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A NOVEL APPROACH FOR FINGERPRINT RECOGNITION WITH DYNAMIC TIME WARPING

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ABSTRACT

Biological features such as face, fingerprint, palm print and iris are widely used for the identification of a human. Due to low cost acquisition devices and high accuracy, fingerprint recognition is broadly used. Fingerprint is unique and pattern unchanged during the life time. A novel approach for fingerprint recognition system based on Gabor Wavelets and Dynamic time Warping is proposed in this work. Firstly, image enhancement has done in both spatial and frequency domains with Histogram Equalization and Fast Fourier Transform. 24 optimized Gabor kernels are generated in spatial and frequency domains and those are invariant to 6 orientations and 4 scales. In this work, the performance of the proposed method is evaluated on VFR and FVC-2006 databases. Based on the constraints of Dynamic Time Warping, an optimal warp has identified among the feature vectors and achieved 94.2% and 83.6% recognition rates on VFR and FVC-2006 databases respectively.

Keywords: *Fingerprint Recognition, Histogram Equalization, Fast Fourier Transform, Gabor Wavelets, Dynamic Time Warping*

1. INTRODUCTION

Fingerprint Recognition [1, 2] has achieved high recognition rates with low cost and small sized acquisition devices. They familiarly used in forensic and criminal detection agencies. Fingerprint Recognition was affected by sensitivity of fingers and small sized acquisition devices. Ridges and valleys on fingertips will generate distinctive patterns and those are unique for every human being. Fingerprint is remained unchanged during his/ her life.

Fingerprints provide a more security and reliability compared to the passwords and ID cards. With all those characteristics fingerprints usage in several biometric applications has widely increased. In most of the fingerprint recognition systems, person identification [3, 4] is done based on Minutia points. Minutia is a set of abnormal points like Termination and Bifurcation points. Termination point is an immediate ending of a ridge and where two branches are derived from a ridge is called bifurcation point.

Fingerprint matching is done in two ways, first one is local feature based i.e., minutia based [6, 7, 8, 9] which presents the fingerprint as a set of local features, like termination and bifurcation points. Second approach is global feature [4, 5] based i.e., fingerprint matching is done based on global features of a whole fingerprint image.

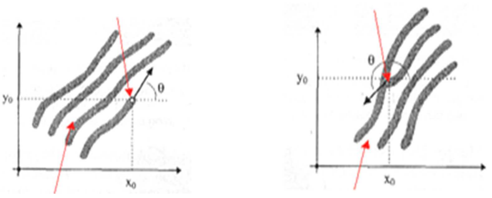

Fig 1: (A) Termination Point (B) Bifurcation Point

In the generic architecture of the fingerprint recognition system, three basic steps, those are Data Acquisition, Minutiae Extraction and Matching.

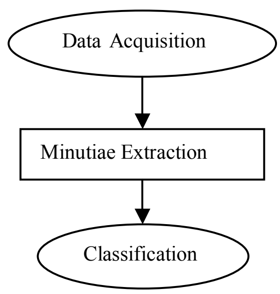

Fig 2: Generic Architecture Of Fingerprint Recognition System

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Details of the work is organized as follows: Literature Survey is discussed in Section 2, section 3 deals with preprocessing steps and feature extraction using Gabor Wavelets and classification with Dynamic Time Warping are presented in Section 4. In Section 5, experimental results of the proposed method with different datasets are given.

2. LITERATURE SURVEY

A Fingerprint recognition system proposed by Wang Yuan et.al.,[3] to handle small area fingerprint sensors using minutiae matching algorithm. Wang also stressed the importance of image enhancement and also quality control. M.P Dale et.al.,[4] presented DCT based feature vector generation for fingerprint representation and matching. DCT applied image has divided into various blocks and generated standard deviation from that image. Dale has achieved 100% of results for a specific threshold value. XU Cheng et.al.,[5] presented a novel approach for identification using wavelet and Gabor transforms. Around central point, the area has decomposed into different sub images and Gabor wavelets are used to generate Gabor features for those sub-images. Cheng has achieved high recognition rates at different scales and orientations. Vincenzo Conti et.al.,[6] proposed state of the art advancement of multi biometrics, in which feature vectors of Iris and Fingerprint are fused. Similarity among feature vectors is computed using hamming distance.

R Kaur et.al.,[7] discussed about presence of inherent noise in fingerprint samples which causes the spurious minutiae. Kaur recommended a new smoothing algorithm with eight different masks to identify ridges in the fingerprints. Zhou Shihai et.al.,[8] discussed the applications of fingerprint recognition systems in various applications. Yin et.al.,[9] proposed a hybrid fusion of both minutiae and ridge based matching algorithms. Yin has achieved 9.4% false accept rate with parallel fusion.

Fanglin Chen et.al.,[10] used multi features in identification with reduced searching time. Anum Batool et.al,[12] proposed adjacent feature vector technique and it outperforms other techniques. To enhance the ridge structures' clarity and continuity Wang et.al.,[15] proposed wavelet based method. Jaiver [18] discussed the importance of enhancement to the biometrics before extracting features from the databases. Qing Zhang et.al., presented a novel framework for the inconveniences & in efficiency with parallel multimodal systems and in this Zhang discussed the need of dimensionality reduction. Shao et.al., proposed compression based minutiae extraction. Shao compressed the fingerprints using JPEG and WSQ techniques. Those compressed images are used for extraction. Ajay Kumar developed new score level fusion and compared the results with other existing fusion techniques. The effectiveness of the proposed method is evaluated and it outperforms other methods.

3 FINGERPRINT ENHANCEMENT

Fingerprint Enhancement is required to improve quality of the image and prepare the images for further operations. In Data Acquisition phase, fingerprint samples acquired from sensors or other media are poor in quality. To improve the quality of the samples, contrast stretching is applied among ridges and furrows to connect false broken points of ridges. Proposed approach is depicted in Figure 3. To decrease the computational time and also the space complexity the input fingerprint image is resized to 150*200.

Histogram Equalization is used to normalize the fingerprint image. Image enhancement is done in spatial domain by histogram equalization and in the frequency domain by Fast Fourier Transform with block size of 16*16.

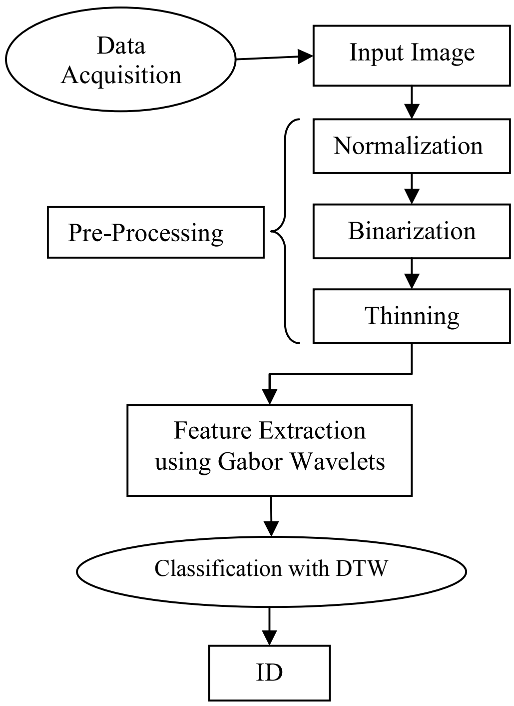

Fig 3: Architecture Of The Proposed Method

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3.1 Histogram Equalization

Histogram Equalization is a normalization technique used to adjust the pixel intensity values to enhance image contrast. Let P be the image, whose intensity values are ranging from 0 to m-1 and Q be the normalized histogram of P with bin for each intensity value.

$$Q_m = \frac{No.of\ pixels\ with\ intensity\ m}{Total\ No.of\ pixels} \quad (1)$$

Histogram equalized image R is defined as $R_{ij} = \text{floor}((m-1)\sum_{n=0}^{Pij} Q_n)$ (2)

The general histogram equalization formula is defined as

$$R(v) = round\left(\frac{cdf(P) - cdf_{min}}{(wid*hei) - cdf_{min}} * (m-1)\right) \quad (3)$$

cdf_{min} is the smallest non-zero value of the cumulative distributive function. The width and height of an image P is given as wid and hei respectively. m is the No. of grey levels.

Fig 4: Normalized Images With Histogram Equalization

3.2 Fast Fourier Transform

Fast Fourier Transform (FFT) is a quick edition of Discrete Fourier Transform (DFT). The time complexity of FFT is lower than DFT. DFT generates a discrete frequency domain representation. Frequency variables are defined as ω_1 and ω_2. $F(\omega_1,\omega_2)$ is defined as frequency representation of f(p, q) and it is complex valued with period π.

$$F(\omega1, \omega2) = \sum_{p=-\infty}^{\infty} \sum_{q=-\infty}^{\infty} f(p,q) e^{-j\omega 1 p} e^{-j\omega 2 q} \quad (4)$$

In the simple version, f(p,q) is considered as continuous where p and q are discrete variables.

Fig 5: Normalized Images With Fast Fourier Transform

FFT divides the data set transformed into a series of smaller data sets. Finally, DFT is calculated for every small data set.

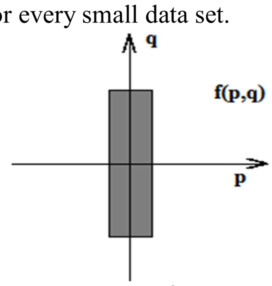

Fig 6: Rectangular Region

3.3 Binarization

Binarization results a binary image from gray-scale image. With Binarization, speed, low complexity, quality and robustness will be achieved. f(x, y) is the gray level image and g(x, y) is the binarized image. Based on the threshold value T, all the pixel intensity values of block will get changed.

$$g(x,y) = \begin{cases} 1 \text{ if } f(x,y) > T \\ 0 \text{ if } f(x,y) <= T \end{cases} \quad (5)$$

Fig 7: Binarized Images

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3.4 Thinning

Thinning is used to convert input binary image into a connected skeleton with unit width. Thinning process improves feature selection and it decreases the time complexity in feature extraction.

Fig 8: Binarized Images

4. HYBRID FINGERPINT RECOGNITION WITH DYNAMIC TIME WARPING

Feature Extraction plays a vital role in the Biometric Recognition Systems. A robust feature extraction method has a significant impact on the classification accuracy. In this paper, Gabor wavelets are used to extract features from the images.

4.1 Gabor Wavelets

Gabor Filters [22,23] are applied to extract features aligned at various orientations or angles. Gabor filters acquire localized optimization in both spatial and frequency domains and they were widely used in several applications. Gabor Filter banks able to generate frequency spectrum in eight orientations with five scaling. Gabor Filter in a spatial domain is represented as:

$$\varphi(x,y) = \frac{f^2}{\pi\gamma\eta}\exp\left(-\left(-\frac{f^2}{\gamma^2}x_r^2 + \frac{f^2}{\gamma^2}y_r^2\right)\right)\exp(j2\pi f x_r)$$

$$x_r = x\cos\theta + y\sin\theta$$

$$y_r = -x\sin\theta + y\cos\theta$$

Where f is the frequency of the sinusoidal curve and θ is the orientation, (x, y) is the pixel location in the spatial domain. Gabor filter will pay extra attention in retrieving the information related to ridges and valleys. Gabor features are invariant to variations in the ridges and intensity levels of the fingerprint pattern. Gabor type receptive field retrieve most of the information from local pixel regions. Therefore both spatial and frequency domains are optimized with Gabor filters. Gabor Filters are failed to optimize broad spectral information in spatial domain localization.

4.2 Classification with Dynamic Time Warping

Dynamic Time Warping [24, 25] is a kind of dynamic programming method used to match the time series like patterns. Dynamic Time Warping algorithm initially used for the classification of speech signals there after the usage of DTW has extended for several applications.

In the identification of optimal warp using DTW, the initial comparison starts with (1,1) i.e., top left cell in the distance matrix and the warp continues from top left corner to bottom right cell in the matrix (m, n). This constraint is referred as boundary constraint. In the continuation of warp, it is required to visit all of the adjacent cells (m^1,n^1) i.e., $|m - m^1|$<=1 and $|n - n^1| \leq 1$ this constraint is referred as Continuity. (m, n) is a point in the warp then the further point is (m^1, n^1) should obey the rule $m<=m^1$ and $n<=n^1$ and this constraint is referred as Monotonicity constraint. The next point to be visited is identified by the formula

$$w(m,n) = \operatorname{argmin}^{x(m1,n1)}_{(m1,n1)\in((m-1,n-1),(m,n-1),(m-1,n))}$$

With all above constraints an optimum warp has identified between two series using the formula

$$X[m, n] = d(A[m], B[n]) + \min\{X[m-1, n-1], X[m, n-1], X[m-1, n]\}$$

5 EXPERIMENTAL RESULTS

In this paper, the performance of proposed method is evaluated on two Fingerprint Recognition Databases. At first, proposed method is evaluated on Vignan Fingerprint Recognition (VFR) Database, which was created using NITGEN (NTG-HFDU14(A)) device. VFR database has generated with 110 male and female subjects each with 8 samples and having 300dpi resolution. Subjects' age may range from 16 years to 65 years. Each sample of size 260*300 and database consists of 880 samples. Samples were collected during different atmospheric conditions. The sample images of VFR database are as follows:

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Fig 9: Sample Images Of VFR Database

The proposed method is evaluated on VFR database, 3 samples per each subject are used for training, and remaining 5 samples are used for testing. Each sample is resized to 150*200 and the results of the proposed method with VFR Database is compared with other existing methods and results are tabulated is as follows.

Table 1: Recognition Rates Of Proposed Method With VFR Database

Method	Recognition Rate with 3 Training Sample	Recognition Rate with 4 Training Samples
PCA+ ED	45	65.2
LDA+ ED	58.7	79.8
Gabor+ DTW	88.5	93.5
Gabor+2D-DTW	91.5	94.2

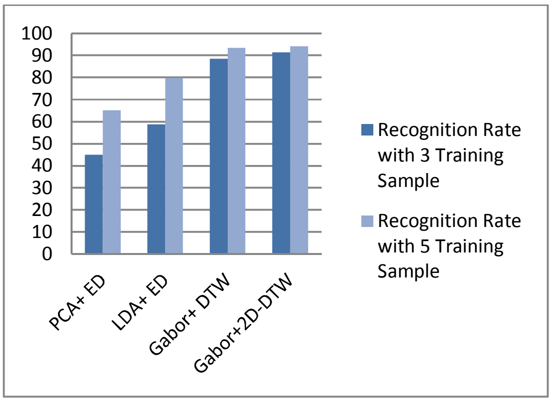

Fig 10: Comparative Study Of Recognition Rates With VFR Database

Recognition rates of proposed method on VFR database with 4 training samples has outperformed other existing methods like PCA and LDA. Optimum performance is obtained with 24 Gabor kernels. As the number of Gabor kernels are reduced, the performance of the system is decreased. Proposed method is also evaluated on FVC 2006 DB1 dataset [16]. FVC dataset includes 150 classes with 12 samples per each. Large rotation and displacement is offered during acquisition phase. The sample images of FVC 2006 are shown below:

Fig 11: FVC Database Sample Images

Proposed method assessed on FVC-2006 DB1 dataset and achieved 83.6% & 85.3% recognition rates with 4 & 5 samples as training per each class. Results of the proposed method along with other methods are tabulated in Table 2.

Table 2: Recognition Rates Of Proposed Method With FVC-2006

Method	Recognition Rate with 4 Training Samples	Recognition Rate with 5 Training Samples
PCA+ ED	38.5	48.9
LDA+ ED	54.2	63.8
Gabor+ DTW	81.4	84.5
Gabor+2D-DTW	83.6	85.3

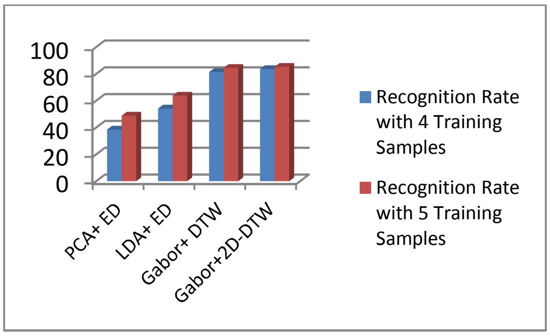

Fig 11: Comparative Study Of Recognition Rates With FVC-2006 Database

Proposed method is evaluated on VFR database with different no. of kernels. Optimum time complexity is achieved with six orientations and four scaling of Gabor wavelets and considered the phase angle as $3\pi/2$. The proposed method outperforms existing pattern matching methods.

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Table 3: Recognition Rates Of Proposed Method On VFR Database With Different No. Of Gabor Kernels

No. of Kernels	Phase Angle	Recognition Rate with 3 Training Samples	Recognition Rate with 4 Training Samples
8*5=40	Π	93	97.2
7*5=35	Π	93	97.2
6*5=30	3 π/2	92.7	95.8
5*5=25	3 π/2	89.5	92.4
8*4=32	Π	91.8	95.2
7*4=28	Π	91.5	94.9
6*4=24	3 π/2	91.5	94.2
5*4=20	3 π/2	82.4	84.4

6 CONCLUSION

The fingerprint recognition/ identification systems have been widely used in several application areas and witnessed several developments in recent years. Fingerprint Recognition Systems are limited with poor performance both in accuracy and speed. In this paper, both histogram equalization and Fast Fourier Transform are used to normalize the fingerprint images in spatial and frequency domains. Gabor Wavelets are used to generate feature vectors with 24 kernels and those are classified using 2D-Dynamic Time Warping. Proposed method is evaluated on VFR and FVC-2006 databases and achieved about 94.2% and 83.6% recognition rates respectively. The proposed method outperforms other existing methods.

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