Nonminutiae Based Fingerprint Matching

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***Abstract*— Fingerprint verification is one of the most reliable personal identification method However, manual fingerprint verification is tedious, time consuming and expensive. Thus it is incapable to match the required speed and accuracy expected in modern world. Minutiae based and image based are two major approaches for fingerprint recognition. Image based approach offers much higher computation efficiency with minimum pre processing and proves effective when the image quality is too low to allow a reliable minutiae extraction. In this work, a novel method of image based fingerprint matching which uses the orientation field as a feature vector is proposed. The proposed method overcomes problems of shape distortion, variation in position, rotation and translation of image. Optimal core point detection of fingerprint (image) helps in improving accuracy of fingerprint matching system. Based on orientation feature, a fingerprint matching system is designed. The algorithm has been tested on two databases (10 subjects with five impressions from database available from neurotechnologija and 8 subjects with five impressions from FVC2002 D1_b). The performance of algorithm is measured in terms of receiver operating characteristics. For the neurotechnologija database at 0% false acceptance rate (FAR) the genuine acceptance GAR observed is 75% and at 21.1% FAR, GAR is 95%.For the FVC2002 database at 2.8% FAR the GAR observed is 80% and at 8.66% FAR the GAR is 97.5%.Computational Complexity of proposed algorithm is low and hence can be implemented as automatic fingerprint identification system.**

Keywords-Biometrics; Image based; orientation; verifictaion;

I. Introduction

Fingerprint biometrics are increasingly being used in commercial, civilian and financial domains. Fingerprint feature extraction and matching methods may be broadly classified into three categories: minutiae-based, image-based and hybrid. Minutiae based methods use a feature vector extracted from fingerprints as sets of points in a multi-dimensional plane. These methods involve time consuming steps of fingerprint enhancement, directional filtering, segmentation and thinning and may erroneously introduce false minutiae and reject some real minutiae points. In addition these methods may not fully utilize the rich discriminatory information available in fingerprint with high computational complexity. There are number of verification methods that do not use minutiae points for matching and are called image – based methods. They extract features for matching by applying a certain type of filter banks or using special transformations. The features other than print ridge pattern, such as local orientation and frequency, ridge shape, and texture information are used. They usually require less preprocessing effort than minutiae based methods using global information from a fingerprint. Hybrid methods using features from both approaches have recently been researched.

In this work, an image –based algorithm using variance feature of orientation field for fingerprint matching is proposed. It reliably finds a reference point with a proposed preprocessing and aligns the input image with the template using orientation, which makes the algorithm rotation invariant. As the area of interest for finding the orientation field is the area around the core point, hence the segmentation process to separate the foreground from background is not required, this also makes the algorithm translation invariant. A set of features based on orientation is extracted to represent the fingerprint as information of the local structure. Fingerprint matching is based on the Euclidean distance.

II. Prior Related Work

Image based methods are frequently used for fingerprint recognition In [11] , a wavelet based fingerprint recognition method has been presented where recognition rate is improved with an increase in number of fingerprint images stored in database per user and hence larger memory size is needed for

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performance improvement. In [1], verification is achieved using the features extracted by applying eight Gabor filters around the core point. Two alternations of Gabor filter method are present in[4,5]..In [4], at first a sub sampling at the block level is performed on fingerprint image to improve the efficiency and then Gabor filters are applied. In[5], Instead of storing the response of each filter at each sub sampling point, only the index of filter with highest response is used for fingerprint matching.

Hybrid fingerprint matching schemes [2] based on both minutiae and feature maps, utilize merits from both approaches. However, it is very difficult to accurately detect all minutiae, which may significantly affect the robustness of these approaches. Moreover, the computation required for feature maps extracted on each minutiae with Gabor filters becomes very high. There is discriminatory information found in orientation of fingerprint ridges that can be used for fingerprint verification [8]. In [12] steepest descent algorithm for fingerprint registration and verification based on orientation field is used. Decision level fusion of different verification methods is a challenge for performance improvement in fingerprint verification especially in low quality images. Transform based methods using digital wavelet transform features [11] or digital cosine transform show a high matching accuracy for inputs identical to templates on its database. However, these methods have not considered the invariance to an affine transform to deal with different input conditions. A fingerprint verification system based on the correlation of fingerprint is proposed in [3]. Rotation of fingerprint is not included in this approach which may increase computation complexity.

III. PROPSED APPROACH

In this work, an image–based algorithm using variance feature of orientation field for fingerprint matching is proposed as shown in Figure 1.

A. *Preprocessing with STFT analysis*

The quality of acquired images may vary in both the printed location and the clarity of the image itself. The STFT can be used to analyze the fingerprint image both in space and in frequency and hence enhance the fingerprint completely. The enhancement technique uses a Fourier domain-based block wise contextual filter approach for enhancing fingerprint images.[13]

B. *Determination of reference point*

A point of maximum curvature on convex ridge is defined as the reference point. The reliable detection of a reference point can be accomplished by detecting the maximum curvature using complex filtering methods [9].

C. *Image cropping*

The region of interest (ROI) based on reference point is determined and tessellate the ROI into number of square cells. The fingerprint image is cropped into 96 by 96 pixels

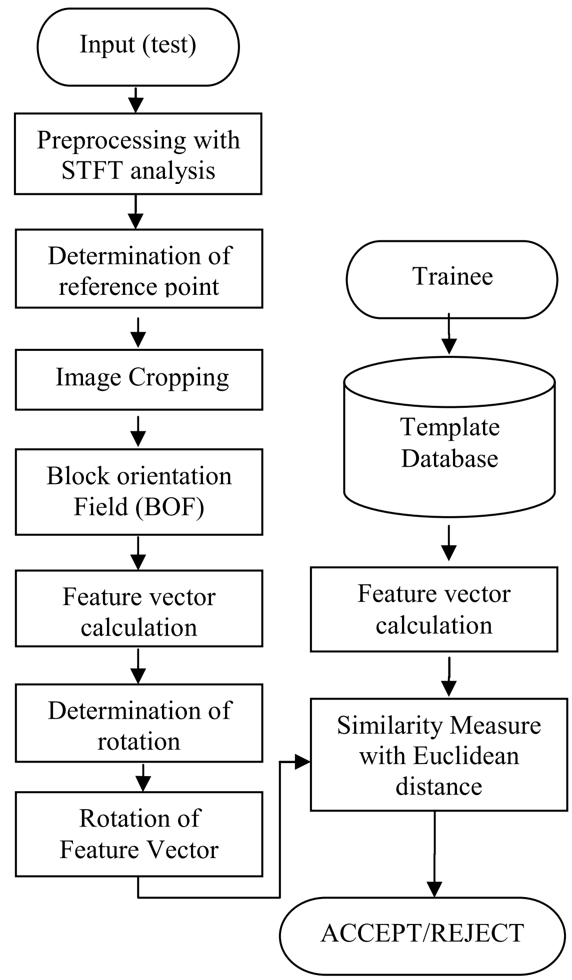

Fig.1. Algorithm steps

D. *Block orientation field (BOF)*

The proposed method utilizes the likeness of BOFs for similarity measuring of two fingerprints. The cropped fingerprint image is divided into number of non overlapping blocks and an orientation representation of ridges in the block is assigned to the block based on grayscale gradients in the block. The block orientation can be determined from pixel gradients by averaging. [6]The orientation field of block (i, j) is given by

$$\mathcal{V}_x(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} 2\partial_x(u,v)\partial_y(u,v)$$

$$\mathcal{V}_y(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} (\partial_x^2(u,v) - \partial_y^2(u,v))$$

$$\mathcal{O}(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{\mathcal{V}_y(i,j)}{\mathcal{V}_x(i,j)}\right)$$

Where O (i, j) or θ (i, j) is the block orientation.

E. *Determination of rotation*

From the orientation field of test and trainee fingerprint images the amount of rotation of test fingerprint with respect to trainee fingerprint is estimated. The amount of rotation is given by

$$\theta r = (\theta' (1,1) - \theta(1,1)) + (\theta'(m, n) - \theta(m, n)) / 2$$

Where θ' (1, 1) and θ (1, 1) are orientations of first block of test and trainee fingerprint images respectively. Similarly θ' (m, n) and θ (m, n) are orientations of block (m, n) of test and trainee fingerprint images, respectively.

F. *Feature vector of trainee image*

The variance feature vector of BOF of the cropped trainee is computed as follows [6]:

$$\sigma_k^2 = \sum_{i=1}^{n} (\theta(i, k) - \mu_k)^2 \quad \text{for } k = 1, \ldots, m,$$

Where μ_k is the mean of kth column of θ, m and n are the no. of columns and rows of θ respectively. The feature vector is $v = [\sigma 1^2\ \sigma 2^2 \ldots \sigma m^2]$

G. *Feature vector of test image*

The feature vector of test fingerprint image is calculated using previous step.

H. *Rotation of feature vector*

The feature vector obtained in previous step is rotated by θr to obtain rotated feature vector of the test input image.

I. *Similarity measure*

To measure the similarity between feature vectors of an input test fingerprint and of the trainee stored in template database, the Euclidean distance is employed.

$$D = \| v' - v \|^2$$

Where v' and v are the feature vectors of test and trainee fingerprint images, respectively

IV. EXPERIMENTAL RESULTS

The algorithm is evaluated on fingerprint images taken from FVC2002 and Neurotechnologija database. Performance of algorithm has been measured in terms of false accept rate (FAR) and false reject rate (FRR) for various thresholds. N is the number of subjects with five fingerprints each. Total fingerprint images are T = 5 × N. A single template per subject has been considered for experimentation. Total trials carried out for finding true claims and imposter claims are N × (T – 1), out of which total true claims are N × 4 and imposter claims are (total trials – true claims).

FRR%=(true claims rejected/total true claims) × 100

FAR%=(imposter claims accepted/total imposter claims) × 100

GAR% = 100 – FRR in percentage.

A receiver Operating Curve (ROC) is a plot of genuine acceptance rate against false acceptance rate for all possible values of thresholds. Neurotechnologija database consists of images of 10 subjects with eight images of each subject. Total 10 × 8 = 80 images. The size of the image is 480 × 504 and the resolution of database is 500dpi. Experimentation was done with six impressions of each finger. For a single threshold total trials carried out for computation of FAR and FRR were 10 × (60 -1) = 590. The GAR reported 70% at 1.85% FAR and 96% at 20.9% FAR.

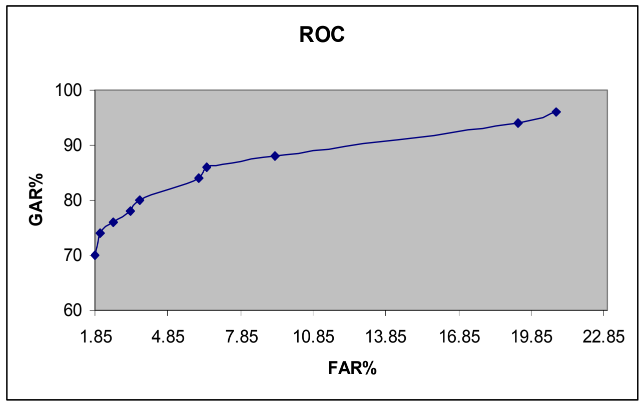

Fig 2. ROC Neurotechnologija (six impressions)

In next set of experimentation three out of eight impressions of each subject in database were rejected as the accurate core point could not be located or the rotation of the test fingerprint image with respect to the template was too high. With five impressions per subject the GAR reported 75% at 0% FAR and 95% at 21.1% FAR. ROC curve showing GAR and FAR for various values of threshold are shown in Fig.3

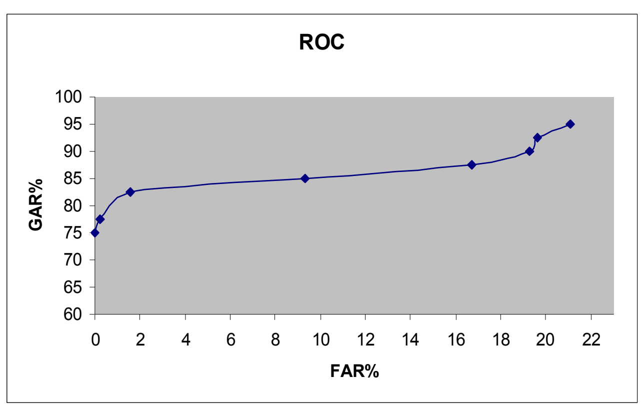

Fig 3.ROC Neurotechnologija (five impressions)

The performance of algorithm on FVC2002 and University of Bologna database with eight impressions per subject [6]is shown in Figure 4.

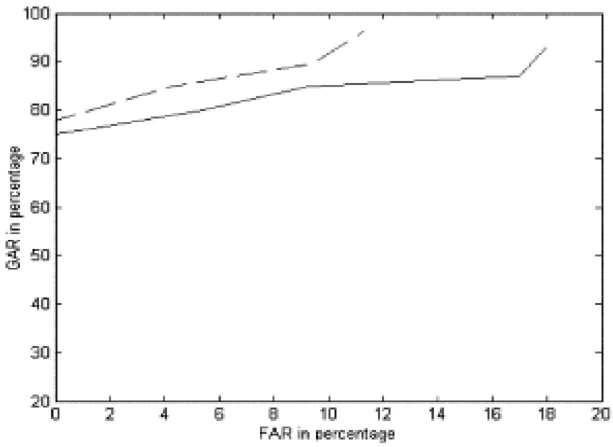

Fig. 4. Performance curve on university of Bologna database (-----) and FVC2002 (   ).

For experimentation eight subjects out of ten with five impressions of each subject of Db1_b of FVC2002 have been used. Three impressions have no core point due to the exaggerate displacement or the rotation between the test and trainee is too high. Also the core point detection is fairly accurate in some of the images. Results reported for various thresholds on FVC2002 database are given in Figure 5.The GAR reported 80% at 2.8%FAR and 97.5% for 8.66%FAR.

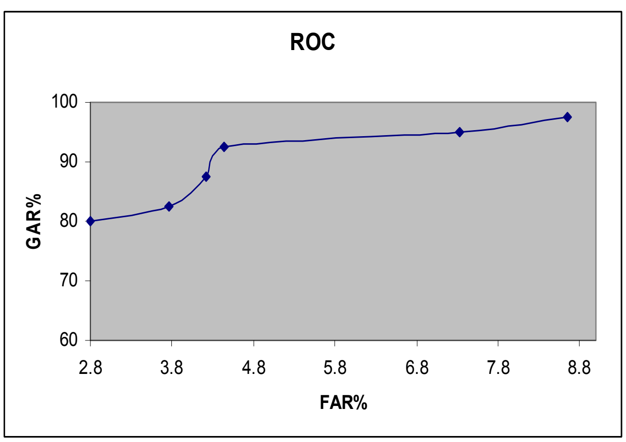

Fig. 5. ROC for images from FVC2002 (five impressions)

V. Conclusion

The main features of the proposed algorithm are
(1) A preprocessing with STFT can remove multi-spectral noises while enhancing structural information in images, and help to find a reference point accurately and reliably which improves the performance of fingerprint feature extraction and matching steps as both depend heavily upon the quality of the input fingerprint image. (2) As the performance of a fingerprint matching algorithm relies upon the efficiency of its feature extraction stage, the proposed algorithm rotates the feature vector generated by using orientation of fingerprint image for alignment to overcome the rotation between test and trainee fingerprint image instead of rotating the test fingerprint image. (3) Extracting orientation features from non-overlapping tessellated cells significantly reduces the effect from noise and nonlinear distortions, and thus preserves the local information. (4) Fixed length vectors are used to represent orientation features and it reduces the computation load. Overall feature extraction and matching to a template are faster using fixed length vectors. (5) The experimentation carried out for obtaining the performance of the proposed algorithm in this work is rigorous .For impostor comparisons each impression of a finger is considered and compared with all the impressions of all other fingers instead of comparing only the first instance of each finger against the first instance of all other fingers.

In the proposed image based algorithm, simple orientation feature has been used as a feature vector. Performance of this module can be improved by using other discriminatory information like texture and spectral features of fingerprint image. Further the decision level information fusion of these features will improve the accuracy of the system.. Also, the shortcoming of using single biometric is that no one technology is suitable for all applications. Therefore, instead of using fingerprint alone, face and iris can be combined with fingerprint to gain the advantages of multimodal biometrics. The other area which can be investigated is designing hybrid approaches based on both minutiae and numerical features.

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