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Overview of Fingerprint Recognition System

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***Abstract*— This article is an overview of a current research based on fingerprint recognition system. In this paper we highlighted on the previous studies of fingerprint recognition system. This paper is a brief review in the conceptual and structure of fingerprint recognition. The basic fingerprint recognition system consists of four stages: firstly, the sensor which is used for enrolment & recognition to capture the biometric data. Secondly, the pre-processing stage which is used to remove unwanted data and increase the clarity of ridge structure by using enhancement technique. Thirdly, feature extraction stage which take the input from the output of the pre-processing stage to extract the fingerprint features. Fourthly, the matching stage is to compare the acquired feature with the template in the database. Finally, the database which stores the features for the matching stags. The aim of this paper is to review various recently work on fingerprint recognition system and explain fingerprint recognition stages step by step and give summaries of fingerprint databases with characteristics.**

***Keywords:* - Fingerprint, Pre-processing, Feature extraction, Matching, Databases .**

I. INTRODUCTION

Along of various biometrics techniques, In the past few decades, human-beings have been addicted to various technologies such as captured photos, scanned signatures, bar code systems, verification Id & so on. Also, Biometrics is one of the applications in Image processing which refers to technologies that used physiological or behavioral characteristics of human body for the user authentication. The biometric authentication system based on two modes: Enrolment and Recognition. In the enrolment mode, the biometric data is acquired from the sensor and stored in a database along with the person's identity for the recognition. In the recognition mode, the biometric data is re-acquired from the sensor and compared to the stored data to determine the user identity.

Biometric recognition based on uniqueness and permanence. The uniqueness means that there is no similarity of feature between two different biometrics data. For example, there are no two humans having the same fingerprint feature even if they are twins. And when the features of biometrics do not change over the lifetime or aging, it is called permanence.
Biometrics can have physiological or behavioral characteristics. The physiological characteristics are included in the physical part of body such as (fingerprint, palm print, iris, face, DNA, hand geometry, retina... etc). The behavioral characteristics are based on an action taken by a person such as (Voice recognition, keystroke-scan, and signature-scan).
Any biometrics system including two phases first phase is enrollment phase and second is recognition phase. The recognition phase divided to two things which is verification and identification. During the enrollment phase the biometrics data are captured and generate digital image then Pre-processing apply to digital image for removing unwanted data and apply the post-processing than store this data in database.

In the case of identification process the fingerprint acquired from one person is compared with all the fingerprints which store in database. Also it is known as (1:N) matching. it is used in the process of seeking the criminals.

In the verification process the person's fingerprint is verified from the database by using matching algorithms. Also it is known as (1:1) Matching. It is the comparison of a claimant fingerprint against enroll fingerprint, initially the person enrolls his/her fingerprint into verification system, and the result show whether the fingerprint which take from the user is matching with the fingerprint store as a template in database or not match.
The Enrollment, Identification and Verification process shown in the Fig. 1

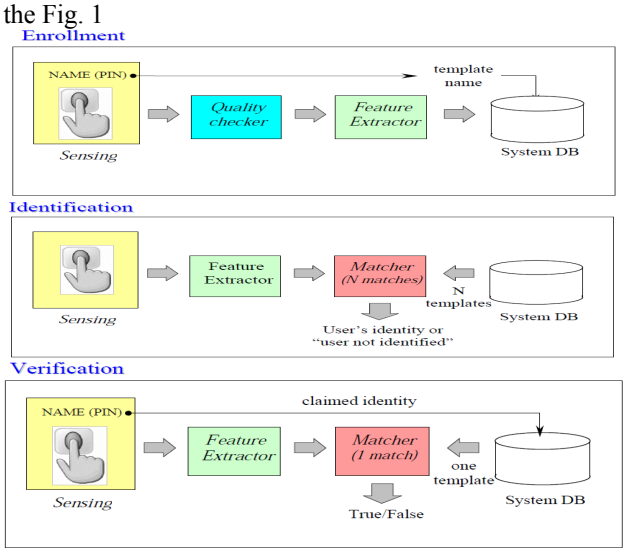

Fig.1.Process of Enrollment, identification and verification

The fingertip surface is a combination of many of ridges and many of valleys. In case of the ridge which declare as black lines and the valleys declare as white lines are show in Fig.2. The minutiae points are the points where the ridge structure changes such as bifurcation and end point.

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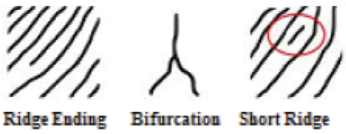


Fig.2. Graphical of ridge and valleys Ridge Ending, Bifurcation and short Ridge [14]

II. FINGERPRINT

Fingerprints are graphical patterns of ridges and valleys on the surface of fingertips, the ridge ending and ridge bifurcation is called minutiae as shown in fig.3. There are many methods based on minutiae-based fingerprint representation were proposed in [1], [2]. Every person has a unique fingerprint from any other person. The fingerprint identification is based on two basic assumptions: - Invariance and Singularity Invariance**:** means the fingerprint characteristics do not change along the life.

Singularity**:** means the fingerprint is unique and no two persons have the same pattern of fingerprint.

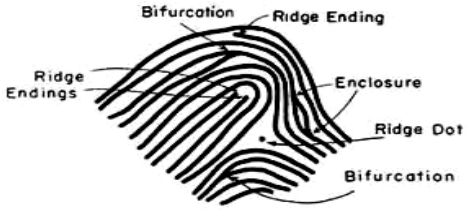


Fig.3. different ridge features on Fingerprint image

Table I. shows the terms and definitions of fingerprint structure

No	*Term*	*Definition*
1	Termination	The location where a ridge comes to an end.
2	Bifurcation	The location where a ridge divides into two separate ridges.
3	Binarization	a process to transform the image from 256 levels to two levels(0,1)refers to (black and white) respectively
4	Thinning	The process of reducing the width of each ridge to one pixel .
5	Termination Angle	Concidered as angle between the direction of the ridge and the horizontal .
6	Bifurcation Angle	Which Concidered as the angle between the direction of the valley ending between the bifurcations and the horizontal.
7	Matching Score	It is the mesure of similarity between the input and template data
8	False Non Matching Ratio	The system fail to detect a match between input and template in database .

The main stages of fingerprint recognition system are shown in fig.4

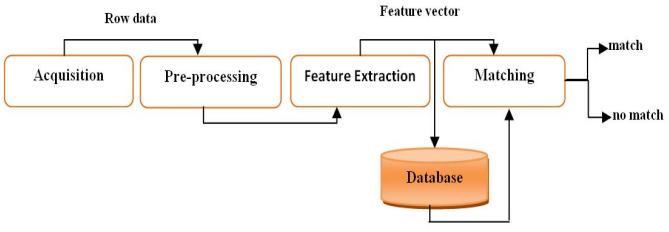


Fig.4. Fundamental Steps of Fingerprint Recognition System

A. Image Capture or Image Acquisition stage

The Image Acquisition stage is the process to obtain images by different ways. There are two ways to capture fingerprint image; online and offline. In the online fingerprint identification the optical fingerprint reader is used to capture the image of fingerprint. The size of fingerprint image will be 260*300 pixels. The offline fingerprint identification is obtained by ink in the area of finger and then put a sheet of white paper on the fingerprint and finally scans the paper to get a digital image.

B. Image Pre-processing Stage

The pre-processing stage is the process of removing unwanted data in the fingerprint image such as noise, reflection .etc. The fingerprint image pre-processing is used to increase the clarity of ridge structure. There are many steps for doing this process shown in fig.5,such as Image Segmentation, Binarization, Elimination of noise, smoothing and thinning which are used to enhance the fingerprint image. In [3], the Gaussian filter, Short Time Fourier Transform analysis are adopted to enhance fingerprint image quality. In some cases the binarized of fingerprint image are contains a some of false minutiae .In [4]. A detailed pre-processing is mentioned to remove false minutiae. In fig 6 shows the preprocessing steps.

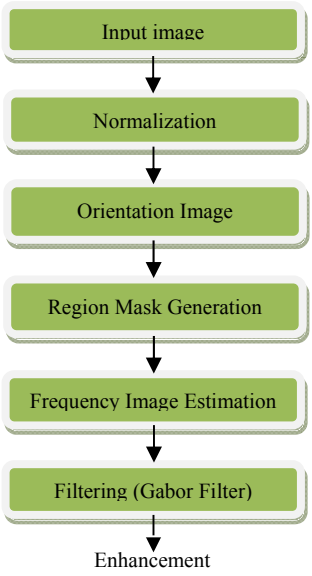


Fig.5. main steps of fingerprint Enhancement

Jiao Ruili et. al., [5] they are do an automatic fingerprint identification system the acquisition and pre-processing system with a fixed point DSP, TMS320VC5509A and a fingerprint sensor, MatBF200. And they said that the system is diminutive and flexible and they are presents a VC5509A based fingerprint pre-processing system, accomplished fingerprint image acquisition. The pre-processing system is accomplished with the properly selected algorithm on a DSP platform. Comparing the results of the algorithms, appropriate algorithms are selected for fingerprint identification pre-processing. They are Median Filtering, Directional Filtering

Enhancement, Fixed Threshold Binarization, and Hilditch Thinning.

Yun and Cho [6] in this work they adaptive pre-processing method on fingerprint image and extracts five features from it. and they used clustering method for analyses image quality, and enhance it by their characteristics. This is what pre-processing is performed after distinguishing the fingerprint image quality related to its characteristics.

(a) (b) (c)

Fig.6 preprocessing steps (a) original image (b) enhancement(c) binary image

The Table II shows the some recent research of pre-processing

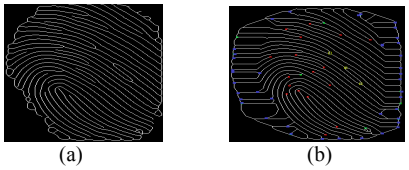
Table II. Summary of fingerprint pre-processing stage

Ref	*Year*	*Pre-processing*	*Database*
[21]	2004	Orintation field :Modal-based method , region segmention ,orientation filed ,ridge enhancement	THU
[22]	2006	Hierarchical Discrete wavelet Transformation(DWT)	FVC2002
[23]	2007	Gabor filters,mask estimation, Binarization ,Thinnig	FVC2002
[24]	2008	Minutiae feature by using CNN	----------
[25]	2013	Normalization,Ridge segmention , Ridge orintation Core point detection.	FVC2002
[26]	2012	Enhancement using two stage determination of reference point and determination of ROI	FVC2002
[27]	2007	Gray scale image ,binarization	----------
[28]	2013	Gabor filter and FFT, Normalization, localorientation,local frequency, region mask , filter, Binarization	FVC2004

C. Feature extraction stage

The feature extraction process of fingerprint image applied on the output of pre-processing stage. The process of feature extraction depends on set of algorithms. A fingerprint feature extraction program is to locate, measure and encode ridge endings and bifurcations in the fingerprint. There are various methods for extracting the features from the fingerprint image. The famous methods is minutiae extraction algorithm which is find the minutiae points and map their relative placement on the fingerprint .There are two types of minutiae points; Ridge ending and Ridge bifurcation [7]. In[8] they are used an advanced method for extract feature from fingerprint which done by extract minutiae directly from original gray-level images without use binarization and thinning and they use gabor filter methods to extract features from fingerprint [9].

Afsar et. al., [10] In their research the extract the minutiae from fingerprint image after apply the binarized, thinned and segmented version of a fingerprint image. In this system the fingerprint classification for indexing during fingerprint matching. Zebbiche and Khelifi [11] presented biometric images as one Region of Interest (ROI). In their method use Discrete Wavelet Transform and Discrete Fourier Transform to perform their algorithm. Yi Chen and Anil K Jain [12] proposed an algorithm based on fingerprint features that means minutiae features and ridges features also Pattern and Pores. Their find the correlation between Fingerprint features and their distributions in their model. Tachaphetpiboont and Amornraksa [13] propose a feature extraction method based on FFT for the fingerprint matching. The recognition rate obtained from the proposed method is also evaluated by the k-NN classifier. The amount of time required for the extraction and verification is very less in this approach. In fig.7, show the feature extraction of fingerprint. and table III show some summary of feature extraction researches.



(a) (b)

Fig 7.feature extraction (a) thinning image (b) minutiae

Table III. Show the Summary of fingerprint feature extraction

Ref	*Year*	*Feature extraction*	*Database*
[29]	1992	Orientation field	NIST4
[30]	1996	Singularities	NIST4
[31]	1998	Ridge structure	NIST4
[32]	1999	Singularities and ridge	NIST4
[33]	2001	Fingercode	NIST4
[34]	2002	Ridge Distribution	NIST4
[35]	2003	Relational graph, fingercode	NIST4
[21]	2004	Minutiae extraction	THU
[22]	2006	Seven Invariant moment, fingercode, refrences point	FVC2002
[23]	2007	Ridge ending and ridge bifurcation	FVC2002
[24]	2008	Minutiae feature by using CNN	----------
[25]	2013	ROI,Compute LDP Code (local Directional pattern)	FVC2002
[36]	2014	Fixed length represntion that provide extract aligment between features.	FVC2002/ FVC2004
[26]	2012	Local and globle Invariant moment Feature and PCA for feature selection	FVC2002

D. Matching stage:-

The matching stage is the process to compare the acquired feature with the template in the database. In other words the process of matching stage is to calculate the degree of similarity between the input test image (for user when he wants to prove his/her identity) and a training image from database (the template which created at the time of enrolment). Matching can be done in three methods: hierarchical approach, classification approach and Coding approaches. The hierarchical approach is increases matching speed at the cost of accuracy [14].Classification approaches assign a class to each biometric in a database. There are many classification methods including KNN classifier [15]. Coding approaches which use one matching function to search entire databases.

Arun Ross et. al., [16] proposed the hybrid fingerprint matcher which employs the combination of ridge strengths and a set of minutiae points.

Johg Ku Kum et. al., [17] presented a study on Hybrid fingerprint matching methods. They combining minutiae matching and image based fingerprints verification methods

and the matching done by using the shapes of fingerprint such as cross(diamond and dispersed) and square .

Swapnali Mahadik et. al.,[18] in their work the Alignment based Minutiae Matching algorithm used for matching . in this case the images are subjected to translation Rotation and Scaling to do the matching stage. Anil Jain et. al., [19] in this work the matching stage perform by integrate three fingerprint matching algorithms which is Hough transform, string distance and 2D dynamic programming based matching using the logistic regression method.

Aparecido Nilcau Marana and Jain [20] in this work the matching is perform by using Ridge Based using the Hough transform method. In the fig. 8 shows the example of some fingerprint matching of two fingerprints.

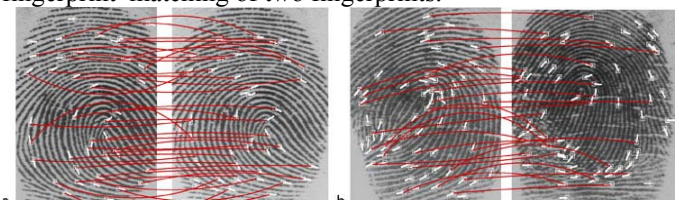


Fig .8.Example of fingerprint matching

The table IV. Show some summary of some research related with fingerprint marching and which matching methods used and in which database are test.

Table IV. show the Summary of fingerprint matching

Ref	*Year*	*Matching*	*Database*
[37]	1996	Hough transform-based approaches	----------
[38]	1997	Ridge-based relative pre-alignment	----------
[21]	2004	Minutiae matching	THU
[39]	2005	Global matching of clusters of minutiae	----------
[22]	2006	Invariant moment fingerCode and LVQ	FVC2002
[40]	2006	Global minutiae matching with image correlation	----------
[23]	2007	Minutiae matching, vector matching ,weight modification and local area matching process	FVC2002
[24]	2008	Minutiae matching ,which find the similartiy between two images and by calculating the correlation between these images.	**---------**
[41]	2009	Global matching by evolutionary algorithms	**--------**
[42]	2010	Weighted global matching with adjustment of scores	**---------**
[43]	2012	Orientation image-based relative pre-alignment	----------
[25]	2013	LDP and SLFNN	FVC2002
[44]	2013	Hierarchical and/or multilevel minutiae matching	----------
[27]	2007	Minutiae matching ,RMI and Fuzzy operator	---------
[26]	2012	ELM and R-ELM	FVC2002

III. DATABASES

There are many fingerprint databases which are defer from other by total images, number of subject, number of sample , image size, resolution and type sensor which are captured the image of fingerprint the table V. show the some standards databases available with some of characteristics of it[45,46,47,48].

Table V. Some fingerprint databases

Database		**Total images**	**Subject / sample**	**Image Size**	**Resolution dpi**	**Sensor type**
FVC **2000**	DB1_B	880	110- 8	300x300	500 dpi	Optical
	DB2_B	880	110- 8	256x364	500 dpi	capacitive
	DB3_B	880	110-8	448x478	500 dpi	Optical
	DB4_B	880	110-8	240x320	~500dpi	Synthetic Generator
FVC **2002**	DB1_B	880	110-8	388x374	500 dpi	Optical
	DB2_B	880	110-8	296x560	569 dpi	Optical
	DB3_B	880	110-8	300x300	500 dpi	capacitive
	DB4_B	880	110-8	288x384	~500dpi	sFinGe v2.51
FVC **2004**	DB1_A	1440	120-12	640x480	500 dpi	Optical
	DB2_A	1440	120-12	328x480	500 dpi	Optical
	DB3_A	1440	120-12	300x480	512 dpi	thermal sweeping
	DB4_A	1440	120-12	288x384	~500dpi	sFinGe v3.0
FVC **2006**	DB1	1,800	150-12	96×96	250 dpi	Electric Field
	DB2	1,800	150-12	400×560	569 dpi	Optical
	DB3	1,800	150-12	400×500	500 dpi	Thermal sweeping
	DB4	1,800	150-12	288×384	~500 dpi	SFinGev 3.0
polyU		3170	140-22		~1,200 dpi	Optical
CASIA		20000	4000-5	328×356	------	Optical
polyU (HRF)		1480	148-10	320x240	1200 dpi	custom built
FingerDOS		3600	360 - 10	260x300	500dpi	Optical

IV. CONCLUSIONS

This paper gave an overview of the fingerprint recognition. We highlighted in details the fingerprint recognition step by step. We also referred to the image acquisition stage, image pre-processing stage, feature extraction stage and matching stage for recognition purpose in details with some previous work. In addition to that we introduced some techniques for fingerprint recognition and the finally the summary of fingerprint databases with some characteristics.

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