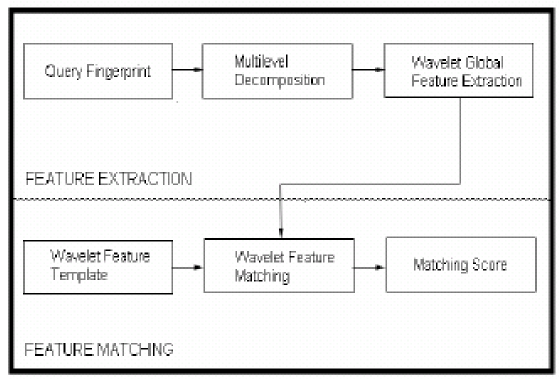

Fig.2 Fingerprint matching using wavelet transforms

Wavelet transforms have important characteristics which make them valuable tools for many tasks in signal processing [9]. Figure 3 shows the wavelet statistical feature set extraction process:

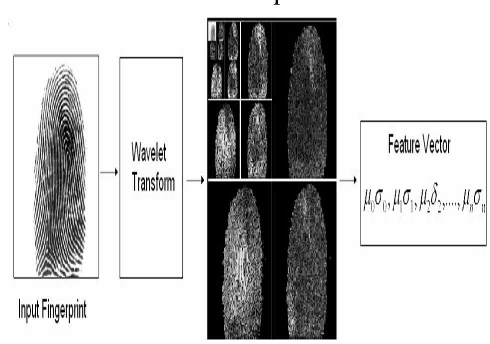

Fig. 3 Wavelet Feature Extractions

The two-dimensional (2D) wavelet decomposition on J octaves of a discrete image a_0 [n, m] represents the image in terms of $3J + 1$ sub images as in Eq. (1)

$$[a_J, \{d^1_j, d^2_j, d^3_j\}\ j = 1,..., J\,] \ldots\ldots \quad (1)$$

Where a_J is a low resolution approximation of the original image, and d^k_j are the wavelet sub images containing the image details at different scales (2^j) and orientations (k) [8],[9].Wavelet coefficients of large amplitude in d^1_j, d^2_j,and d^3_j correspond to vertical high frequencies (horizontal edges), horizontal high frequencies (vertical edges), and high frequencies in both directions respectively [9]-[10].

In the matching process wavelet statistical features of input (query) fingerprint are matched against wavelet features of template fingerprint stored in feature library using Euclidean distance vector formula given below in Eq.(2). Euclidean Distance between points $P(p_1,p_2,p_3,\ldots,p_n)$ and $Q(q_1,q_2,q_3,\ldots,q_n)$ is calculated as shown below in Eq.(2):

$$\sqrt{(p_1-q_1)^2 + (p_2-q_2)^2 + \ldots + (p_n-q_n)^2} \quad (2)$$

where $P(p_1,p_2,p_3,\ldots,p_n)$ represents the features of input test fingerprint while $Q(q_1,q_2,q_3,\ldots,q_n)$ represents the features of n^{th} template fingerprint in the library. The input fingerprint is compared with all the fingerprints stored in feature library and minimum of all distances is found. This minimum distance corresponds to wavelet Matching Score of the input image which is further used in calculating final matching score [11].

3. The Proposed Method -Hybrid Fingerprint matching

To accentuate the strengths of both the minutiae-based method and the wavelet based method and limit the inherent weaknesses, the proposed method is Hybrid fingerprint matching. The proposed method does the fusion of two distinct sets of fingerprint information: minutiae features and wavelet statistical features. The hybrid fingerprint matching system is shown below in figure 4

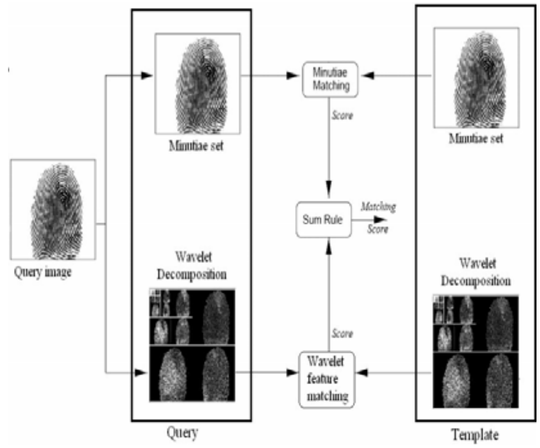

Fig. 4 Hybrid Fingerprint Matching System

When a query image is presented, the matching proceeds as follows: (i) the query and template minutiae features are matched to generate a minutiae matching score. Similarly the query and the template wavelet features are matched to generate a wavelet feature matching score. (ii) The minutiae and the wavelet features are combined to generate a single matching score. In order to explore the fusion of the minutiae –based and the wavelet based fingerprint identification methods in a wide way, the rank, decision and score level fusion are used.

3.1 Rank Level Fusion

The output of the matching module of a biometric system can be a rank of the registered users in the database. The objective of the rank level fusion is to consolidate the rank obtained individually by the methods in order to derivate a consensual rank for each user. For this fusion level the following techniques can be used:

1. **Highest Rank:** The best rank position is associated to the image.
2. **Borda Count:** The Borda count uses the sum of the rank positions obtained by the methods.
3. **Logistic Regression:** It is a generalization of the Borda method, which associates a weight for each method.

Ties are broken randomly to arrive at a strict ranking order.

3.2 Decision Level Fusion

Many biometric systems provide just a final decision as output. This final decision represents the user identity whose template image best matches the query image. The fusion at decision level aims to consolidate the decisions made individually by the methods in order to derive a consensual decision.

For the fusion at decision level, the Bayesian Decision technique can be used. This fusion scheme consists in transforming the decision labels (classes) of each method in probability rates. In order to do it, it is necessary required a training stage where the confusion matrix for each method is calculated.

3.3 Score Level Fusion

The matching score is a measure of the similarity between the query image and the template image. After the image and the feature vectors, the matching score represents the richest information of a biometric system. However as the scores of different matching algorithms can provide values in different ranges, it becomes necessary to include a normalization stage of those scores.
The following score normalization techniques can be used to make possible the score level fusion:

1. **Min-Max:** This normalization technique is the most used when the bound values (minimum and maximum score values) are known. The realization of this method will transform all the scores in a common range ([0, 1]).
2. **Double Sigmoid Function:** This normalization technique consist in transforming all the scores in a common range [0, 1] using three points of reference: i) ŕ: a point of the region between a genuine score distribution and imposter score distribution, ii) α_1 and α_2 points that correspond to the extend of the overlap between the genuine and the imposter distributions, representing their inferior and superior limits respectively.
3. **Tanh – estimators:** This normalization technique uses the mean and the standard deviation of the genuine score distribution. This normalization scheme reduces the score influence on the extremes of the distribution through reference points.

After the scores normalization, the following fusion techniques can be applied at the score level: **Sum** of the scores, **Product** of the scores, **Max**-score, **Min**-score and **weighted sum.**

4. Experimental Results

The matching scores generated by comparing the minutiae sets and wavelet statistical features, are combined in order to generate a single matching score. Here the sum rule is used [11], [12], [13], [14]. Let Minutiae Matching Score (MMS) and Wavelet Matching Score (WMS) indicate the matching scores obtained using minutiae matching and wavelet statistical feature matching respectively. Then, the final matching score (FMS) is computed as in Eq. (3)

$$FMS = \alpha \times MMS + (1-\alpha) \times WMS$$

Where, $\alpha \; \varepsilon \; [0, 1]$. Here, α is set as 0.5

4.1 Dataset

The hybrid fingerprint matching system consists of a fingerprint database collected for fingerprint verification competition 2004 (FVC 2004) [15], [16] .It uses DB1, set A dataset that consists of 800 fingerprint images from 100 individuals.

4.2 Measuring Performance.

The performance of the hybrid fingerprint identification system can be evaluated by measuring its False Reject Rate (FRR) and False Accept Rate (FAR). By evaluating the FRR & FAR, the threshold of the matching score deciding whether to reject or accept a match is set for optimizing the performance. The simulation results are shown in Table 1.

Table 1: Simulation results of fingerprint matching with different threshold.

Threshold	False Acceptance Rate (FAR)	False Reject Rate (FRR)
38	0.10	25.00
43	1.00	4.65

Here incorrect matches and high reject rates are due to fingerprint images of poor quality. The identification results will get automatically improved, if these poor quality images are removed from database.

5. Conclusion and Future work

A hybrid fingerprint recognition system based on minutiae features and wavelet statistical features is proposed here. Minutiae give rich information for fingerprint matching. However, due to different problems like small commonality of imaged area between different images of the same finger, skin distortion, artifacts due to noise and wet fingers, poor contrast due to skin dryness or low contact pressure, minutiae extraction is a difficult and computationally intensive task. Further, these algorithm show very poor performance, if poor quality or incomplete images are input. In order to improve efficiency of these algorithms, it is necessary to utilize some additional discriminating information useful for matching. The wavelet features exhibit valuable properties for matching complex patterns of oriented texture- like patterns. Here, wavelet statistical features are combined with minutiae features. The features are extracted directly from the gray scale fingerprint image without preprocessing. Experimental results have shown that, the proposed method is suitable for real time authentication systems with a large number of identities enrolled into them.

Here, following are the directions for improving the accuracy of this algorithm:

- Feature level fusion or decision level fusion may improve the performance of this method.
- Wavelet packet transform and other powerful texture features can improve the performance of the system [17], [18] [19].
- Level 3 features like pores, ridge details can be used to increase the performance of the system.

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