Multimodal Biometrics Enhancement Recognition System based on Fusion of Fingerprint and PalmPrint: A Review

Mouad. M. H. Ali [α] & A. T. Gaikwad [σ]

Abstract- This article is an overview of a current multimodal biometrics research based on fingerprint and palm-print. It explains the pervious study for each modal separately and its fusion technique with another biometric modal. The basic biometric system consists of four stages: firstly, the sensor which is used for enrolment & recognition the biometrics data. Secondly, the pre-processing stage which includes the enhancement and segmentation of Region-Of-Interest ROI. Thirdly, features extracted from the output of the pre-processing and each modal of biometrics having different type of 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. Multimodal is being gathered of various types of biometrics objects from the same human. In this paper, the biometric system gives an explanation for each model. Also, the modalities of biometrics are discussed as well as focused on two different modalities: fingerprint and Palm-Print.

Keywords: multimodal, ROI, fingerprint and palm-print, fusion.

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. Biometrics refers to technologies that measure and analyze human body characteristics 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 behavioural 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).

Author α: Research Scholar at Dr. Babasaheb Ambedkar Marathwada University Aurangabad, Maharashtra , India.
e-mail: Mouad198080@gmail.com
Author σ: A.T.Gaikwad,Institute of Management Studies and Information Technology, Aurangabad, Maharashtra, India.
e-mail: drashokgaikwad@gmail.com

II. Biometric Modalities

a) Fingerprint

The fingertip surface consists of ridges and valleys. The ridge declare as black lines and the valleys declare as white lines Fig.1 .The minutiae points are the points where the ridge structure changes such as bifurcation and end point

Figure 1 : Graphical of ridge and valleys Ridge Ending, Bifurcation and short Ridge[14]

b) Palm Print

The human palm means the inner area between the fingers and wrist. The area of palm print compared to fingerprint is much larger, and then it can extract more features than a fingerprint. The palm print is similar to the fingerprint in ridges and valleys but the palm has also principle lines and wrinkles which can be acquired with a lower resolution scanner.

c) Face

Face recognition is the popular way for the humans to recognize each other. The face is the front part of a head from chin to the forehead. Face recognition can be used in surveillance application because the face is one of the few biometric traits that can be recognized by people at distance [1].

d) Iris

Iris means a ring-shaped behind the cornea of the eye. The iris is very difficult to use after death because it's one of the first parts of the body to decay after death. Also the right iris is different from the left iris.

e) Retina

Retina is the layer of blood vessels which is located on the back of the eye. It is one of most secure in Biometrics because it is not easy to change or replicate the retinal vasculature.

f) Hand geometry

Hand geometry recognition measures the size and shape of palm, and length and width of fingers. The merits are easy to use, technique is very simple. The demerit of hand geometry is that it can't be embedded to small devices like laptops, because the hand geometry sensor is large. Therefore, the hand geometry is suitable for verification only.

g) Voice

Voice Recognition is the task of recognizing people from their voices. It is a combination of behavior and physical biometrics. The physical features of voice are vocal tracts, mouth, nasal cavities, and lips which used to create the voices

h) Gait

Gait is the way of walking. Gait Biometrics can be used in surveillance application because it can be recognised at a distance.

i) Signature

Signature is a type of behavior biometrics and it can be changed by the person. The biometric system identifies the signature from the way of holding the pen and the time taken to sign. Also, it can be online or offline.

j) Keystroke

Keystroke is the way of typing on the keyboard. Most people have different ways to deal with the keyboard but this type of biometrics cannot be based for security accessing, thus it can be used after a strong biometrics for verification only 1:1.

k) DNA

DNA refers to deoxyribonucleic acid. This type of biometric is used in crime investigation. The identical twins have the same DNA pattern.

III. 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.2. 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.

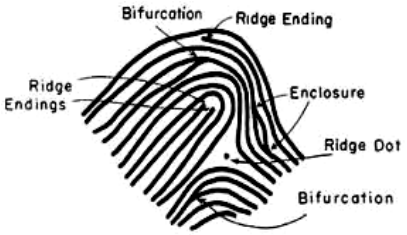

Figure 2 : Fingerprint image showing different ridge features

Table 1 : 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	The process of converting the original gray scale image to a black-and white image.
4	Thinning	The process of reducing the width of each ridge to one pixel .
5	Termination Angle	The angle between the horizontal and the direction of the ridge.
6	Bifurcation Angle	The angle between the horizontal and the direction of the valley ending between the bifurcations.
7	Matching Score	it is used to calculate the matching score between the input and template data
8	False Non Matching Ratio	It is the probability that the system denies access to an approved user.

The main stages of fingerprint recognition system are shown in fig.3

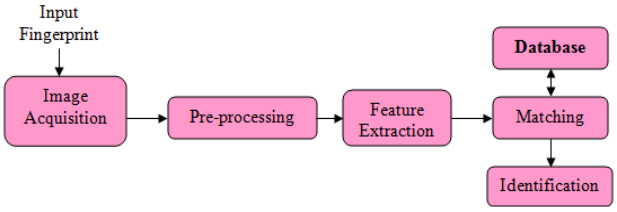

Figure 3 : Fundamental Steps of Fingerprint Recognition System

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 such as Image Segmentation, Binarization, Elimination of noise ,smoothing and thinning. The propose of all these steps is to enhanced fingerprint image at the time of enrolment. In [3],in addition to Gaussian filter, Short Time Fourier Transform (STFT) analysis is adopted to enhance fingerprint image quality. Sometimes the binarized fingerprint image contains a number of false minutiae. In [4].a detailed pre -processing is mentioned to remove false minutiae. Jiao Ruili et. al., [5] proposed an automatic fingerprint acquisition and pre-processing system with a fixed point DSP, TMS320VC5509A and a fingerprint sensor, MBF200. The system is diminutive and flexible. The author 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] proposed an adaptive pre-processing method, which extracts five features from the fingerprint images, analyses image quality with clustering method, and enhances the images according to their characteristics. The pre-processing is performed after distinguishing the fingerprint image quality according to its characteristics. The Table show the some recent research of pre-processing.

Table 2 : Summary of fingerprint pre-processing stage

Ref	Year	Pre-processing	Database
[67]	2004	Orintation field :Modal-based method, region segmention, orientation filed, ridge enhancement	THU
[68]	2006	Hierarchical Discrete wavelet Transformation(DWT)	FVC2002
[69]	2007	Gabor filters, mask estimation, Binarization, Thinnig	FVC2002
[70]	2008	Minutiae feature by using CNN	
[71]	2013	Normalization, Ridge segmention, Ridge orintation Core point detection.	FVC2002
[74]	2012	Enhancement using two stage determination of reference point and determination of ROI	FVC2002
[73]	2007	Gray scale image, binarization	------
[84]	2013	Gabor filter and FFT, Normalization, local orientation, 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. For extracting the features from the fingerprint image, a popular method is minutiae extraction. Minutiae extraction algorithm will find out the minute points from the fingerprint and then map their relative placement on the finger.

There are two types of minutiae points: Ridge ending and Ridge bifurcation[7]. In [8] an advanced fingerprint feature extraction method is introduced through which minutiae are extracted directly from original gray-level fingerprint images without binarization and thinning. Gabor filter bank can also be used to extract features from fingerprint [9]. Afsar et. al., [10] presented the minutiae based Automatic Fingerprint Identification Systems. The technique is based on the extraction of minutiae from the thinned, binarized and segmented version of a fingerprint image. The system uses fingerprint classification for indexing during fingerprint matching. Zebbiche and Khelifi [11] presented biometric images as one Region of Interest (ROI). The scheme consists of embedding the watermark into ROI in fingerprint images. Discrete

Wavelet Transform and Discrete Fourier Transform are used for the proposed algorithm. Yi Chen and Anil K Jain [12] proposed an algorithm based on fingerprint features viz., minutiae and ridges, Pattern and Pores. The correlation among Fingerprint features and their distributions are considered for the model. Tachaphetpiboont and Amornraksa [13] proposes 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.

Table 3 : Show the Summary of fingerprint feature extraction

Ref	Year	Feature extraction	Database
[60]	1992	Orientation field	NIST4
[61]	1996	Singularities	NIST4
[62]	1998	Ridge structure	NIST4
[63]	1999	Singularities and ridge	NIST4
[64]	2001	Fingercode	NIST4
[65]	2002	Ridge Distribution	NIST4
[66]	2003	Relational graph, fingercode	NIST4
[67]	2004	Minutiae extraction	THU
[68]	2006	Seven Invariant moment, fingercode, refrences point	FVC2002
[69]	2007	Ridge ending and ridge bifurcation	FVC2002
[70]	2008	Minutiae feature by using CNN	
A dina	2012	Scale Invariant Feature Transformtion (SIFT)	FVC2002
[71]	2013	ROI,Compute LDP Code (local Directional pattern)	FVC2002
[72]	2014	Fixed length represntion that provide extract aligment between features.	FVC2002/ FVC2004
[74]	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 which employs simple but computationally effective features to retrieve a subset of templates in a given database. This approach increases matching speed at the cost of accuracy[14], classification: Classification approaches assign a class to each biometric in a database. There are many classification methods including KNN classifier [15].and Coding approaches will 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. The minutiae and image based fingerprints verification methods are implemented together. The shapes in the fingerprint such as square, diamond, cross and dispersed cross are used for matching. Swapnali Mahadik et. al., [18] described an Alignment based Minutiae Matching algorithm. The minutiae extraction involves Filtering, Binarization, Orientation Estimation, Region of interest, Thinning and Minutiae Extraction. In the matching stage the images are subjected to translation Rotation and Scaling. Anil Jain et. al., [19] described the use of logistic regression method to integrate multiple fingerprint matching algorithms. The integration of Hough transform based matching, string distance based matching and 2D dynamic programming based matching using the logistic regression has minimized the False Rejection Rate for a specified level of False Acceptance Ratio. Aparecido Nilcau Marana and Jain [20] proposed Ridge Based Fingerprint matching using the Hough transform. The major straight lines that match the fingerprint ridges are used to estimate rotation and translation parameters.

Table 4 : Show the Summary of fingerprint matching

Ref	Year	Matching	Database
[76]	1996	Hough transform-based approaches	----------
[77]	1997	Ridge-based relative pre-alignment	----------
[67]	2004	Minutiae matching	THU
[78]	2005	Global matching of clusters of minutiae	----------
[68]	2006	Invariant moment finger Code and LVQ	FVC2002
[80]	2006	Global minutiae matching with image correlation	----------
[69]	2007	Minutiae matching, vector matching ,weight modification and local area matching process	FVC2002
[70]	2008	Minutiae matching, which find the similartiy between two images and by calculating the correlation between these images.	--------
[83]	2009	Global matching by evolutionary algorithms	--------
[82]	2010	Weighted global matching with adjustment of scores	--------
[81]	2012	Orientation image-based relative pre-alignment	--------
[71]	2013	LDP and SLFNN	FVC2002
[79]	2013	Hierarchical and/or multilevel minutiae matching	--------
[73]	2007	Minutiae matching, RMI and Fuzzy operator	--------
[74]	2012	ELM and R-ELM	FVC2002

IV. Palm Print

The palm used in fortune telling 3000 years ago, but in 1998 Wei and David [21] studied the palm print as personal identification and it became one type of physical biometrics. Wei and David found that the features of palm print are geometry, principle lines (life, heart and head), wrinkle, delta point and minutiae. No two humans' palms are identical. The space of palm is greater than the fingerprint space so the palm had more information than a fingerprint. The palmprint is to contain principal lines and wrinkles in addition to pattern of ridges and valleys similar to fingerprints. The principle lines and wrinkles can be captured by a lower resolution sensor fig.4 (b),whereas the ridges and valleys in palm are captured by high resolution . The ridges are shown as dark lines; and the valleys are the white lines between those black lines. The minutiae are the points where the ridges changed such as bifurcation and endpoint. The area of palm print is larger than the fingerprint area, then the number of minutes in a palm print around ten times the minutes in a fingerprint [22]. The palm can be captured from normal scanners.

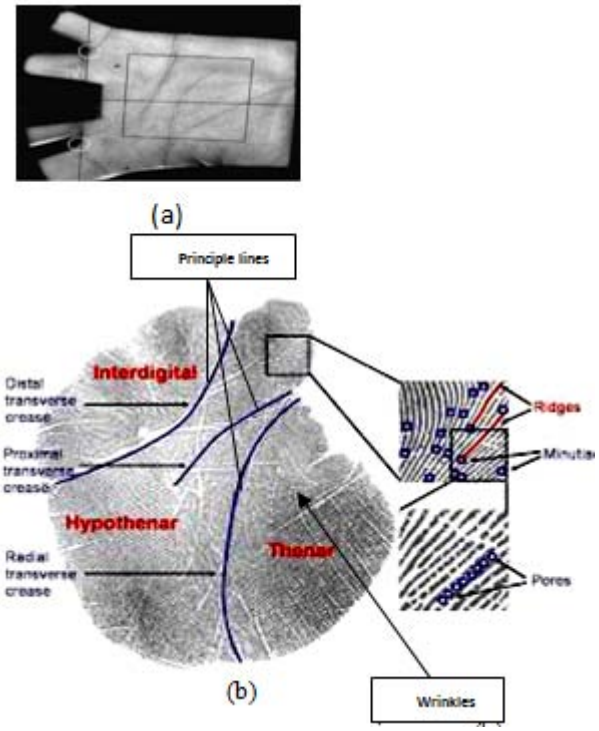

Figure 4 : (a) CCD-based palm print image, (b) ROI, ridges and valleys of palm

The palm print system recognition consists of four parts as shown in fig.5

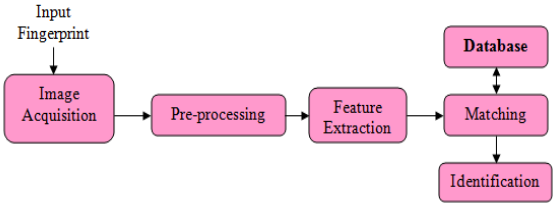

Figure 5 : Palm print recognition system

a) Image Acquisition

There are four types of devices that can capture the palm: CCD-based palmprint scanner, digital camera, digital scanner and video camera. The offline palmprint identification obtaines images by ink the area of palm and then put a sheet of white paper on the palm and then scans the paper to get a digital image [23]. Zhang et al [24] were the first research team to develop online palmprint identification (CCD-based palmprint scanner) and it captured high quality palmprint image. The CCD-based palmprint scanner is depended on the lens, camera and the light sources fig.6.

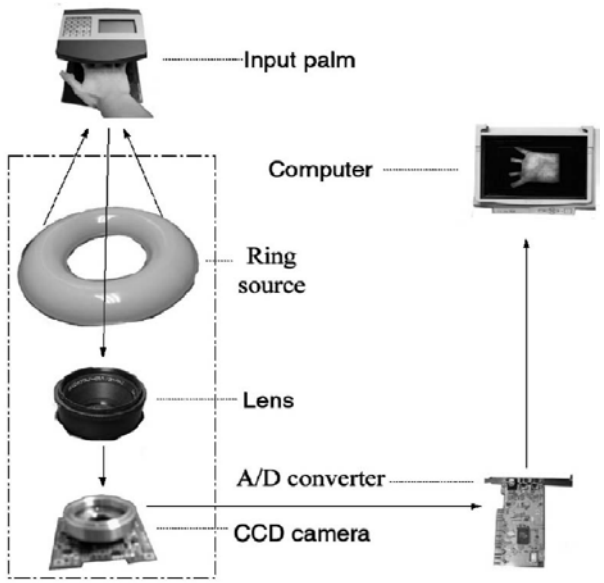

Figure 6 : Diagram of the palm print captured devices CCD [24]

b) Pre-Processing

The pro-processing stage in palm print applied to align the various palm images and to segment the region of interest ROI for feature extraction. The most common steps of pre-processing in palm print recognition as shown in the below diagram:-

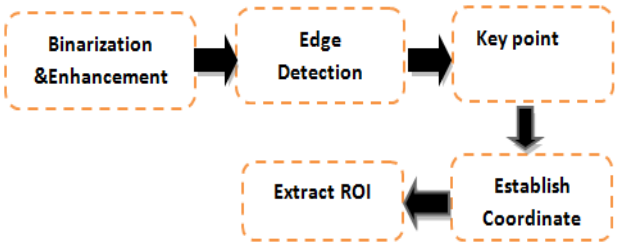

Figure 7 : Diagram of the most common steps of pre-processing

Zhang et al.[24] presented the Gaussian smoothing for the original image of palmprint, then transformed it into binary image. After that it used the boundary tracing algorithm for detect the edges, then computed the tangent between the two gaps of fingers to get the Y-axis and finally extracted a sub image of a fixed size based on coordinate system. However, in [25] it cropped the area of fingers to reduce the time of compute the tangent, and enhance the ROI to extend the gray scope into 256 to make the lines clear for feature extraction.

C. C. Han et al [26] applied to full palmprint images (scanner image) , it used the border tracing algorithm after convert the image into binary image, then located the five fingers tips and four fingers roots by used wavelet based segmentation, and from the ring fingers points are establish the coordinate of ROI.

K. Chuang et al. [27] applied the opening morphology operation for removing the noise of binary image of palm print, and then shrink the region of palm print image by segmented a rectangular region bounded by four lines: upper and lower bound should less than 200 white pixels, right and left bound should be less than 95 white pixels. It detected the boundary by using Sobel edge detection. Then, it took a double derivation of palm boundary to locate three points between the fingers. Next, it created a line by connecting the two points in the upper curve and lower curve, and this line used to align the difference palm print image. It created a point in the middle of the align line M. This point with the middle curve point used to establish the central point of coordinate of ROI.

In case of offline palm print image, no need for binarizing the palm print image because it is already black and white.

R. Wang et. al.[28] utilized Gaussian filter to remove the noise from the palm print image, and then used canny edge detection and convex hull to detected the end points of heart line and life line (datum points).

Table 5 : Summary of palm print pre-processing

Author name	Remove noise	Edge detection	Key points
D. Zhang et al. [24]	Gaussian smoothing then Binarizing	Boundary tracking algorithm	Gap fingers tangent
K. Chuang et al. [27]	Binarizing then opening operation	Sobel edge detection	Double derivation and get 3 points between fingers
C. C. Han et al [26]	Binarizing by using threshold histogram	Border tracing algorithm	Wavelet to locate the five fingers tips and four fingers root
R. Wang et. al.[28]	Gaussian filter	Canny edge detection	Convex hull to detect the end points of heart line and life line

c) Feature Extraction

The feature extraction applied on the output of pre-processing phase which is a fixed size of image. And extract the feature of palm like principle lines, wrinkles and minutiae, and each feature belongs to a different resolution.

Wei and Zhang [29] extracted the datum points and the line features from the palm print image. The datum points are defined as the points of palm print registration. Therefore, it detected the principle lines and their endpoints by using the directional projection algorithm. Moreover, the authors have improved template algorithm to extract the ridges and wrinkles as straight lines.

D. Zhang et al. [24] since the stack filter algorithm is able to extract the principle lines of palm print, but the principle lines are not sufficient to prove the uniqueness of palm print. Thus, the author's proposed the 2D Gabor to represent the palm print for extracting the texture features of palm print from low-resolution.

J. Gan and D. Zhou [25] decomposed the palm print image into sub-images by using the 2-dimensional multi-scale wavelet, then four images are obtained; one of those sub-images is the approximation image for low-frequency components, and the rest of sub-images are demonstrated for the high-frequency component. After that, segment each wavelet sub-image into n^2 blocks

C. C. Han et al [26] applied four directions of Sobel operators to extract the feature points of ROI of palm print, and then applied a complex morphology operator to extract the features of palm print image.

Yao et al. [30] proposed Gabor transformation to extract the texture of palm print features which divided the palm print image into 32 regions. And it was used eight direction $(0, \pi/8, \pi/4, 3\pi/8, \pi/2, 5\pi/8, 3\pi/4, 7\pi/8)$ and four scales (2,4,8,16) 8*4=32 regions to obtain the image texture characteristics. Then it was resized the domination of Gabor image into 1/16 of original image. After that, researchers used ICA (Independent Compo nent Analysis) for further extracted features.

d) Matching

The matching stage is to compare the acquired feature with the template in the database. In [29] proposed the Euclidean distances to match between the endpoints of two lines. And computed the three parameters (slope, intercept and angle) of each line segmented in the two palm print images and decided whether the two lines are equal or not. But in [31] it utilized the energy difference and Hausdroff distance to match between the two palms features. Gan and Zhou [25] the matching based on Euclidean distance between feature vectors and NND (Nearest Neighbour Distance) rule.

D. Zhang et al. [24] determined the similarity measurement of two palm print by using the Humming distance. And in [26] authors proposed two verification mechanisms, one is the correlation function to measure the similarity between the two feature vectors, and the second is Back propagation neural network (BPNN) with the scaled conjugate-gradient algorithm. Also, researchers in [30] identified the weight features by BBNN. X.Y Jing and D. Zhang [32] took the first five samples of each individual in database as training samples and the reminders as test samples, and then the number of training and testing will be 950 training and 2090 testing. The first twenty low frequency bands are selected. Thus, the principle components are 210 and it obtained 181 discrimination vectors. In this paper the result of the recognition accuracy is 98.13%.

Table 6 : Summary of palm print recognition

Ref no	Feature based	Feature extraction	Matching technique	Database
[29]	Straight lines	Directional projection algorithm	Euclidian distance	Offline, 200 samples
[31]	Texture & feature points	--------	Energy different & Hausdroff distance	Offline, 200 samples
[24]	Lines & textures	Stack filter & 2D Gabor	Humming distance	Online, 193*40 samples
[33]	Textures	LPQ	--------	PolyU 189*20
[26]	Lines feature	Sobel operator & morphology	Correlation function & BPNN	--------
[25]	Features vector	Multi-scale wavelet	Euclidean distance & NND rules	Online, 100*60 samples
[30]	Texture	Gabor transformation & ICA	BPNN	50*10 samples
[34]	Orientation features	Six Gabor filter on diff direction	Humming distance	--------
[32]	Discriminant DCT features	Improve Fisher Palm method	Neural network	Online 190*16 samples

Table 7 : Comparison between fingerprint and palmprint trait

No	Fingerprint	Palm print
1.	It contains pattern of ridges and Valleys	It contains pattern of ridges and Valleys also it contains additional features such as principal lines, wrinkles, dathm points.
2.	It is difficult to be captured even with the lower resolution scanner.	It is easy to be captured even with a lower resolution scanner.
3.	Both deal with the some problems like noisy data, Non-universality, intra- class variations, spoof attack.etc.	
4.	The area of finger is less.	The area of palm is much large in comparison to finger.
5.	It is less distinctive	It is more distinctive.

V. Multi-Modal

The multimodal biometrics combine more than one modalities of biometrics to improve the recognition accuracy [37]. The recognition system which acquires biometric information from many sources for the same person in order to determine the identity of a person known as multi-biometrics system. Any piece of evidence can be independently used to recognize a person is called a source of biometric information [38]. Biometric systems are becoming popular as measures to identify human being by measuring one's physiological or behavioral characteristics. The multimodal biometric systems provide advantage over the conventional Unimodal biometric systems in various ways [39].

The main goals of multi-modal biometrics are to reduce at least one of the following; FAR (False Accept Rate), FRR (False Reject Rate), FTE (Failure To Enrollment rate) and Susceptibility to artifacts or mimics. But it also increases sensor cost, enrollment time, transit time and system development [37,39].Multimodal biometric system acquires the input from one or more sensors measuring two or more different modalities of biometric characteristics.

VI. Fusion

[30] Proposed two steps for fusion the palm print and face feature at the feature level: firstly, since the huge difference between the face and palm then it normalized their features as certain range. Secondly, utilized User-specific weighting rule, where the weights of palm print are varies from 0.1 to 0.9, and the weights of face are varies from 0.9 to 0.1. Then selected the weight based on the highest recognition rate of all pairs weights of palm print and face varies weight.

In [33] proposed fusion of face and palm print at the four levels and each level had difference techniques: at the sensor level used wavelets based image fusion scheme, at the feature level used few normalization techniques, at the score level used a some rules of fusion such as sum, max and min rule to combine the matching score, finally at the score level used a logical AND & OR operators.

a) Levels of Fusion

i. *Sensor-level fusion*

The raw biometric data (e.g., a face image) acquired from an individual represents the richest source of information although it is expected to be contaminated by noise (e.g., non-uniform illumination, background clutter, etc.). Sensor level fusion refers to

the consolidation of (a) raw data obtained using multiple sensors, or (b) multiple snapshots of a biometric using a single sensor.

ii. *Feature-level fusion*

In feature-level fusion, the feature sets originating from multiple biometric algorithms are consolidated into a single feature set by the application of appropriate feature normalization, transformation and reduction schemes. The primary benefit of feature- level fusion is the detection of correlated feature values generated by different biometric algorithms and, in the process, identifying a salient set of features that can improve recognition accuracy. Eliciting this feature set typically requires the use of dimensionality reduction methods and, therefore, feature-level fusion assumes the availability of a large number of training data. Also, the feature sets being fused are typically expected to reside in commensurate vector space in order to permit the application of a suitable matching technique upon consolidating the feature sets.

iii. *Score-level fusion*

In score-level fusion the match scores output by multiple biometric matchers are combined to generate a new match score (a scalar) that can be subsequently used by the verification or identification modules for rendering an identity decision. Fusion at this level is the most commonly discussed approach in the biometric literature primarily due to the ease of accessing and processing match scores (compared to the raw biometric data or the feature set extracted from the data). Fusion methods at this level can be broadly classified into three categories: density-based schemes [56], transformation-based schemes [58] and classifier based schemes. The fig 8.show levels of fusions.

iv. *Decision-level fusion*

Many commercial off-the-shelf (COTS) biometric matchers provide access only to the final recognition decision. When such COTS matchers are used to build a multi biometric system, only decision level fusion is feasible. Methods proposed in the literature for decision level fusion include "AND" and "OR" rules [57], majority voting weighted majority voting, Bayesian decision fusion the Dumpster-Shafer theory of evidence and behavior knowledge space [59].

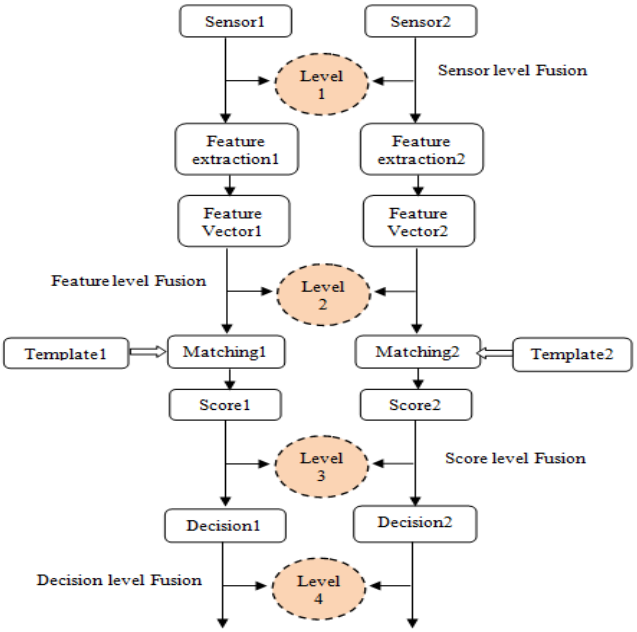

Figure 8 : Levels of fusions in biometric system

b) Fusion Methods

The fusion methods are divided into the following three categories: rule-based methods, classification based methods, and estimation-based methods. This categorization is based on the basic nature of these methods and it inherently means the classification of the problem space, such as, a problem of estimating parameters is solved by estimation-based methods. Similarly the problem of obtaining a decision based on certain observation can be solved by classification-based or rule based methods. However, if the observation is obtained from different modalities, the method would require fusion of the observation scores before estimation or making a classification decision. [59]. The figure 9 shows the Categorization of the Fusion Methods.

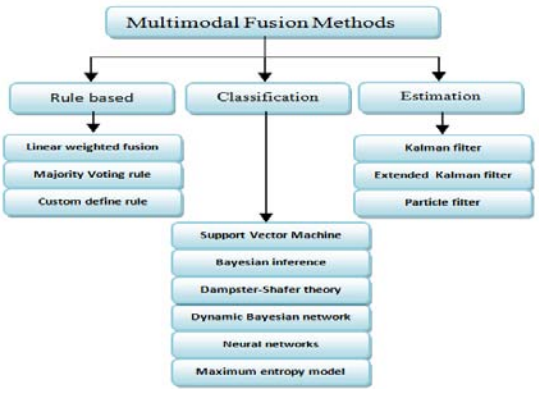

Figure 9 : Fusion Methods[59]

Table 8 : Fusion based on palm print, fingerprint and face

Ref	Biometrics modalities	Fusion level	Techniques	Notes
[30]	Face & palmprint	feature level	Weighting rules	BBNN for recognition the fusion
[33]	Face & palmprint	All levels	---------	--------
[35]	Face & palmprint	Feature level	----------	---------
[36]	Palmprint & fingerprint	Feature level	Fuzzy vault	--------

Table 9 : Some Recent Work on multimodal biometrics

Modality	Level of Fusion	Fusion Strategies	Authors
Palmprint and Face	Matching Level	Sum of Score	[40]
Fingerprint and Face	Score and Decision	Sum Rule and Likelihoods	[41]
Face, Fingerprint, and Hand Geometry	Matching Level	Sum Rule	[42]
Fingerprint and Hand-Geometry	Combination Approach	Sum, Max, Min Scores	[43]
Fingerprint, Palmprint, and Hand- Geometry	Feature Level	ANN	[44]
Face and Fingerprint	Matching Level	Sum, Min-Max, and Zscore	[44]
Face and palmprint	Feature	Feature concatenation	[45]
Fingerprint and signature	Match score	SVM in which quality measures are incorporated	[46]
Face and fingerprint	Match Score	Product rule	[47]
Face, fingerprint and voice	Match Score	Likelihood ratio	[48]
Face, fingerprint and hand geometry	Match Score	Sum rule; decision trees; linear discriminant function	[49]
Face and fingerprint	Match Score	Sum rule, Weighted sum rule	[50]
Fingerprint, hand geometry and voice	Match score	Weighted sum rule	[51]
Fingerprint and hand geometry	Match score	Reduced multivariate polynomial model	[52]
Fingerprint and voice	Match score	Functional link network	[53]

Many researches for person verification using multi biometrics with decision fusion traits are done.

Table10 : Summarized most important researches [55]

Researcher /Year	Multibiometric traits	Algorithm
Arun R., et al /2004	Information fusion in biometrics	The research used score level fusion multibiometrics system by combining three traits(face, fingerprint and hand geometry) are presented, using compare for the feature extraction in each single traits [5]
Rajiv.J, et al /2006	Multimodal Biometric using Face, Iris, palmprint and Signature Features	Multimodal biometric system of iris, palm print, face and signature based on wavelet packet analysis is adopted. The fused image is then extracted by using Inverse Discrete Wavelet Packet transform[8]
Kumar, A, et al. /2008	Fusion of Hand Based Biometrics using Particle Swarm optimization	The researchers applied palmprint and hand geometry over other biometric modalities. It implemented particle swarm based optimization technique for selecting optimal parameters through decision level fusion of two modalities: palmprint and hand geometry [42].

KarthikN.r, et al /2009	Fusion in Multibiometric Identification Systems	This research applied likelihood ratio-based score fusion and Bayesian approach for consolidating ranks and a hybrid scheme that utilizes both ranks and scores to perform fusion in identification systems[43].
Giot R., et al /2010	Fast Learning For Multibiometrics Systems Using Genetic Algorithms	This research use algorithm to learn the parameters of different multibiometrics fusion functions. It interested in biometric systems usable on any computer (they do not require specific material). In order to improve the speed of the learning, we defined a fitness function based on a fast ERR, FAR and GAR also, the search calculate the time that required to recognition the person [12].
Maya V. , et al /2013	Multimodal Biometrics at Feature Level Fusion using Texture Features	It presents a feature level fusion algorithm based on texture features. The system combines fingerprint, face and off-line signature. Texture features are extracted from Curvelet transform. The Curvelet feature dimension is selected based on d-prime number [45].

VII. Conclusions

This paper gave an overview of the fingerprint and palm print recognition . We highlighted in details the fingerprint and palm separately. We also referred to the image acquisition stage , image pre-processing stage, feature extraction stage and matching stage for recognition purpose in details. In addition to that we introduced some techniques for both modalities .Also ,we gave an elaboration about multimodal biometric system recognition and the fusion of biometric trait.

References Références Referencias

1. N. K. Ratha, K. Karu, S. Chen, and A. K. Jain," A real-time matching system for large fingerprint data bases,"IEEE Trans. Pattern Anal.Mach Intell.,vol.18, no.8.pp 779-813,Aug.1996.
2. K. Jain and L. Hong, "Online fingerprint verification," IEEE Trans. Pattern Anal. Mach Intell., vol.19, no.4. pp 302-341,Apr.1997.
3. Kumar, A., Zhang, D. 2006. Combining fingerprint, palmprint and hand-shape for user authentication. In Pattern Recognition, 2006. ICPR 2006. 18th International Conference on (Vol. 4, pp. 549-552). IEEE.
4. Zhao, F., Tang, X. 2007. Preprocessing and post processing for skeleton-based fingerprint minutiae extraction. Pattern Recognition 40 (2007) 1270 – 1281.
5. Jiao Ruili and Fan Jing,"VC5509A Based Fingerprint Identification Preprocessing System," International Conference on Signal Processing, pp. 2859 – 2863, 2008.
6. E. K. Yun and S. B. Cho, "Adaptive Fingerprint Image Enhancement with Fingerprint Image Quality Analysis," International conference of Image and Vision Computing, pp. 101–110, 2006.
7. Deshpande, A., S., Patil, S., M., Lathi, R. 2012. A Multimodel Biometric Recognition System based on Fusion of Palmprint Fingerprint and Face. International Journal of Electronics and Computer Science Engineering. ISSN-2277-1956.
8. Zhao, F., Tang, X. 2007. Preprocessing and post processing for skeleton-based finger print minutiae extraction. Pattern Recognition, 40(4), 1270-1281.
9. Jain, A. K., Prabhakar, S., Hong, L. 1999. A multichannel approach to fingerprint classification. Pattern Analysis and Machine Intelligence, IEEE Transactions on, 21(4), 348-359.
10. F. A. Afsar, M. Arif and M. Hussain, "Fingerprint Identification and Verification System using Minutiae Matching," National Conference on Emerging Technologies, pp.141-146, 2004.
11. K Zebbiche and F Khelifi "Region-Based Watermarking of Biometrics Images: Case Study in Fingerprint Images," Proceedings of International Journal of Digital Multimedia Broadcasting, pp.1-13, 2008.
12. Yi Chen and A K Jain, "Beyond Minutiae: A Fingerprint Individuality Model with Patteren, Ridge and Pore Features," International Conference on Biometrics, pp. 523-533, 2009.
13. S Tachaphetpiboont and T Amornraksa, "Applying FFT Features for Fingerprint Matching, "Proceedings of the IEEE Conference on Wireless Pervasive Computing, pp. 1-5, 2006.
14. J. You, W.K. Kong, D. Zhang, K.H. Cheung, "On hierarchical palmprint coding with multiple features for personal identification in large databases", IEEE Transactions on Circuits and Systems for Video Technology 14 (2) (2004) 234–243.
15. Gayathri, R. Ramamoorthy, P. 2012. Fingerprint and palmprint Recognition Approach based on Multiple Feature extraction. European Journal of scientific research. Vol 76, No 4.
16. Arun Ross, Anil Jain and James Reisman, "A Hybrid Fingerprint Matcher," Proceedings of International Conference on Pattern Recognition, pp .1661-1673, 2003.

17. Jong KU Kin, Seung - Hoon Chae, Sung Jin Lim and Sung Bum Pan, "A Study on the Performance Analysis of Hybrid Fingerprint Matching Methods," International Journal of Future Generation Communication and Networking, pp. 23-28, 2008.
18. Swapnali Mahadik, K Narayanan, D V Bhoir and Darshana Shah, "Access Control System using Fingerprint Recognition," International Conference on Advances in Computing, Communication and Control, pp. 306-311, 2009.
19. A K Jain, S Prabhakar and A Chen, "Combining Multiple Matchers for a High Security Fingerprint Verification System," Pattern Recognition Letters, Elsevier Science Direct, vol. 20, pp. 1371- 1379, 1999.
20. A N Marana and A K Jain, "Ridge-Based Fingerprint Matching using Hough Transform," Proceedings of the IEEE Brazilliab Symposium on Computer Graphica and Image Processing, pp.112-119, 2005.
21. W. Shu and D. Zhang, "automated personal identification by palmprint", SPIE [s0091-3286(98) 01908-4],1998.
22. Anil K. jain, Arun A. Ross, Karthik Nandakumar, "introduction to biometrics", Springer Sciences + Business Media, LLC, 233 Spring Street, New York, NY 10013, USA , July 2011.
23. David D. Zhang, "palmprint authentication", Springer science, 2004.
24. D. Zhang, W. Kong, J. You and M. Wong, "online palmprint identification", IEEE transactions on pattern analysis and machine intelligence, vol. 25, no. 9 , Sep 2003.
25. J. Gan, D. Zhou, "a novel method for palmprint recognition based on wavelet transform", IEEE icsp 2006 proceedings, 0-7803-9737-1, 2006.
26. C. Han, H. Cheng, C.Lin and K. Fan, "personal authentication using palmprint features ", PERGAMON pattern recognition 36, 371-381, 2003.
27. K. Chuang, C Liu and S. Zheng, "a region of interest segmentation algorithm for palmprint images", the 29th workshop on combinatorial mathematics and computation theory, National Chin-Yi University of Technology, Taiwan.
28. R. Wang, D. Ramos, J. Fierrez and R. P. Krish, "automatic region segmentation for high-resolution palmprint recognition: towards forensic scenarios ", ATVS- biometric recognition group, Universidad autonoma de Madrid(UAM), Spain.
29. D. Zhang and W Shu, "two novel characteristics in palmprint verification: datum point invariance and line feature matching", PERGAMON pattern recognition 32 society published by Elsevier science, 691-702, 1999.
30. Y. Fu, Z. Ma, M. Qi, J. Li, X. Li, and Y. Lu, "a novel user-specific face and palmprint feature level fusion", IEEE second international symposium on intelligent information technology application, 987-0-7695-3497-8/08, Chine 2008.
31. J. You, W. Li and D. Zhang, "hierarchical palmprint identification via multiple feature extraction", PERGAMON pattern recognition 35, 847-859, 2002.
32. X.Y. Jing and D. Zhang, " a face and palmprint recognition approach based on discriminant DCT feature extraction", IEEE transaction on system, man, and cybernetics-part B: cybernetics 34 (6) (2004) 2405 2415.
33. D. Zhang, W. Shu, Tow novel characteristics in palmprint verification: datum point invariance and line feature machine, pattern recognition 32 (4) (1999) 691-702.
34. D. Zhang, Z Guo, G. Lu, L. Zhang, and W. Zuo, "an online system of multispectral palm print verification", IEEE transaction on instrumentation and measurement, vol. 59, no. 2, Feb 2010.
35. Ahmad, M. I.; Woo, W.L.; Dlay, S.S., "Multimodal biometric fusion at feature level: Face and palmprint," Communication Systems Networks and Digital Signal Processing (CSNDSP), 2010 7th International Symposium on, vol., no., pp.801 -805, 21-23 July 2010.
36. V. E. Brindha and AM Nataajan, "multi-modal biometric template security: fingerprint and palmprint based fuzzy vault", OMICS publishing group, ISSN: 2155-6180, 2012.
37. Teddy ko, "multimodal biometric identification for large user population using fingerprint, face and iris recognition", IEEE Proceedings of the 34th Applied Imagery and Pattern Recognition Workshop (AIPR05),2005.
38. Anil K. jain, Arun A. Ross, Karthik Nandakumar, "introduction to biometrics", Springer Sciences + Business Media, LLC, 233 Spring Street, New York,NY 10013, USA , July 2011.
39. Ashish Mishra, "Multimodal biometrics it is : need for future system", International journal of computer applications (0975-8887) volume 3-No.4,june 2010.
40. Nageshkumar. M, Mahesh. PK, and M.N. ShanmukhaSwamy, "An Efficient Secure Multimodal Biometric Fusion Using Palm print and Face Image", IJCSI International Journal of Computer Science Issues, Vol. 2, 2009.
41. KalyanVeeramachaneni, Lisa Osadciw, ArunRoss, and NishaSrinivas, "Decision-level Fusion Strategies for Correlated Biometric Classifiers", Biometric Authentication, 2004 –Springer.
42. ArunRoss and RohinGovindarajanb, "Feature Level Fusion Using Hand and Face Biometrics", SPIE Conference on Biometric Technology for Human.
43. Anil Jain, Karthik Nandakumara, and Arun Ross, "Score normalization in multimodal biometric systems", Pattern Recognition 38 (2005) 2270–2285, 18 January 2005,www.elsevier.com/locate/patcog.

44. Farhat Anwar, Arafatur Rahman, and Saiful Azad, "Multibiometric Systems Based Verification Technique",European Journal of Scientific Research ISSN 1450-216X Vol.34 No.2 (2009), pp. 260-270© EuroJournals Publishing.
45. Robert Snelick, Mike Indovina, James Yen, and Alan Mink, "Multimodal Biometrics: Issues in Design and Testing", ICMI'03, November 5-7, 2003, Vancouver, British Columbia, Canada. ACM 1-58113-621-8/03/0011
46. G. Feng, K. Dong, D. Hu, and D. Zhang. When Faces are Combined with Palmprints: A Novel Biometric Fusion Strategy. In First International Conference on Biometric Authentication (ICBA), pages 701–707, Hong Kong, China, July 2004.
47. J. Fierrez-Aguilar, J. Ortega-Garcia, J. Gonzalez-Rodriguez, and J. Bigun. Discriminative Multimodal Biometric Authentication based on Quality Measures. Pattern Recognition, 38(5): 777–779, May 2005.
48. L. Hong and A. K. Jain. Integrating Faces and Fingerprints for Personal Identification. IEEE Transactions on Pattern Analysis and Machine Intelligence, 20(12): 1295–1307, December 1998.
49. K. Jain, L. Hong, and Y. Kulkarni. A Multimodal Biometric System using Fingerprint, Face and Speech. In Second International Conference on Audio and Video-based Biometric Person Authentication (AVBPA), pages 182–187,Washing-ton D.C., USA, March 1999.
50. Ross, A. K. Jain, and J. Reisman. A Hybrid Fingerprint Matcher. Pattern Recognition,36(7): 1661–1673, July 2003.
51. R. Snelick, U. Uludag, A. Mink, M. Indovina, and A. K. Jain. Large Scale Evaluation of Multimodal Biometric Authentication Using State-of-the-Art Systems. IEEE Transactions on Pattern Analysis and Machine Intelligence, 27(3): 450– 455, March 2005.
52. K.-A. Toh, X. Jiang, and W.-Y. Yau. Exploiting Global and Local Decisions for Multimodal Biometrics Verification. IEEE Transactions on Signal Processing (Supplement on Secure Media), 52(10): 3059–3072, October 2004.
53. K.-A. Toh, W. Xiong, W.-Y. Yau, and X. Jiang. Combining Fingerprint and Hand-Geometry Verification Decisions. In Fourth International Conference on Audio- and Video-based Biometric Person Authentication (AVBPA), pages 688– 696, Guildford, UK, June 2003.
54. K.-A. Toh and W.-Y. Yau. Fingerprint and Speaker Verification Decisions Fusion Using a Functional Link Network. IEEE Transactions on Systems, Man, and Cybernetics, Part A: Applications and Reviews, 35(3): 357–370, August 2005.
55. Ibrahim A. Saleh, Laheeb M. " Decision Level Fusion of Iris and Signature Biometrics for Personal Identification using Ant Colony Optimization" Alzoubiady (IJEIT) Volume 3, Issue 11, May 2014.
56. J. Kittler, M. Hatef, R.P.W. Duin, and J. Matas, "On Combining Classifiers," IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 20, no. 3, pp. 226-239, Mar. 1998.
57. G. Doddington, W. Liggett, A. Martin, M. Przybocki, and D. Reynolds, "Sheeps, Goats, Lambs and Wolves: A Statistical Analysis of Speaker Performance in the NIST 1998 Speaker Recognition Evaluation," Proc. ICSLD 98, Nov. 1998.
58. Arun Ross, Anil Jain * "Information fusion in biometrics" Pattern Recognition Letters 24 (2003) 2115–2125.
59. Dapinder and Gaganpreet ,"Level of Fusion in Multimodal Biometrics: a Review",IJARCSSE, Volume 3, Issue 2, February 2013.
60. Wilson CL, Candela GT, Grother PJ, Watson CI, Wilkinson RA ," Massively parallel neural network fingerprint classification system. National Institute of Standards and Technology; NISTIR 4880. 1992.
61. Karu K,Jain A,"Fingerprint classification".Patt Recog 29(3): 389–404, 1996.
62. Senior A ,"A hidden Markov model fingerprint classifier".Conference record of the Thirty-First Asilomar Conference on Signals, Systems & Computers 1: 306–310, 1997.
63. Hong L, Jain." Classification of fingerprint images". In: Proceedings of the 11th Scandinavian Confere nce on Image Analysis, Kangerlussuaq, Greenland, June 1999.
64. Yao Y, Frasconi P, Pontil M,Fingerprint classification with combinations of support vector machines".In: Proceedings of the 3rd International Conference on Audio and Video Based Biometric Person Authentication, Halmstad, Sweden, June 2001.
65. Chang J, Fan K," A new model for fingerprint classification by ridge distribution sequences". Patt Recog 35(6): 1209–1223, 2002.
66. Yao Y, Marcialis G, Pontil M, Frasconi P, Roli F," Combining flat and structured representations for fingerprint classification with recursive neural networks and support vector machines" .Patt Recog 36(2): 397–406, 2003.
67. Jinwei Gu," A model-based method for the computa tion of fingerprints' orientation field", IEEE Transactions on Image Processing, Volume: 13, No.6,Pages: 821 - 835, DOI: 10.1109/TIP.2003.822608, 2004.
68. JuchengYang; jinWook Shin; BungJun Min; JongBin Park; Dongsun Park," Fingerprint Matching Using Invariant Moment FingerCode and Learning Vector Quantization Neural Network", IEEE Conference Publications on Computational Intelligence and Security,Volume:1,Pages: 735 738, DOI: 10.1109/ICCIAS.2006.294231, 2006.

69. WangYuan; YaoLixiu Zhou Fuqiang A Real Time Fingerprint Recognition System Based On Novel Fingerprint Matching Strategy", 8th International Conference on Electronic Measurement and Instruments. ICEMI '07. Pages: 1-81 - 1-85, DOI: 10.1109/ICEMI.2007.4350576 , 2007.
70. Abrishambaf, R.; Demirel, Hasan; Kale, I,"A fully CNN based fingerprint recognition system",11th International Workshop on Cellular Neural Networks and Their Applications. CNNA 2008. IEEE Conference Publications, Pages: 146 - 149, DOI: 10.1109/CNNA.2008.4588667, 2008.
71. Kumar, R.; Chandra, P.; Hanmandlu, M.,"Local directional pattern (LDP) based fingerprint matching using SLFNN", IEEE Second International Conference on Image Information Processing (ICIIP),Pages: 493 - 498, DOI: 10.1109/ICIIP.2013. 6707640, 2013.
72. Akhil Vij, Anoop Namboodiri," Learning Minutiae Neighborhoods: A New Binary Representation for Matching Fingerprints", 2014 IEEE Conference on Computer Vision and Pattern Recognition Workshops ,2014.
73. Montesanto, A.; Baldassarri, P.; Vallesi, G.; Tascini, G.,"Fingerprints Recognition Using Minutiae Extraction:a Fuzzy Approach.", IEEE Conference Publications,14th International Conference on Image Analysis and Processing, ICIAP 2007, Pages: 229 - 234, DOI: 10.1109/ICIAP.2007.4362784 2007.
74. Jucheng Yang, Shanjuan Xie, Sook Yoon, Dongsun Park, Zhijun Fang, Shouyuan Yang ,"Fingerprint matching based on extreme learning machine", Neural comput & applic(2013)22:35-445,DOI 10. 1007/s00521-011-0806-0, Springer-Verlag London 2012.
75. Liu, T. Xia, H. Li, A hierarchical hough transform for fingerprint matching, in: International Conference on Biometric Authentication (ICBA), Lecture 737 Notes in Computer Science, vol. 3072, Springer, 2004, pp. 373–379.
76. N.K. Ratha, K. Karu, S. Chen, A.K. Jain, A real-time matching system for large fingerprint databases, IEEE Trans. Pattern Anal. Mach. Intell. 18 (1996) 793 799–813.
77. A.K. Jain, L. Hong, R.M. Bolle, On-line fingerprint verification, IEEE Trans. Pattern Anal. Mach. Intell. 19 (1997) 302–314.
78. E. Zhu, J. Yin, G. Zhang, Fingerprint matching based on global alignment of multiple reference minutiae, Pattern Recogn. 38 (2005) 1685–1694.
79. F. Chen, X. Huang, J. Zhou, Hierarchical minutiae matching for fingerprint and palmprint identification, IEEE Trans. Image Process. 22 (2013) 4964– 632 4971.
80. Wan, J. Zhou, Fingerprint recognition using model-based density map, IEEE Trans. Image Process. 15 (2006) 1690–1696.
81. X. Jiang, X. You, Y. Yuan, M. Gong, A method using long digital straight segments for fingerprint recognition, Neurocomputing 77 (2012) 28–35.
82. R. Kumar, B.R.D. Vikram, Fingerprint matching using multi-dimensional ann, Eng. Appl. Artif. Intell. 23 (2010) 222–228.
83. W. Sheng, G. Howells, M. Fairhurst, F. Deravi, K. Harmer, Consensus fingerprint matching with genetically optimised approach, Pattern Recogn. 42 802 (2009) 1399–1407.
84. Morteza Zahedi, Ozra Rostami Ghadi," Combining Gabor filter and FFT for fingerprint enhancement based on a regional adaption method and automatic segmentation", springer verlag london 2013,SIViP,DOI 1.