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Automatic Fingerprint Recognition Systems: A Review

Prof.ShilpaP. Kodgire **Anju Mohan**

***Abstract*- Of all the biometrics used in personal identification, fingerprintrecognition is considered to be the the most prominent and reliable one. Fingerprint recognition means matching an incoming fingerprint with stored fingerprints in database called as templates of every other user. Various techniques and algorithms were developed for fingerprint feature extraction and matching which gave the accurate results for the recognition system. The purpose of this paper isto study various fingerprint feature extraction and matching algorithms used in fingerprint recognition systems and to determine which technique is more reliable and secure.**

***Keywords*-Biometrics, Core point, fingerprint, Minutia, Ridges, SVM etc.**

I.INTRODUCTION

Biometrics means measure of unique physiological or behavioural characteristics in order to identify a person. Biometrics is a unique trait which is a part of us, so there is no need of worrying about remembering passwords, or carries any document for identification. Biometric characteristics can be divided in two main types. A. Physiological character: This is related to the shape of the body and thus it varies from person to person. Examples are fingerprints, face recognition, hand geometry and iris recognition.B.Behavioural character: It deals with behaviour of a person like signature, key stroke dynamics and voice. Behavioural characteristics can change with age.

Out of all biometrics based recognition systems, identification of a person using fingerprint is considered to be the most reliable one because of its certain advantages. A fingerprint is the pattern of friction ridges on a human finger, which provides increased friction for gripping. Friction ridges are constructed from small ridge units whose size, shape, density and alignment are unique to individuals. During ridge formation, ridge units are fused together under random forces into various ridge characteristics, the most representative of which are ridge bifurcations and endings. Friction ridge formation cannot be genetically controlled [1].No two persons, even identical twins does not have fingerprints that share exactly the same location, shape and inter-relationship of these ridge characteristics [2]. There are three principles of fingerprints:

1. A fingerprint is an individual characteristic: No two persons, even identical twins does not have similar fingerprint pattern.
2. Fingerprints remain unchanged during a lifetime. Only a very deep cut would result in changes in a fingerprint
3. Fingerprint has general ridge patterns that permit them to be classified.

The aim of this paper is to study the various techniques and algorithms for fingerprint feature extraction and matching. The problem is to develop a Fingerprint Recognition System that returns relevant results to a query fingerprint image in a relevant time.This paper is organized as follows: In first section we discuss the various attributes of fingerprints. In next section we describe various features of fingerprint .In next section we discuss the outcomes of algorithm considered in literature and draws results from different papers on the theme. In last section, we draw a conclusion out of all the discussions followed by a list of references.

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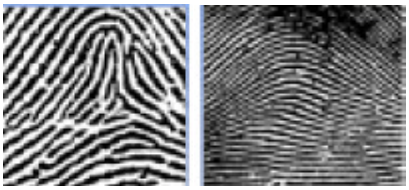
II. VARIOUS ATTRIBUTES OF FINGERPRINT

A.Basic concepts

- Fingerprint: It is the impression of finger left on a flat surface. A fingerprint is comprised of ridges and valleys. The ridges are the dark area of the fingerprint and the valleys are the white area that exists between the ridges. Depending on visual pattern, there are three classes of fingerprint.

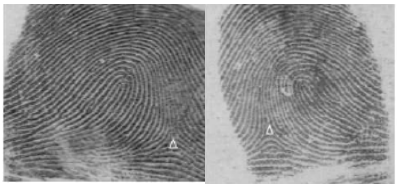
Fig.1. Fingerprint Pattern

- Arches: A fingerprint pattern in which the ridge pattern originates from one side of the pattern and leaves from other side. Arches can be of two types, plain arch and tented arch.
- Loops: A fingerprint pattern in which the ridge pattern flows inward and returns in the direction of the origin. There are two types of loops, left loop and right loop.
- Whorls: Ridges form circularly around a central point on the finger.



(a) (b)

Fig.2.Arches



(a) (b)

Fig.3.Loops

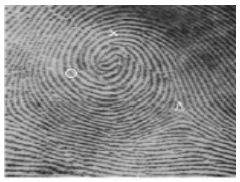
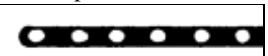
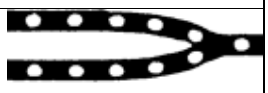
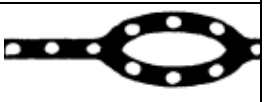
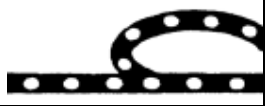


Fig.4.Whorl

- Ridges: Friction ridges are what make up a fingerprint. They provide friction and grip to keep hands and feet from slipping. Finger skin is made up of friction ridges and sweat pores all along these ridges. Friction ridges are created during fetal life and only the general shape is genetically defined [3].
- Minutia: Minutiae, in fingerprints are the points of interest in a fingerprint, such as bifurcations (a ridge splitting into two) and ridge endings.

Table below shows the points considered as minutia from ridges.

TABLE I.Ridges where Minutia points are considered.

Ridge Termination	
Bifurcation	
Independent Ridge	
Dot or Island	
Lake	
Spur	
Cross Over	

1. Ridge endings - A ridge that ends abruptly.
2. Ridge bifurcation - A single ridge that divides into two ridges.
3. Short ridges, island or independent ridge – A ridge that commences, travels a short distance and then ends.
4. Ridge enclosures - A single ridge that bifurcates and reunites shortly afterward to continue as a single ridge.
5. Spur - A bifurcation with a short ridge branching off a longer ridge
6. Crossover or bridge - A short ridge that runs between two parallel ridges [3].

B.Fingerprint Features

Fingerprint recognition means extracting different features of fingerprint during enrolment phase and matching these features during identification phase [4].

1. Local Features

Local features are unique characteristics which can be used for identification like “minutia points” [5].

2. Global Features

Global Features are the characteristics that human being can see with the naked eye .Some of the global features are:

- Core point: Finger prints approximate centre, which is used as reference point for reading/classifying the print is called as core point. Itis also defined as the topmost point on the innermost upwardly curving ridgeline.

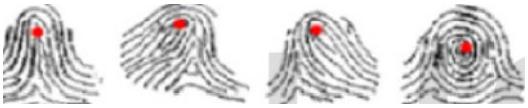


Fig.5.Core Point

- Type Lines - Two innermost ridges that start parallel, diverge, and tend to surround the pattern area [6].

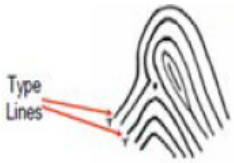


Fig.6.Type Lines

- Delta-It is the point on a friction ridge at or nearest to the point of divergence of two type lines [6].

Fig.7.Delta Point

3. Very fine level features: These are intra ridge details like: sweat pores [6].

III. LITERATURESURVEY

Various Pattern recognition techniques used in finger print recognition systems:

A. Minutia Score Matching Technique

ChiragDadlani [7], proposed a system of fingerprint identification and verification system based on the topological structural matching of minutiae points by considering two kinds ofminutiae; ridge endings and bifurcations. They used an enhancement algorithm which constituted following steps. Normalisation, Local Orientation estimation, Frequency Estimation and filtering. For minutia matching,they used a minutiae matching algorithm involving computation of local and global minutiae features. Their algorithm grouped all the minutiae into triplets of minutiae. For each of thesetriplets of minutiae they stored the distance of one of the minutiae from both otherminutiae and the angle formed in between these two distances were calculated. Hence, there was a need to compute and store these triplets for both the incoming image and the stored image. The minutiae triplets are matched using bruteforcemethod and the number of matching triplets is computed.Eventhough this algorithm is easy to implement and does not require the use of image rotation, it is computationally difficult to form all the minutiae triplets andto then use a brute-force method to try and search for matching triplets. Thisimplementation is not very wellsuitedfor real time applications to match two minutiae tables. The genuine and imposter scores were calculated by matching fingerprint images from the database of 80 images. The Equal Error Rate (ERR) was found to be0.0329 at a threshold value of 0.2623.

Rohit Singh[8]implemented a fingerprint recognition system based on Minutiae based matching whichis frequently used in various fingerprint algorithms and techniques. In this system minutia points are extracted from the sample fingerprint images and then perform fingerprint matching based on the number of minutiae pairings among two fingerprints in question. Their implementation mainly incorporates image enhancement, image segmentation, feature (minutiae) extraction and minutiae matching. It finally generates a percent score which tells whether two fingerprints matches or not. The project is coded in MATLAB. From their experiments distribution curve, it gives an average correct match score of about 30 and average incorrect match score of 25 on the database chosen. FAR and FRR values were 30-35% approximately. Thus at a threshold match score of about 28, the verification rate of the algorithm is about 65-70%. The low percentage of verification rate is due to the poor quality of images in the database and the inefficient matching algorithm which lead to incorrect matches.

B.Core Point Detection based fingerprint recognition systems:

Luigi Rosa [9] developed an algorithm for core point detection based on orthogonal gradient magnitudes of orientation field of fingerprint image. For input fingerprint image, the orientation field is estimated. Orientation field, $\Theta(x, y)$, represents the ridge flow of a fingerprint at each location and it is defined in the interval $[0; \pi]$. Also the Region of Interested (ROI) is computed for fingerprint image. This segmentation creates a binary mask that can assume logical values. Then orthogonal matrices are computed.Their results showed that Core points are detected in a fast and efficient way.

Fingerprint verification based on Gabor filter enhancement:

Lavanya.B. N. [10]proposed a Touch less fingerprint verification system in which a fingerprint image is acquired through a digital camera [. The proposed system consisted of different stages like pre-processing, feature extraction and matching stages. Feature extraction (Minutia)is done by Gabor filter and spurious Minutiae were removed and true minutiae points were imposed on image andmatching of fingerprint image is done by Support Vector Machine (SVM).For Minutia extraction two types are considered; ridge ending and ridge bifurcation. The minutiae are extracted based on the number of pixels in the 9 – pixel neighbourhood. Database of FVC2004 (DB1) is considered to establish the ground truth of the minutiae. The Sensitivity (SEN) and Specificity (SPE) are measured over the database. The SEN and SPE were obtained as 80.8 and 87.29.

UmerMunandDr.MuhammadYounasJaved[11]proposed a system in which the core point in fingerprint image is detected using two different techniques; Core point detection using Poincare index and Core point detection using slope. Then the optimal core point is calculated. Then tessellation of fingerprint image is performed. Region of interest is calculated by collection of sectors. Normalization is performed to remove the effects of sensor noise and gray level background due to finger pressure differences. Extraction of texture information from fingerprint images is done by Gabor filter. Fingerprint matching is done by finding the Euclidean distance between the corresponding feature vectors. If the Euclidean distance between two feature vectors is less than a threshold, then the decision that “the two images come from the same finger” is made, otherwise a decision that “the two images come from different fingers” is made.According to their results,the Gabor filter based fingerprint technique takes ~ 7.1seconds onPentium – IV, 2.4 GHz processor, for

featureextraction and matching. About 95% of the total time i.e. ~6.7 seconds, is taken by the convolution of the input image with 16 Gabor filters.

D.Fingerprint verification system using artificial neural network:

Md.Mamunur Rashid and A.K.M. AkatarHossain[12]proposed a system in which minutia features of fingerprint are extracted. To remove noise from input image and enhance the ridge patterns, images are pre-processed using filtering feature of graphics editor. Then fingerprint image is transformed to 480x360 pixel images by using image scaling process. Extraction algorithm is used to extract minutia from gray scale fingerprint image by examining the neighbourhood pixels around each pixel of the thinned ridges. At the same time the minutia points are located and these locations of minutia are preserved for fingerprint matching purpose. The digital values of the extracted features are applied to the input of neural network for training purpose using Back propagation algorithm of Artificial Neural Network.During the training period ,the values of these nodes are updated and stored in a relational knowledge base.The learning rate of network is set to be 0.6 and spread factor as 0.7.For recognition the error tolerance is set to be 0.01.After the training the updated weights and threshold values are stored in a file,for verification process.For that purpose,new fingerprint image is taken from aperson and features are extracted to form a feature matrix.The feature matrix is applied as input of backpropogation neural network to observe whether the system recognised the fingerprint or not or show false recognition. Accuracy obtained through the above verification system is 92.5%.

E.Multi resolution Feature Based Subspace Analysis forFingerprint Recognition using PCA

Dattatray V. Jadhav and Pawan K. Ajmera[13] proposed a pattern recognition framework based on multiresolution features and PCA for fingerprint recognition. The proposed technique of fingerprint recognition detects the core point and crops the image to apredefined size to extract the region ofinterest. Then theimage is decomposed using Daubechies wavelet DB3 and further decomposed the LL component. Thenconcatenate the rows of LL component to derive the multiresolution features of fingerprint images and form the data matrix. Then Eigen values and eigenvectors of covariance matrixC are computed and order the eigenvectors according to descending Eigen values and normalize them. Then project the multiresolution features into Eigen space which arestored in database as reference feature vectors. The performance of the proposed system was evaluated using two databases: FVC2000, and University of Bologna (part of FVC 2000). The FVC2000 database consists ofDB1, DB2, and DB3 subparts and has been captured using opticalscanner. They selected 600 images of 100 subjects (six images per subject) from DB1_a database with image size of 388 X 374for the experiments. University of Bologna database consists of images of 20 subjects with eight images per subject. The recognition is done using the nearest neighbour classifier on the basis of Euclidean distance between training and test image feature vectors. The equal rate of algorithm is 4%.The accuracy obtained for them using their algorithm is 96.3%

Finger Print Recognition using Discrete Wavelet Transform:

K Thaiyalnayaki [14] proposedaneffective combination of features for multi-scale andmulti-directional recognition of fingerprints. The featuresinclude standard deviation, kurtosis, and skewness. Fingerprint images of ten persons were taken and there were two rotated images for every person. A combination of three texture descriptors namely Standard Deviation, Kurtosis and skewness were proposed. Discrete Wavelet Transform is used for texture analysis. Level 2 daubechies transform and second level LL image is used for analysis that contains most of the important texture information. They used an algorithm for texture analysis and featureextraction with DWT. They trained 30 images and obtained an overall performance up to 95%.

G.Fingerprint Identification based on Support vector Machine:

ZakariaElberrichi[15] proposed a method in which the minutia image of fingerprint has to be converted into a vector code, also called finger code by using Gabor filter bank. Each fingerprint image is represented as a vector of 256 real values. Following steps were used to create finger code.Pre-processing of input image by window wise normalisation, Histogram Equalisation, low pass and Median filtering. Then detect core point location using max concavity estimation.tessellation of circular region around the reference point.Sectorwise normalisation followed by application of bank of Gabor filters in the spatial domain. Finally feature code generation by obtaining standard deviation values of all the vectors. They used Support vector Machine (SVM) for matching fingerprints and to perform recognition using one to all search of database. The proposed system was tested with four databases of FVC2004 and Finger cell databases. They have used a bank of 190 images with same number of different sets of fingers, but a different number of pictures related to various acquisition of same finger (10 images. The recognition rate achieved through their proposed method is 94.7%.

Table below shows the results of various pattern recognition techniques used in fingerprint feature extraction (minutia, core point, delta etc.) and matching along with its results in percentage by various researchers.

TABLE II. Comparison between Pattern recognition Techniques used.

Recognition technique	Results (%)
Minutia score matching method[8]	65-70%
Core point detection method[9]	90%
Gabor filter method[11]	95%
Artificial Neural network[12]	92.5%
Principal component Analysis Method[13]	96.3%
Discrete Wavelet Transform Method[14]	95%
Support vector Machine method[15]	94.7%

CONCLUSION

In this paper, we have discussed various pattern recognition methods used for fingerprint recognition that includes minutia extraction, SVM, neural network etc. Among these pattern recognition techniques, minutia feature is mostly extracted. Also in this paper we have discussed various attributes of fingerprint, variety of features. But in existing techniques of feature extraction and pattern recognition,fingerprint recognition does not provide more accurate results in terms of false acceptance rate and false rejection rates for practical implementation of secure fingerprint recognition systems. So there is a need of research in existing pattern recognition systems as well as minutia feature extraction techniques to improve performance of the system.

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AUTHOR'S PROFILE

Prof. Shilpa P.Kodgire
Is working as an Associate professor in M.I.T College, Aurangabad.She had done her Bachelor of engineering from Nagpur University and Masters from Dr.Babasaheb AmbedkarUniversity.Currently She is pursuing P.hd in VLSI from Dr. BabasahebAmbedkar University.

Anju. Mohan
is a P.G. student inM.I.T College, Aurangabad.She had done her Bachelor of Engineering from P.E.S collegeofEngineering,Aurangabad.