Fingerprint Recognition using Combined Feature Vector

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ABSTRACT

Biometrics offers greater security and convenience than traditional methods of personal recognition. In some applications, biometrics can replace or supplement the existing technology. A biometric system is essentially a pattern-recognition system that recognizes a person based on a feature vector derived from a specific physiological or behavioral characteristic that the person possesses. Fingerprint recognition has been successfully used in law enforcement and forensics to identify suspects and victims for over a century. The probability of fingerprints two be same are \(1 \text{ in } 1.9 \times 10^{15}\). In this paper, Fingerprint biometric system is considered to develop a recognition model. Various texture features are extracted using Local Binary Pattern (LBP), Local Gabor XOR Pattern, Gray Level Co-occurrence matrix, Gabor features to form a combined feature vector in order to train the Neural Network using Bat algorithm. The performance of recognition model is analyzed by using sample database.

Keywords--- Core point, ROI, LBP, GLCM, Gabor, LGXP, Bat

I. INTRODUCTION

In today’s life style, security is one of the most important concerns. By identifying a person more precisely, the system’s security can improve. A reliable identity management system is a critical component in several applications that render their services only to legitimate users. Examples of such applications include physical access control to a secure facility, e-commerce, access to computer networks and welfare distribution. The primary task in an identity management system is the determination of an individual’s identity. One of the methods to identify a person is biometrics. Biometrics is the most widely used area which helps in identifying a person via his behavioral and physiological properties. Each human being is unique in terms of characteristics, which make him or her different from all others. The physical attributes such as finger prints, color of iris, color of hair, hand geometry, and behavioral characteristics such as tone and accent of speech, signature, or the way of typing keys of computer keyboard etc., make a person stand separate from the rest. Fingerprints were accepted formally as valid personal identifier in the early twentieth century and have since then become a widely used authentication technique in law enforcement agencies worldwide. Compared with other biometrics features, fingerprint-based biometrics is the most proven technique and has the largest market shares. The most matured and accepted biometric system is the fingerprint recognition system. In this paper, Fingerprint biometric is considered as it is convenient and reliable.

II. FINGERPRINT BIOMETRIC

Fingerprint identification is a convenient and quick method for establishing individual’s identity. Fingerprint recognition is getting more acceptability compared to other biometrics due to its invariability in different people. The probability of fingerprints two be same are \(1 \text{ in } 1.9 \times 10^{15}\). Fingerprint recognition is highly used in security areas. A finger consists of ridges and valleys. The dark lines on the fingerprint are called ridges and there are white gaps between ridges called valleys. A ridge can either end or can bifurcate into two ridges. The ending point of ridge is called termination or ridge end, where as ridge bifurcates is called bifurcation or branch point. Finger prints are preferred compared to other parts of the body because they can be taken with minimum effort, time and cost. To reduce the search time and computational complexity, it is desirable to classify fingerprints in an accurate and consistent manner such that the input fingerprint needs to be matched only with a subset of the fingerprints in the database. The following Figure shows the structure of the finger.
Even identical twins, with identical DNA, have different fingerprints. This uniqueness allows fingerprints to be used in all sorts of ways, including for background checks, biometric security, mass disaster identification, and of course, in criminal situations.

Despite the success of fingerprint recognition technique in many large-scale and diverse person identification applications, several challenging issues in fingerprint recognition still need to be addressed. The challenges faced in fingerprint recognition are lighting variations, rotations or noises generated during acquisition. Many fingers wrinkle or shrivel when immersed in water. When used for biometric identification, the recognition rate for wrinkled fingers degrades.

Fingerprint recognition can be categorized into verification and identification. Fingerprint verification is the process of accepting or rejecting the identity claim of a person using fingerprint. On the other hand, determining which registered individual provides a given print is identification. Fingerprint identification can be categorized into minutiae based, correlation based, spectral features based, texture based features. In forensic science, minutiae are the major features which are considered for recognition. Minutiae points include ridge ending, cross over, delta, core. In ridge ending there will be abrupt end of ridge, whereas in cross over a short ridge that runs between two parallel ridges, in delta y shaped ridge meeting and in core U turn in ridge pattern. In the minutiae based matching extraction technique, the minutiae points are extracted and translated into a code that serve as a template. The corresponding minutiae points are extracted from the image and compared with the template which is stored in the data base for recognition [2][3]. To match two fingerprints 10 to 16 minutiae points should match. whereas, in spectral features the frequency spectrum of the fingerprint will be considered. The representation does not use the core, delta and orientation field. In this paper, texture based features are considered for recognition, as these type of features can be helpful for even low quality images where the minutiae details cannot be extracted reliably.

III. FINGERPRINT RECOGNITION

Fingerprint Recognition system consist of four phases namely image acquisition, preprocessing, feature extraction and recognition.

3.1 IMAGE ACQUISITION

This is the first phased in recognition process and there exist number of methods to acquire the fingerprints. Among them, Inkless fingerprint acquisition, Inked impression are widely acquisition methods. Fingerprint quality is important since it directly affects the feature extraction process.

3.2 PREPROCESSING

The captured fingerprint image may contain noises, thus it decreases the recognition accuracy. To improve the recognition accuracy preprocessing is done to enhance the quality of the image. Preprocessing is done before extracting the texture features from the image. The preprocessing includes converting color image to gray level image, reduction of noise, contrast enhancement using histogram equalization, Binarization [1].

3.2.1 RGB CONVERSION

Since color information does not help in finding important edges in the image. So, it is required to convert color images to gray scale images. Gray scale images carry only intensity information. Images of this sort, also known as black-and-white, are composed exclusively of shades of gray, varying from black(0) at the weakest intensity to white(1) at the strongest. The following figure shows the gray scaled image and its histogram.

![Gray Scale Image and its Histogram](image-url)
3.2.2 Reduction Of Noise

It is widely used filtering technique since it preserves the edges while removing the noise. The filter works by moving through the image pixel by pixel, replacing each value with the median value of neighboring pixels. Instead of simply replacing the pixel value with the mean of neighboring pixel values, it replaces it with the median of those values. The median is calculated by first sorting all the pixel values from the surrounding neighborhood into numerical order and then replacing the pixel being considered with the middle pixel value.

3.2.3 CONTRAST ENHANCEMENT

Image enhancement is a processing on an image in order to make it more appropriate for certain applications. The objective of enhancement is to process an image so that the result is more suitable than the original image for a specific application. Enhancement techniques are categorized into two categories namely spatial domain methods and frequency domain methods. In this paper spatial domain enhancement technique is considered since manipulations are carried out directly on the pixels of the image. Histogram equalization is a widely used contrast enhancement technique. It transforms the histogram of the fingerprint image into a uniform histogram by distributing the entire range of gray levels uniformly over the histogram of an image. It also helps in highlighting the edges and borders between different objects [2].

3.2.4 REFERENCE POINT DETERMINATION

In fingerprint rich textual features are centered at the reference point. The core point is used as a reference point. To determine the location of the core point we first need to estimate the orientation field of the fingerprint. The core point is found in the middle of the spiral. It is approximated at the center of finger impression. The ridges are of two types loops and deltas. The curves that recurve back on themselves to form loops, where the ridges flow diverges into two different directions. A delta point is defined as the center of the three different directions of the ridge flow. It is defined as the topmost point of the innermost ridge line [3]. The core point is detected using the following formula:

\[
\text{Core}[x,y] = \text{Coherence}[x,y] + \text{Angular Coherence}[x,y] - \text{Poincare}[x,y]
\]

Though all fingerprints don’t possess core point still this formula is useful to detect high curvature regions and gives high accuracy as it combines advantages form individual features. The following Figure shows the detected core point.

3.2.5 REGION OF INTEREST (ROI)

The objective of obtaining ROI from fingerprint image is the process of recognition become much easier task. After identifying the core point, using this core point as the center the fingerprint image is cropped to 100*100 pixels. By considering the most essential texture features which are located near to the core point the image is segmented. The texture features are computed using LBP, LGXP, GLCM, Gabor for the required ROI. By considering only ROI than considering an entire image gives considerable memory reduction and fastens the processing. The ROI which has enough information produce better results[2]. The following Figure shows the ROI of fingerprint.
3.2.6 BINARIZATION

The enhanced ROI fingerprint image is converted to binary image. A binary image can be processed better than gray scale image. The basic idea of converting is all the pixels whose values are more than the threshold are converted into white pixels and the pixels whose values are less than or equal to threshold are converted into black pixels. The threshold value is calculated using Otsu method [6]. Otsu’s thresholding chooses the threshold to minimize the intraclass variance of the thresholded black and white pixels [4][5]. The otsu formula is given as follows.

\[ \sigma^2_w(t) = q_1(t) \sigma^2_1(t) + q_2(t) \sigma^2_2(t) \]

The class probabilities are estimated as follows

\[ q_1(t) = \sum_{i=1}^{t} P(i) \quad q_2(t) = \sum_{i=t+1}^{I} P(i) \]

The class variance are given by

\[ \sigma^2_1(t) = \sum_{i=1}^{t} (i - \mu_1(t))^2 \frac{P(i)}{q_1(t)} \]

\[ \sigma^2_2(t) = \sum_{i=t+1}^{I} (i - \mu_2(t))^2 \frac{P(i)}{q_2(t)} \]

pick the value that minimizes \( \sigma^2_w(t) \).

The binarization of the image is carried out as follows

\[ g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{if } f(x, y) \leq T \end{cases} \]

where \( f(x,y) \) is the value of pixel in fingerprint image and \( g(x,y) \) is the value of pixel in the gray scale image. The following figure shows the binarized image for the ROI.

3.3 FEATURE EXTRACTION

From the preprocessed and segmented fingerprint texture features are extracted. For each pixel or block in the fingerprint image, the pixel features are extracted, and each block is classified according to the extracted feature values. The features from ROI are extracted using local binary pattern (LBP), local Gabor XOR pattern (LGXP), Gray level co-occurrence matrix (GLCM), Gabor. The features which are involved in image processing includes spectral features, geometrical features, texture features. Color, gradient etc come under spectral features, whereas edge, shape, size are the examples for geometrical features and pattern, spatial frequency fall in category of texture features. In this paper, texture features are considered for extraction and recognition.

Texture is a combination of repeated patterns with a regular frequency. Textures are several types, for example smooth, fine, coarse etc which are often used for classification. It gives information about the spatial arrangement of intensities in a selected region of an image. To analyze the image, two texture features approaches namely structured approach and statistical approach are widely used. In this paper, statistical approach is considered to extract texture features. In statistical approach, spatial distribution of gray values are analyzed by computing the features at each point in the image and deriving set of statistics from the local features.

3.3.1 MODIFIED LOCAL BINARY PATTERN (LBP)

This feature is highly discriminative and has advantages of computational efficiency. LBP is applied to gray scale binarized fingerprint image and features are extracted using histogram. Texture extracted operator which labels the pixels of an image by thresholding the neighborhood of each pixel and consider the result as a binary number. The histogram consists of \( 2^8 = 256 \) different labels can be used as texture descriptor. By using uniform patterns, the length of feature vector can be reduced [6][7]. The following figures shows the LBP applied fingerprint, LBP Histogram and feature values.
3.3.1.2 LOCAL GABOR XOR PATTERN (LGXP)

The phase part of Gabor followed by LBP gives LGXP. Each and every phase value is quantized with the help of the quantization procedure. Subsequently, the LGXP operator is effectively utilized to the quantized phases of the central pixel and each of its neighbors. \( LGXP_{\omega,v}^k \) \( (k = 1,2,...,p) \) denotes the pattern determined between \( \phi_{\omega,v}(l) \) and its neighbor \( H_k \) is evaluated as illustrated below.

\[ LGXP_{\omega,v}^k = q(\varphi_{\omega,v}(H_{ph})) \text{ XOR } q(\varphi_{\omega,v}(H_k)) \]

Here, \( \varphi_{\omega,v}(H_{ph}) \) denotes the phase and \( q(\varphi_{\omega,v}(H_k)) \) represents the quantized value of the phase and where \( \phi_{\omega,v}(l) \) depicts the central pixel. At last, the consequential binary labels are concatenated jointly as the local pattern of the central pixel.

\[ LGXP_{\omega,v}(H_{ph}) = \sum_{k=1}^{n} 2^{k-1} \cdot LGXP_{\omega,v}^k \]

3.3.2 GLCM

The fingerprints possess strong directional information, the GLCM is thought to be a good technique for fingerprint feature extraction. A single GLCM is not enough for extracting the features from enhanced preprocessed image. For this reason, GLCM is computed for various angles like \( 0^\circ, 45^\circ, 90^\circ, \) and \( 135^\circ \) with relative distance as one pixel. By second order statistics, the distribution of pixel gray levels can be described like the probability of two pixels having particular gray levels at particular spatial relationships. The information can be represented in two dimensional matrix called gray level co-occurrence matrices which can be computed over various distances and orientations[8]. Some of the features are homogeneity, energy, contrast etc.

- The sum of squares of pixels is given by energy.

\[ \sum_{f=\text{i,j}} p(i, j)^2 \]

- contrast measures the local variation in the gray level

\[ f_1 = \sum_{i,j} |i - j|^2 p(i, j) \]

The following values shows the sample GLCM and statistical values.

<table>
<thead>
<tr>
<th>GLCM</th>
<th>Energy</th>
<th>Homogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1228</td>
<td>0.4530</td>
<td>0.4239</td>
</tr>
<tr>
<td>1000</td>
<td>0.1560</td>
<td>0.3549</td>
</tr>
</tbody>
</table>

3.3.3 GABOR FEATURES

Gabor Features are nothing but texture based features which are obtained by convolving the image with Gabor filter, this is a linear filter used for edge detection. Gabor filters provide a response that is similar to that of the human visual system, and hence used in this case to extract the texture features from the biometrics [13]. The following figure shows the Gabor filtered image. [9][10]
In this paper, all the above said features such as Modified LBP, GLCM, Gabor are combined to form a feature vector. These features plays a significant role to improve the Recognition accuracy. Such final feature vector will be having larger dimension and also will be strong enough such that the recognition accuracy increases. This feature vector is used as input to the next phase i.e Recognition Phase. The following figure shows the combined feature vector.

![Fig. 8. Gabour Filtered Image](image)

3.4 RECOGNITION

Once the combined feature vector of fingerprint images is created, the recognition process starts. The recognition is performed using Neural Network based recognition. The chosen features are identified with the help of the artificial neural network. A multilayer feed forward neural network is considered. It consists number of layers. Each layer has processing elements called neurons which makes independent computations on the data which is received from the previous layer and pass on the results to the next succeeding layer. The first layer in multilayer feed forward network is called input layer and the last layer is called output layer. Whereas the layers between input layer and output layer are called hidden layers. Synapses between neurons are known as connections, which are represented by edges in the network. The weights are used on the connection between different layers and they have much significance in training of neural network. Neural network with one or two hidden layers are sufficient. In this research one hidden layer is considered. In selecting number of hidden neurons there is a thumb rule which states that for n inputs, the hidden layer would have 2n+1 neurons which is stated in kolmogrov theorem. Activation functions are mathematical formulae that determine the output of each processing unit. Each processing unit calculates net input and applies activation function on it.

Extraction of efficient features is important task for recognition system. In our proposed method we use three layers of ANN. The weights are optimized using Bat algorithm. Bat is a developed by Xin-She Yang and it is metaheuristic algorithm. Bat algorithm is based on the echolocation behavior of microbats with varying pulse rates of emission and loudness. In the proposed Bat algorithm, each position represents a possible solution (i.e., the weight space and the corresponding biases). The weight optimization problem and the position of a food source represent the quality of the solution. In the first epoch, the best weights and biases are initialized with Bat. The rules for position vi and velocities are updated as follows.

$$v^t i = v^{t-1} i + (x^t i - x^f i) f i$$

$$x^t i = x^{t-1} i + v^t i$$

The Bat will continue searching the best weights until the last epoch of the network is reached. Pseudo code is as follows.

1. Initialize Bat population size and neural network structure.
2. Load training data i.e iris combined features.
3. Feed forward neural network runs using weights initialized with Bat.
4. Calculate the error in the network.
5. Update weights and bias in the network by adjusting network parameters using Bat.
6. Bat keeps on calculating the best possible weights at each epoch until the network is converged [11][12][13]. The following Figures shows the structure of neural network and the training of neural network.

![Fig. 10 Structure of Neural Network](image)

![Fig. 11 Training Neural Network](image)
database is considered. Here we are taking 250 fingerprint images. Here 230 images are used for training and remaining 20 are used for testing. Neural Network is trained upon some set of images, and tested upon unseen images. A test case consists of fingerprint images which are subjected to feature extraction. Features that are extracted are taken as test case feature vector which are used for recognition. Experimental results validate the effectiveness of the proposed method in extracting fingerprint features and achieving good performance. Our approach outperforms the minutiae based approach. If the core point is correctly located, the matching process is extremely fast.

IV. CONCLUSION

Fingerprint recognition systems exploit the fact that humans have unique pattern in their fingerprints. In this paper, different texture features such as LBP, LGXP, GLCM and Gabor are combined to develop an effective Iris Recognition model. ANN and Bat algorithm is used to train the Recognition model and also the performance is analyzed with sample data set. The use of LBP features combined with LGXP,GLCM and Gabor features for fingerprint recognition produces high accuracy and reduced errors. From the experimental results it is proved that accuracy of the recognition model is 97%. The experimental results on the public fingerprint database, show high recognition rates.

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