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An Overview of Fingerprint Classification Techniques

Vinni[1], Priyanka[2]
[1, 2] *ECE Department, DCRUST, India*

Abstract: ***Fingerprint-based systems were mostly used for authentication of individual's information and its identity by comparing with data stored in a database. To reduce processing time and search area Fingerprints classes are divided into five such as: Arch, Tented Arch, Whorl, Left Loop and Right Loop. There are different classifiers that have been used to develop fingerprint classification techniques, these are 1)Rule-based, 2)Syntactic, 3)Structural, 4)Statistical, 5)Neural network, 6) Gender based. All of the above mentioned classifiers or classification techniques are based on machine learning processes. Machine learning (ML) techniques were accurate and fast in processing. In present paper the selective approaches for fingerprint classification techniques has been reviewed.***

Keywords: Biometric, Fingerprint (FP), Fingerprint Identification, Fingerprint classification (FPC), fingerprint classification techniques (FPCT).

I. INTRODUCTION

Biometric systems are mostly used for person identification purposes. Biometric systems were defined in two categories : one uses physiological characteristics that uses physical identifier for identification and other is behavioral characteristics. Physical identifiers include fingerprint, facial recognition, DNA matching, retina scanning, iris, voice recognition. Behavioral identifiers include recognition of typing patterns, walking gait and other gestures. Among all the biometric identifiers, fingerprint based identification systems are mostly used due to its unique nature and persistence. The main problem in fingerprint is to identify individuals fingerprint from large volume of fingerprints and identify the person's identity correctly[1]. Huge amount of fingerprints are stored in different applications. It takes a lot of time to identify the person's identity. So to reduce the time and make the process faster, classification of fingerprints has become a necessity. This classification of fingerprint images divide the fingerprints in five major classes: these classes are Arch (A), Tented Arch (TA), Left Loop (LL), Right Loop (RL), Whorl (W). This classification model of fingerprint is known as Henry classification system[2]. After this the ridge flow methods were used in fingerprint identification system. After Henry classification model it was easy for identification system to identify fingerprint correctly within less time and also reduces search area. The block diagram of fingerprint verification system is shown in figure1.

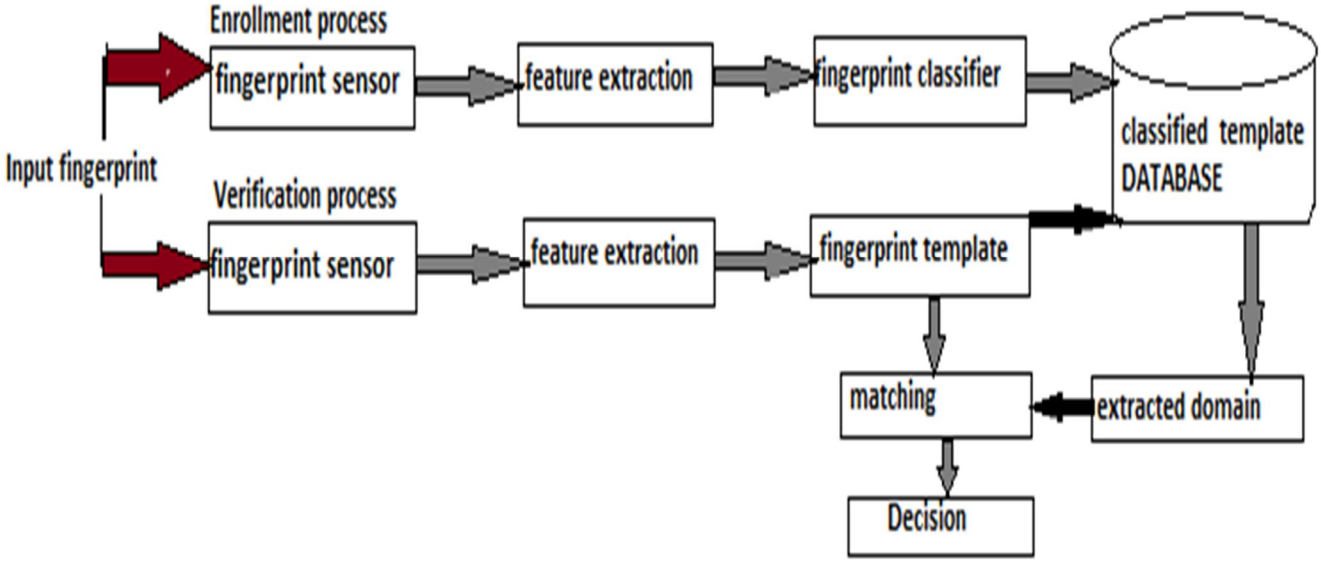

Fig 1. Block diagram of a FVC(Fingerprint Verification system) .

II. FINGERPRINT FEATURES

Fingerprint features are classified into 3 levels [2] and these levels are defined in table 1:

Table No -1: The basic features of different type of levels in fingerprint.

Levels	specifications	Functions
Level 1	Global	This level is used for fingerprint classification. Global level mention global ridge line flow are known orientations and features derived from it are called singular points.
Level 2	Local	Local level consider minutiae details from ridge skeleton. Ridge ending and bifurcations are known as minutiae. This level is used in FP matching.
Level 3	Fine details	This level considers the intra-ridge specifications of image, these are crease, sweat pores, width, shape etc. This is also used for fingerprint matching and this can also provide useful information which is not sufficiently present in other 2 levels. High resolution images are simple to observe in this level.

III. FINGERPRINT CLASSIFICATION

Fingerprints are the combined set of curves. For identification purpose we call them black and white curves. The black curves are known as ridges and white curves are known as furrows or valleys. The combination of curves forms patterns[3]. These patterns of individual fingerprints are unique and never match with any other individual. These shapes and patterns formed by these black and white curves are used to classify fingerprint in different classes. This classification is divided into 5 major classes ;a)Arch (A), b)Tented Arch (TA), c)Left Loop (LL), d)Right Loop (RL), e)Whorl (W). The specifications by which they can differentiate between different fingerprint classes are defined in table 2.

Table No -2: Characteristics of five classes of fingerprints.

Classes	Definition
Arch	FP have no singular points (SP). Flow of ridges from one side to another.
Tented arch	FP having a core & a delta and atleast single ridge shows high curvature.
Left loop	FP having a core & a delta. One or more than one ridges flow towards left side.
Right loop	FP having single core & single delta points. One or more than one ridges flow towards right side in the image.
Whorl	FP having two cores and deltas. And having at least a ridge which makes a full turn around the center.

(a) Arch (b) Tented arch (c) Left loop

(d) Right Loop (e) Whorl

Fig 2: Different FP images in five classes.

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The category of classification other than the above mentioned patterns are shaped by ridges and furrows; 1) singular points ,2) Minutiae features. Figure 3 shows a sample of singular points (SP) and Minutiae features in a fingerprint image[3].

Table no- 3: Define singular points and minutiae features

Patterns	Definition
Singular points	singular points are those which includes core point & delta point.
Minutiae features	The two common type of minutiae found in a FP are ridge ending and bifurcation.

Fig 3: singular points (SP) and Minutiae features are shown in fingerprint image. The specific points are: a)Core point , b) Delta point , c) Bifurcation feature , d) Endpoint feature.

IV. FINGERPRINT CLASSIFICATION TECHNIQUES (FPCT)

Most of the FP classification methods were bestially assigned to one of the categories. Fig 4, represents different categories of FPCT.

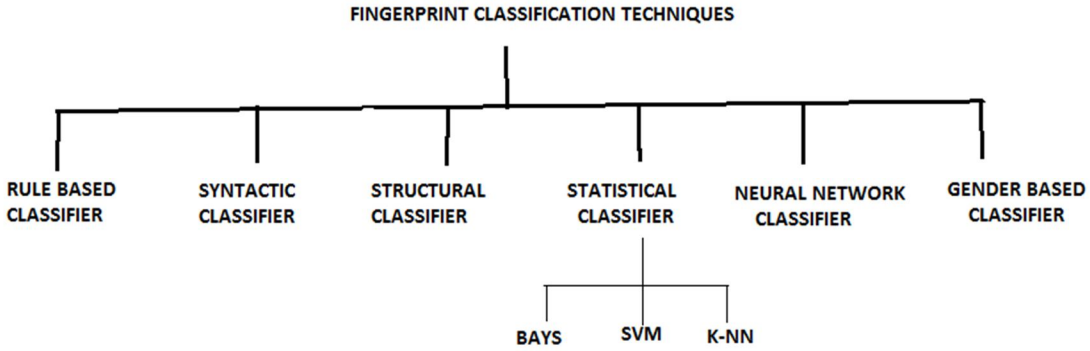

Fig4: Fingerprint classification techniques.

In literature, there are many of works for FPC. Table (4-9), shows selective review of FPCT, which we had studied.

A. Rule based classifier

Table No - 4: Review based on Rule based classification technique.

Authors	Findings
Bouziani et al.[4],2010.	Applicable for high scale database and segmentation is required.
Webbn, Mathekga[5],2014	Singular points are not needed and there is a requirement of additional rules.

B. Syntactic classifier

Table No-5: Review based on Syntactic classification technique.

Author(s)	Findings
Tan et al.[6], 2005	No requirements of finding the reference.
Sakin, firat[3],2013	Ridge distribution sequence is obtained by using pattern recognition.

C. *Structural classifier*

Table No- 6 : Review based on structural classification technique.

Author(s)	Findings
Cappelli[7],1999	Classification is continuous and partitioning is required.
Dario maio et al.[8],1996	Segmentation of fingerprint directional image is obtained using graph matching.
Chong and Ngee[9],1997	Determine global geometric structure of extracted ridges using B-splines.
Chang and fan [10],2002	Determine 10 basic ridge pattern distribution models.
Alaa,Ghazati[11],2014	Segmented regions were extracted from FP orientation image.
Michel Neuhaus and Horst Bunke[12]	Graph matching performed for error tolerance.

D. Statistical classifier

Table No -7 : Review based on statistical classification technique.

Author(s)	Techniques used	Findings
Leung et al.[13], 2011	Bays	Tackles insufficient training samples.
Si ,jie et al.[14], 2015	SVM	Detect distortions.
Jain et al.[15],1999	K- NN	Uses information in ridge pattern.
Zhihua et al.[16],2015	SVM	Using wavelet tanf.& LBP, The test dataset classifier accuracy is 92%.
NurulAin Alias et al. [17] , 2016	SVM	Time taken for train and test of fingerprint database is less.
Anubha parashar [18],2017	SVM, K-NN	Accuracy of SVM is 80.11% , Accuracy of K-NN is 87.72%.
Min-seok[19],2017	K-NN	FP based indoor positioning algorithm achieved 86% accuracy.

E. Neural network classifier

Table No -8 : Review based on neural network based classification technique.

Author(s)	Findings
Jain et al.[15],1999	Uses the information in ridge pattern.
Xiu et al. [20],2011	Higher learning accuracy and good non-linear processing power.
Balti et al. [21],2013	Avoid problems of geometric rotation and translations.
Shan juan et al.[22],2013	Approaches OOCL level and shows lower error rate.
Rodrigo et al.[23],2016	Using CNN, FP liveliness detection accuracy is 97.1%.
Angelo et al.[24],2016	Extraction of level 3 features, sweat pores images captured using touch less acquisition.

F. Gender based classification

Table No -9 : Review based on gender based classification technique.

Author(s)	Techniques used	Findings
Ahmed et al.[25],2006	Neural network	The avg. ridge count and standard deviation is higher in males. Gender classification rate is 88%.
Ritu ,Susmita[26],2012	Frequency domain (FFT, DCT, PSD)	Optimal threshold is chosen. Accuracy is 90%for females and 79.09%for males.
Rijo, Arulkumaran [27], 2013	2D discrete wavelet transforms	Success rate is 70% by using minimum distance classifier.
Mangesh et al.[28],2015	DWT, SVD, K-NN	82.60%of female for left hand little finger. 82.90%of male for left hand index finger. For other fingers-80.40%for male,76.84%for female.
Suchita et al.[29],2015	Frequency domain(6 level DWT, K-NN).	KNN uses Euclidean distance measure, this takes less processing time with fixed feature vector.
Abdullah et al.[30],2016	Global features	74.5% correctly classified of female and male.

V. CONCLUSION

In Rule- based classification segmentation of image and additional rules are required. Ridge distribution sequence is required in Syntactic classifier. In structural classification, image is segmented and different ridge patterns were classified. In Statistical classifier, the database should have unbiased. The percentage accuracy of using wavelet transform for SVM is 92%. The time taken for train and test is less. Neural network classifier should have sufficient training set. Liveliness detection accuracy is 97.1%. This classifier also shows lower error rate. The success rate of Gender based classification is 88% by using neural network and on an average it is 84% in frequency domain.

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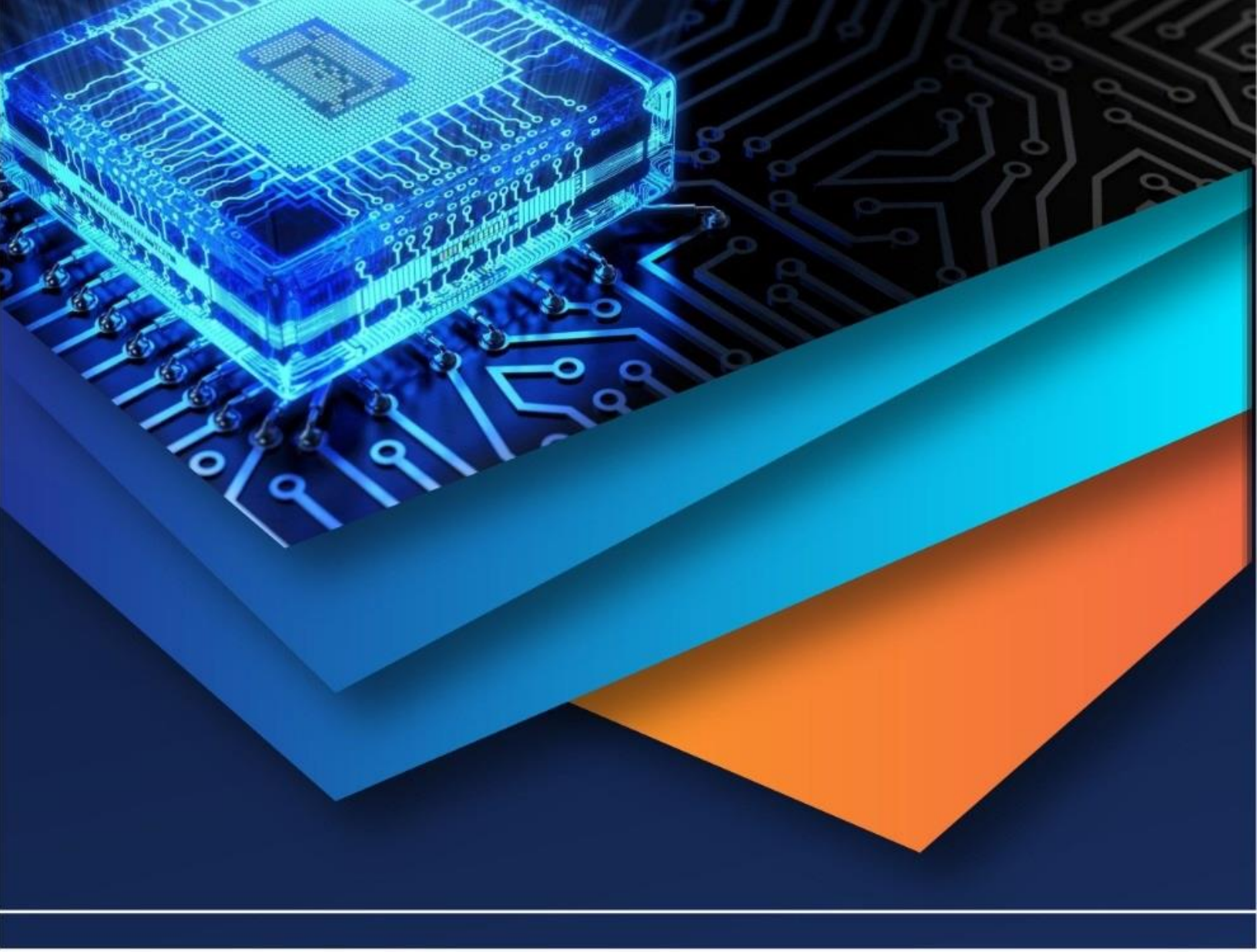

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