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Direct RTI Fingerprint Identification Based on GCMs and Gabor Features Around Core point

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Abstract: A direct RTI(Rotation and translation invariant) fingerprint identification is proposed using the GCMs(generalized complex moments) and Gabor filter-based features from the grey level fingerprint around core point. The core point is located as reference point for the translation invariant matching. And its symmetry axis is detected for the rotation invariant matching from its neighboring region centered at the core point. And then, fingerprint is divided into non-overlapping blocks with respect to the core point and, in contrast to minutiae-based method using various processing steps, features are directly extracted from the blocked grey level fingerprint using Gabor filter, which provides information contained in a particular orientation in the image. The proposed fingerprint identification is based on the Euclidean distance of the corresponding Gabor features between the input and the template fingerprint. Experiments are conducted on 300×300 fingerprints obtained from the CMOS sensor with 500 *dpi* resolution, and the proposed method could obtain 97% identification rate.

1. Introduction

With the advent of electronic banking, e-commerce, and smartcards and an increased emphasis on the privacy and security of information stored in various databases, *automatic* personal identification has become a very important research topic. *Biometric* to identify an individual based on his or her physiological or behavioral characteristics has the capability to reliably distinguish between an authorized person and an imposter.

Among all those biometrics of face, fingerprints, hand geometry, iris, retina, signature, voice, fingerprint, facial thermogram, hand vein, gait, ear, odor, and keystroke dynamics, etc. [1, 2], fingerprint-based identification is one of the most mature and proven technology. Popular fingerprint representation schemes have evolved from an intuitive system design tailored for fingerprint experts who visually match the fingerprints. These schemes are based on predominantly local landmarks such as minutiae-based fingerprint matching system [1,3, 4].

The main steps for minutiae extraction are smoothing, local ridge orientation estimation, ridge extraction, thinning, and minutiae extraction. And then, matching is conducted between their relative placements in a given fingerprint and the stored template [1]. However, it would not be efficient to follow all the images processing steps, and furthermore the identification results are heavily dependent on the accuracy of each step. A good quality fingerprint contains between 60 to 80 minutiae, but different fingerprints have different number of minutiae. The variable sized minutiae-based representation does not utilize a significant component of the rich discriminatory information available in the fingerprints. Local ridge structures cannot be completely characterized by minutiae. Further, typical graph-based [3] and point pattern-based [1,4] approaches in matching the minutiae from the two fingerprints need to align the unregistered minutiae patterns of different sizes which makes them computationally expensive. Therefore, after setting a reference points for the rotation and translation invariant matching, an efficient direct extracting of the feature vectors for matching from grey level image should be studied.

In this paper, RTI fingerprint identification is proposed using the GCMs and the Gabor filter-based features from the grey level fingerprint around core point. In first, the region of interest is detected using local gray level variance of the input fingerprint. And, GST (generalized symmetry transform) is applied to the *sine* component image of fingerprint to locate the core point for translation invariant matching. And, symmetry principal axis is detected by GCMs from the core point centered neighboring region for rotation invariant matching. And then, we divide fingerprint into non-overlapping blocks with respect to the core point and directly extract features from the blocked grey level fingerprint using Gabor filter, which provides information contained in a particular orientation in the image. The fingerprint matching is based the Euclidean distance of the corresponding Gabor filter-based features between input and template fingerprints. From 300×300 fingerprints obtained from the CMOS sensor with 500 *dpi* resolution, we evaluate the performance of the proposed method.

2. Direct RTI Fingerprint Identification based on GCMs and Gabor Features Around core pointS

2.1 Location of the Region on of Interest

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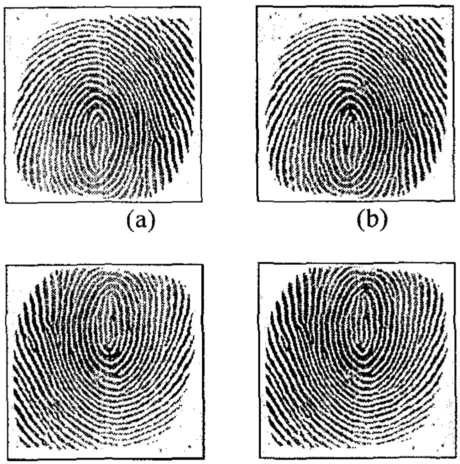
A segmentation algorithm, which is based on the local variance of grey level, is used to locate the region of interest from the fingerprint. In our segmentation algorithm, we assume that there is only one fingerprint in the image.

(a) (b)

Fig. 1. Detection of the region of interest (a) fingerprint, (b) the region of interest; excluding the dark region.

2.2 Detection of the core point

Many previous approaches to determination of a reference point (x_c, y_c) critically relied on the local features like *Poincarè* or some other similar properties of the orientation field [5]. While these methods work well for good quality fingerprints, they fail to correctly localize the reference point for poor quality fingerprints with cracks and scars, dry skin, or poor ridge and valley contrast. Recently, Hong et. al. [5] have attempted to judiciously combine the orientation field information with available ridge details in a fingerprint. However, this method does not reliably handle poor quality fingerprints when the orientation field is very noise and fingerprints are very rotated. We developed a core point detection algorithm that is more robust to noise and rotation than the conventional methods. To find core point, GST (generalized symmetry transform) is applied to the *sine* component image of fingerprint.



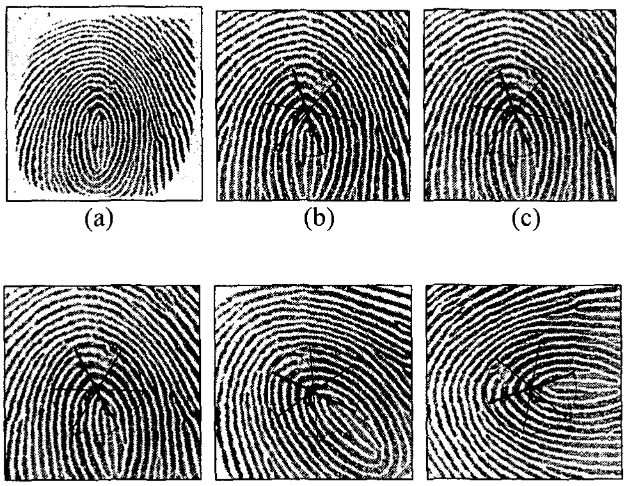
(a) (b)

(c) (d)

Fig. 2. Estimating the core point; (a) fingerprint, (b) core point detection, (c) the result of core point detection for 180° rotated fingerprint (d) the result of conventional method.

2.3 Detection of the Symmetry axis of the core region

To obtain rotation-invariant fingerprint matching, an invariant reference for matching is needed without respect to rotation of the fingerprint. In core region, fingerprint ridges are symmetric because it's shape is elliptical. In this paper, the symmetry axis of core region is detected using GCMs[6, 7]. Among the detected symmetry axes, the most symmetric axis is used as a reference for the rotation invariant matching. As shown in Fig. 3, symmetry axes are detected for the circular region of radius *r* centered at core point. And among the three symmetry axes, the most symmetric is used for rotation invariant matching.



(a) (b) (c)

(d) (e) (f)

Fig. 3. Detection of symmetry axis for the rotated fingerprints: (a) Original fingerprint, (b) 0° rotated, (c) 5° rotated, (d) 10° rotated, (e) 45° rotated, (f) 90° rotated fingerprints, respectively.

2.4 Normalization of each non-overlapping block

Normalization is performed to remove the effects of sensor noise and gray level deformation due to finger pressure difference. Let $I(x, y)$ denote the gray value at pixel (x, y), and M_i and V_i, the estimated mean and variance of non-overlapping block B_i, respectively, and $N_i(x, y)$, the normalized gray-level value at pixel (x, y). For all pixels in sector B_i, the normalized image is defined as:

$$N_i(x,y)=\begin{cases} M_0+\sqrt{\frac{V_0+(I(x,y)-M_i)^2}{V_i}}, & if \quad I(x,y)>M_i \\ M_0-\sqrt{\frac{V_0+(I(x,y)-M_i)^2}{V_i}}, & otherwise. \end{cases} \tag{1}$$

Where M_0 and V_0 are the desired mean and variance values, respectively. Normalization is a pixel-wise operation, which does not change the clarity of the ridge and valley structures. If normalization is performed on the entire image, then it cannot compensate for the intensity variations in different parts of the image due to the elastic nature of the finger. Separate normalization of each individual block alleviates this problem. After cropping the fingerprint into 160× 160 using its core point as the center, normalization is performed on the each non-overlapping block, 16× 16, as shown in Fig. 4(b).

2.5 Extraction of features using Gabor filter

Fingerprints have local parallel ridges and valleys, and well-defined local frequency and orientation. Properly tuned Gabor filter [9] can remove noise, preserve the true ridge and valley structures, and provide information contained in a particular orientation in the image. We used the Gabor filter to extract the feature vectors for the fingerprint. The general form of a 2D Gabor filter is defined by

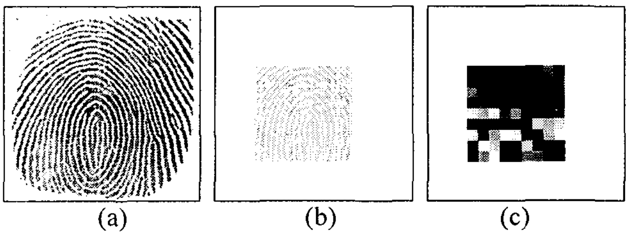
$$h(x, y, \theta_k, f, \sigma_x, \sigma_x) = \exp\left[-\frac{1}{2}\left(\frac{x_{\theta_k}^2}{\sigma_x^2} + \frac{y_{\theta_k}^2}{\sigma_x^2}\right)\right] \times \exp(i2\pi f x_{\theta_k}). \quad (2)$$

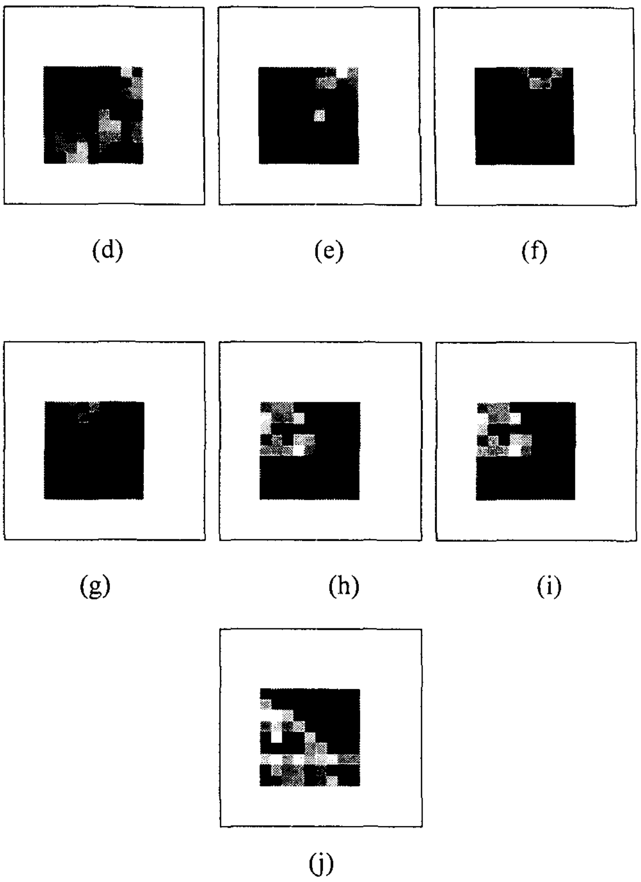
Where, $x_{\theta k} = x\cos\theta_k + y\sin\theta_k$ and $y_{\theta k} = -x\sin\theta_k + y\cos\theta_k$ are the frequency of the sinusoidal plane wave, θ_k is the orientation of the Gabor filter, and σ_k and σ_k are standard deviations of the Gaussian envelope along the x and y axes, respectively. we set f as the reciprocal of half of the average inter-ridge distance and m as the number of orientations. Let $F_{i\theta}(x, y)$ be the θ-direction filtered image for block B_i. the block feature value, $BF_{i\theta}$, is the average absolute deviation(AAD) from the mean defined as:

$$BF_{i\theta} = \frac{1}{n_i}\left(\sum_{n_i}\left|F_{i\theta}(x, y) - BM_{i\theta}\right|\right). \quad (3)$$

Where n_i is the number of pixels in B_i and $BM_{i\theta}$ is the mean of pixel values of $BF_{i\theta}(x, y)$ in block B_i.

In our experiment, we have used eight different values for θ=0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135.5°, 157.5° with respect to the x-axis as shown in Fig. 4(c). The AAD of each block in each of the eight filtered images defines the components of our feature vector.


(a) (b) (c)


(d) (e) (f)

(g) (h) (i)

(j)

Fig. 4. Normalized and Gabor filter-based feature extraction (a) fingerprint, (b) normalized image, (c) filtered block image for each non-overlapping block of size 16× 16

3. Matching

Fingerprint matching is based on finding the Euclidean distance of the corresponding features between input and template fingerprints. The reference point establishes the translation invariant matching. Also, using the symmetry axis on its neighboring region centered at the core point can perform the rotation invariant matching. We formulated the matching score as follows:

$$MS_{IT} = \sum_{i=1}^{N}\sum_{\theta}\sum_{(x,y)\in B_i}\sqrt{\left(IBF_{i\theta}(x, y) - TBF_{i\theta}(x, y)\right)^2}. \quad (4)$$

Where, $IBF_{i\theta}(x, y)$ and $TBF_{i\theta}(x, y)$ are the feature vectors of input and template fingerprints. N is the number of blocks in each fingerprint and θ is the direction of the Gabor filtering.

4. Results and Discussions

We have collected fingerprint using CMOS sensor at 500 *dpi* and 256 grey level resolution. The fingerprints are mainly from the students of Kyungpook National University. We evaluate the proposed method on database with 30 fingerprints. Some of the example fingerprints from the database are displayed in Fig. 5.

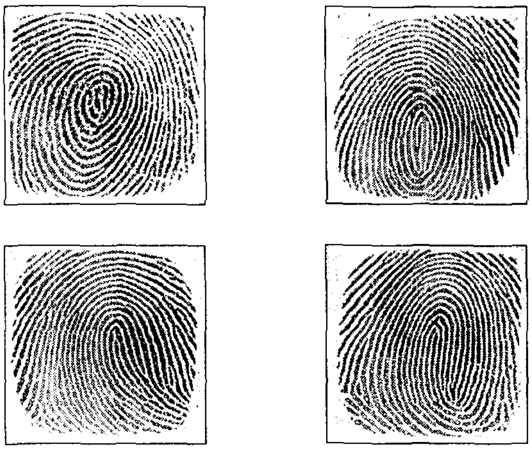


Fig. 5. Some fingerprints of database.

In our experiment, false acceptance ratio(FAR) and false rejection ratio(FRR) are set to zero. The result of identification is depicted in Table 1. We could obtain the high performance of, 97% identification rate. But, the proposed method could not verify input fingerprints for the following circumstances: (i) when the reference point was located at a corner of the image and therefore an appropriate region of interest could not be established, (ii) when the quality of the image was very poor.

Table 1. The result of identification using the proposed method.

Database size	Identification Rate	FAR	FRR
30	97%	0%	0%

5. Conclusions

We proposed a direct rotation and translation invariant matching of fingerprints using GCM- and Gabor filter-based features extracted directly from grey-level images. The translation and rotation invariant matching can be obtained through using the core point and the symmetry axis of the core region as a reference. Through experiment, we could obtain the high performance of 97% identification rate. Further experiments needs to be accomplished to validate the consistent performance on the larger database of fingerprints in various ages and sexes.

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