A High Speed Frequency Based Multimodal Biometric System Using Iris and Fingerprint

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***Abstract* – This paper aims at fusing two biometric features namely Iris and Fingerprint at feature level in frequency domain. A multimodal biometric system is a combination of two or more biometric features that result in greater accuracy and is more dependable way to recognise the subjects. The Iris recognition system consists of segmenting the image, localizing the circular Iris and pupil region, removal of eyelids and eyelashes. The extracted Iris is then normalized into a rectangular linearized block with constant dimensions to account for image inconsistencies. The Fingerprint image is pre-processed and extracted using a novel algorithm which is capable of detecting singular points with precision and less computational time. In this paper, we adopt a unified viewpoint to extract singular points (core and delta) that determine the topological structure and largely influence the orientation field by using the principal of Gabor basis functions. Lastly the points are classified into classes by method of Poincare index for Fingerprint classification. The proposed algorithm outperforms existing algorithms in detection accuracy and calculation speed.**

This paper uses the log Gabor filter to extract the feature vectors from both Iris and Fingerprint and then they are concatenated. Finally the phase data from 1 D log Gabor filters is extracted and quantised to four levels to encode the unique pattern of Iris and Fingerprint into bitwise biometric template. Hamming distance (HD) is used to generate a final match score. Experimental results was verified on database of 50 users accounting to FAR = 0% and FRR = 4.3%. The execution time required to match is reduced to 0.14 seconds.

Keywords* – *Iris recognition, log Gabor filters, multimodal biometric systems, singularity points

I. INTRODUCTION

In this world where it becomes one of the prior thing to safeguard the data and services some of the existing techniques like the simple username-password fails. Chances of forgetting the password or maintaining different passwords for various applications or resources are major problems faced by existing systems. Thus there is a need to develop more secure systems for authentication and recognising subjects. Biometric authentication systems are thus a better option for high level security situations.

Unimodal and multimodal biometric systems can be the two approaches that can be used in biometrics. The existing unimodal systems use a single biometric feature for recognition.

Traditionally biometric systems, operating on a single biometric feature, have many limitations, which are as follows:

1) Trouble with data sensors: Captured sensor data are often affected by noise due to the environmental conditions (insufficient light, powder, etc.) or due to user physiological and physical conditions (cold, cut fingers, etc).
2) Distinctiveness ability: Not all biometric features have the same distinctiveness degree (for example, hand geometry- based biometric systems are less selective than the Fingerprint-based ones).
3) Lack of universality: All biometric features are universal, but due to the wide variety and complexity of the human body, not everyone is endowed with the same physical features and might not contain all the biometric features, which a system might allow.

To overcome these limitations, multimodal biometric systems are developed. Multimodal biometric systems use two or more human traits to recognise and thus provide higher accuracy rate and higher protection rate from spoofing.

In multi-biometrics features can be combined at different levels like fusion at data-sensor level, fusion at the feature extraction level, fusion at the matching level, rank level, and fusion at the decision level. In this paper a feature level template fusion technique is used to combine Iris and Fingerprint biometric features.

II. Related Works

Many researchers have tried multimodal approach on various modalities.

Ratha *et al.* [13] Proposed a unimodal distortion-tolerant Fingerprint authentication technique based on graph representation. Using the Fingerprint minutiae features, a weighted graph of minutiae was constructed for both the query Fingerprint and the reference Fingerprint. The proposed algorithm had been tested with excellent results on a large private database with the use of an optical biometric sensor.

Concerning Iris recognition systems in the Gabor filter and 2-D wavelet filter were used for feature extraction. This method was invariant to translation and rotation and was tolerant to illumination. The classification rate on using the Gabor was 98.3% and the accuracy with wavelet was 82.51% on the Institute of Automation of the Chinese Academy of Sciences (CASIA) database. In the approach proposed in multichannel and Gabor filters had been used to capture local texture information of the Iris which were used to construct a fixed-length feature vector. The results obtained were FAR = 0.01% and FRR = 2.17% on CASIA database.

Generally, unimodal biometric recognition systems present different drawbacks due its dependency on the unique biometric feature. For example feature distinctiveness, feature acquisition, processing errors, and features that are temporally unavailable can all affect system accuracy. A multimodal biometric system should overcome the aforementioned limits by integrating two or more biometric features.

Conti *et al*. [14] proposed a multimodal biometric system using two different Fingerprint acquisitions. The matching module integrates fuzzy-logic methods for matching-score fusion. Experimental trials using both decision-level fusion and matching-score-level fusion were performed. Experimental results have shown an improvement of 6.7% using the matching score- level fusion rather than a monomodal authentication system.

Yang and Ma [15] used Fingerprint, palm print, and hand geometry to implement personal identity verification. Unlike other multimodal biometric systems, these three biometric features can be taken from the same image. They implemented matching score fusion at different levels to establish identity, performing a first fusion of the Fingerprint and palm-print features, and successively, a matching-score fusion between the multimodal system and the palm-geometry unimodal system. The system was tested on a database containing the features self-constructed by 98 subjects.

Besbes *et al.* [16] proposed a multimodal biometric system using Fingerprint and Iris features. They use a hybrid approach based on: 1) Fingerprint minutiae extraction and 2) Iris template encoding through a mathematical representation of the extracted Iris region. This approach was based on two recognition modalities and every part provided its own decision. The final decision was taken by considering the unimodal decision through an “AND” operator. No experimental results have been reported for recognition performance.

Aguilar *et al.* [17] proposed a multibiometric method using a combination of fast Fourier transform (FFT) and Gabor filters to enhance Fingerprint imaging. Successively, a novel stage for recognition using local features and statistical parameters was used. The proposed system uses the Fingerprints of both thumbs. Each Fingerprint was separately processed; successively, the unimodal results were compared in order to give the final fused result. The tests have been performed on a Fingerprint database composed of 50 subjects obtaining FAR = 0.2% and FRR = 1.4%.

Subbarayudu and Prasad presented experimental results of the unimodal Iris system, unimodal palm print system, and multibiometric system (Iris and palm print). The system fusion utilizes a matching score feature in which each system provides a matching score indicating the similarity of the feature vector with the template vector. The experiment was conducted on the Hong Kong Polytechnic University Palm print database. A total of 600 images are collected from 100 different subjects.

In contrast to the approaches found in literature and detailed earlier, the proposed approach introduces an innovative idea to unify and homogenize the final biometric descriptor using two different strong features—the Fingerprint and the Iris. Experimental results show the improvements introduced by adopting the fusion process at the template level as well as the related comparisons against the unimodal elements and the classical matching-score fusion-based multimodal system. The system’s performance was tested on 500 images of 50 subjects.

III. Present Work

In this paper, a multimodal biometric system, based on Fingerprint and Iris characteristics, is proposed. The proposed multimodal biometric system is composed of four main stages: the pre-processing stage, feature extraction, fusion, and matching stage. Iris and Fingerprint images are pre-processed to extract the ROIs, based on singularity regions, surrounding some meaningful points. Despite to the classic minutiae-based approach, the Fingerprint singularity-regions based approach requires a low execution time, since image analysis is based on a few points (core and delta) rather than 30–50 minutiae. The extracted ROIs are used as input for the matching stage. They are normalized, and then, processed through a frequency-based approach, in order to generate a homogeneous template. A matching algorithm is based on the HD to find the similarity degree. In what follows, each phase is briefly described.

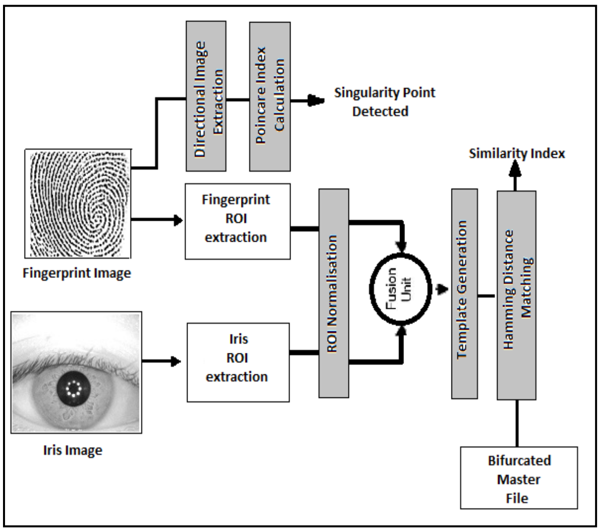

Fig. 1: The proposed system

A. Preprocessing Iris ROIS Extraction:

Iris ROI segmentation process is composed of four tasks: boundary localization, pupil segmentation, Iris segmentation, and eyelid and eyelash erosion.

a) Localization : Edge detection technique is used to determine the boundary of the Iris image which computes the parameters of the Iris and pupil neighbours. This approach aims to detect the circumference, center, and radius of the Iris and pupil region, even if the circumferences are usually not concentric. Finally, the eyelids and eyelashes form are located.

b) Segmentation of pupil : There are two major steps in segmenting the pupil. The first step is an adaptive thresholding, and the second step is a morphological opening operation. The first step is able to identify the pupil, but it cannot eliminate the presence of noise due to the acquisition phase. The step ends when the morphological opening operation reduces the pupil area to approximate the structural element. The identification algorithm is executed in two steps: the first step detects connected circular areas and almost connected circular areas, trying to get the better pair (radius, center) with respect to the previous phase. The second step, starting from a square around the coordinates of the obtained centroid, measures the maximum gradient variations along the circumferences centered in the identified points with a different radius.

c) Segmentation of Iris : Next step is segmenting the Iris. The Iris boundary is detected in two steps. Image-intensity information is a binary edge map. Successively, the set of edge Points are subjected to voting to instantiate the contour of the parametric values. The Canny algorithm is used to recover the edge-map. This operation is based on the thresholding of the magnitude of the image-intensity gradient. In order to incorporate directional tuning, image-intensity derivatives are weighted to amplify certain ranges of orientation. In order to recognize this boundary contour,

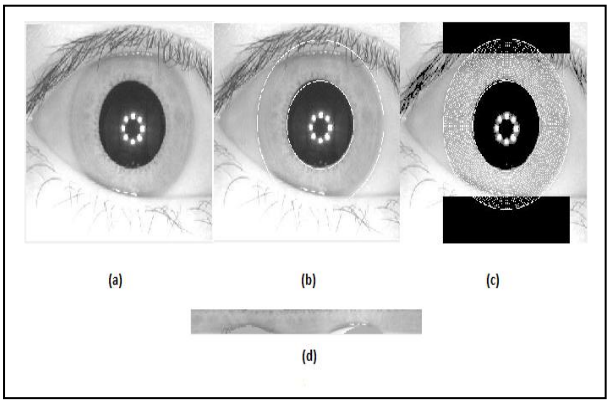

Fig. 2: various stages of Iris preprocessing
(a)Iris image, (b)localized Iris, (c)segmented Iris, (d)normalized linear Iris image

the derivatives are weighted to be selective for vertical edges. The voting procedure of Canny operator extracted points is applied to remove the disconnected points along the edge.

d) Eyelid and eyelash erosion : Eyelids and eyelashes are considered to be "noise," and therefore, are seen to degrade the system performance. Eyelashes are of two types: separable eyelashes and multiple eyelashes. The eyelashes present in our dataset belong to the separable type. The eyelids are isolated by fitting a line to the upper and lower eyelid using the linear Hough transform [7][8]. Finally, the Canny algorithm is used to create the edge map, and only the horizontal gradient information is considered.

Fingerprint:

Core Delta Detection : Singularity points detection is the most challenging and important process in biometrics Fingerprint verification and identification systems. Singular points are used for Fingerprint classification, Fingerprint matching and Fingerprint alignment.

Singularity point : Singularity points are the special points that are present in the Fingerprint. A simple Fingerprint has a number of singularity points which can be used to distinguish between various subjects. The various singularity points [9] present are called the ‘core’ and ‘delta’. Cores are the position that occurs when there is a circular region in the Fingerprint. Delta is present where three different directional lines are present (figure 3).

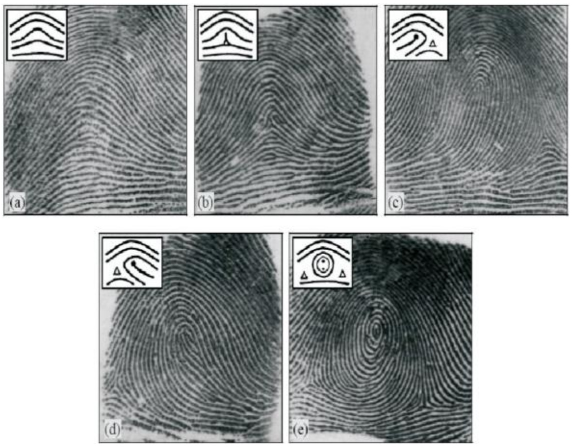

Fig. 3: (a) arch, (b) tented arch, (c) left loop, (d) right loop, (e) whorl [1]

The entire three lines move in different direction creating a triangle shaped region. There are basically many approaches for detecting the singularity points. Here we used the Poincare index approach. It assumes that the core, double core, and delta generate a Poincare index [2], [3] equal to 180°, 360°, and -180°, respectively. Fingerprint singularity region extraction is composed of three main blocks: directional image extraction [1], Poincare index calculation, and singularity-point detection.

Table I: Fingerprint pattern classes and the corresponding number and type of singular points

Pattern class	Core	Delta
Arch	0	0
Tented arch	1	1(middle)
Left loop	1	1(right)
Right loop	1	1(left)
Whorl	2	2

The directional image extraction process can further be divided into four steps:

1) G_x and G_y gradients calculation using Sobel operators [5][6];
2) D_x and D_y derivatives calculation;
3) $\theta\ (i, j)$ angle calculation of the (i, j) block [11];
4) Gaussian smoothing filter application on angle matrix.

Finally the Poincare index algorithm is used to detect the singularity points.

On the basis of the number of core and delta points detected, the Fingerprint images are classified into 5 major classes namely arch, tented arch, left loop, right loop, and whorl(see figure 3).

B. Feature Vector Generation

Normalization : Once the Iris region is successfully segmented from an eye image, the next stage is to transform the Iris region so that it has fixed dimensions in order to allow comparisons. The dimensional inconsistencies between eye images are mainly due to the stretching of the Iris caused by pupil dilation from varying levels of illumination. Other sources of inconsistency include, varying imaging distance, rotation of the camera, head tilt, and rotation of the eye within the eye socket. The normalisation process will produce Iris regions, which have the same constant dimensions, so that two photographs of the same Iris under different conditions will have characteristic features at the same spatial location.

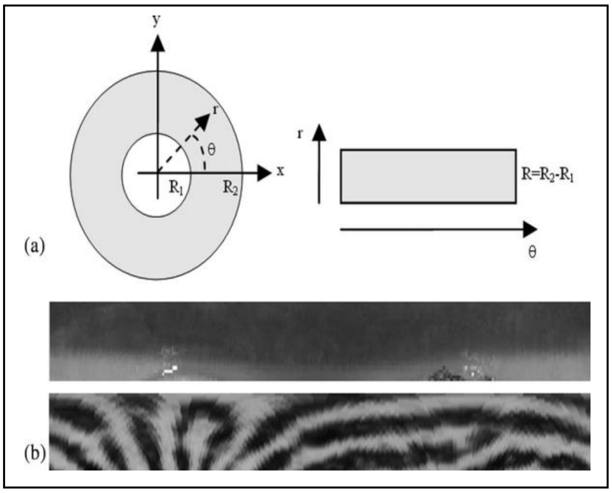

Fig 4: (a) Polar coordinate system for an Iris ROI and the corresponding linearized visualization. (b) Two examples showing the linearized Iris and Fingerprint ROI images, respectively.

The coordinate transformation process produces a 240×20 biometric pattern for each meaningful ROI: 240 is the number of the chosen radial samples (to avoid data loss in the round angle), while 20 pixels are the highest difference between Iris and pupil radius in the

Iris images, or the ROI radius in the Fingerprint images. For each Cartesian point of the ROI image is assigned a polar coordinates pair *(r, θ)*, with $r \in [R1, R2]$ and $\theta \in [0, 2\pi]$, where $R1$ is the pupil radius and $R2$ is the Iris radius. For Fingerprint ROIs, $R1 = 0$.

Since Iris eyelashes and eyelids generate some corrupted areas, a noise mask corresponding to the aforementioned corrupted areas is associated with each linearized ROI. In addition, the phase component will be meaningless in the regions where the amplitude is zero, so that these regions are also added to the noise mask.

Template generation : The homogenous biometric vector from Fingerprint and Iris data is composed of binary sequences representing the unimodal biometric templates. The resulting vector is composed of a header and a biometric pattern. The biometric pattern is composed of two sub patterns as well. The first pattern is related to the extracted Fingerprint singularity points, reporting the codified and normalized ROIs. The second pattern is related to the extracted Iris code, reporting the codified and normalized ROIs.

The template is generated by convolving each 1-D row of the 2-D binary pattern by the Gabor convolve filter. A disadvantage of the Gabor filter is that the even symmetric filter will have a DC component whenever the bandwidth is larger than one octave. However, zero DC components can be obtained for any bandwidth by using a Gabor filter which is Gaussian on a logarithmic scale, this is known as the Log-Gabor filter [4][10]. The frequency response of a Log-Gabor filter is:

$$G(f) = \exp\left(\frac{-\log^2(f/f_0)}{2\log^2(\sigma/f_0)}\right) \cdots\cdots\cdots (1)$$

where f_0 represents the centre frequency, and σ gives the bandwidth of the filter. After rigorous experiments, we finalised the values of f_0 as 0.73.

Feature encoding was implemented by convolving the normalised Iris pattern with 1D Log-Gabor wavelets. The 2D normalised pattern is broken up into a number of 1D signals, and then these 1D signals are convolved with 1D Gabor wavelets. The rows of the 2D normalised pattern are taken as the 1D signal, each row corresponds to a circular ring on the Iris region. The angular direction is taken rather than the radial one, which corresponds to columns of the normalised pattern, since maximum independence occurs in the angular direction. The intensity values at known noise areas in the normalised pattern are set to the average intensity of surrounding pixels to prevent influence of noise in the output of the filtering. The output of filtering is then phase quantised to four levels using the Daugman method [4], with each filter producing two bits of data for each phasor. The output of phase quantisation is chosen to be a grey code, so that when going from one quadrant to another, only 1 bit changes. This will minimise the number of bits disagreeing, if say two intra-class patterns are slightly misaligned and thus will provide more accurate recognition.

C. *Master File Generation*

The generated phase quantised template for each biometric feature is concatenated to get a fused template. This template is used in the matching process. All the final fused templates of various file along with the respective binary mask is stored. This mask is used while applying the matching. This file has the phase quantised vector of all the images. This master file is bifurcated on the basis of the detected singularity points. Those fused templates which has the Fingerprint for which one core is detected is stored together and in this way the master file will be a set of fused vectors grouped together on the basis of the singularity points.

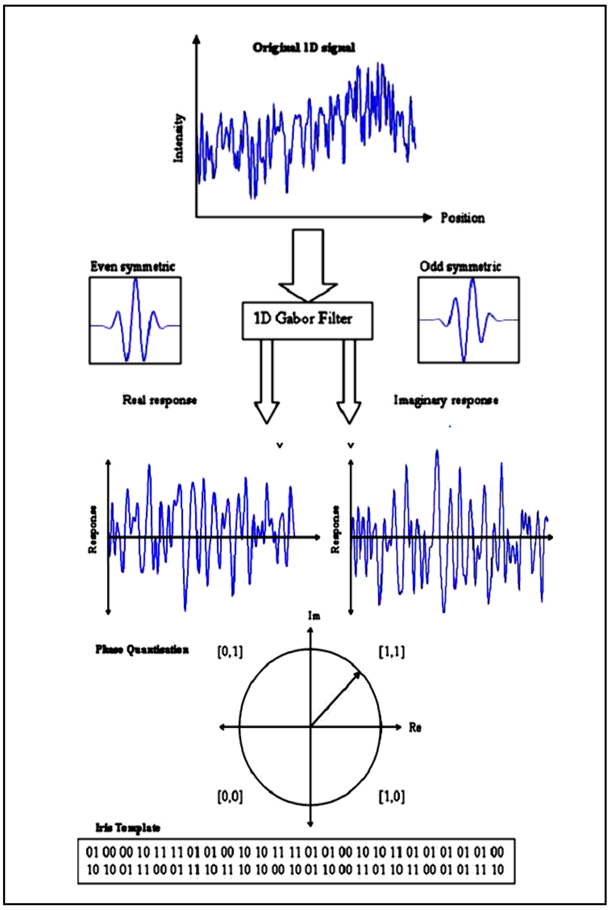

Fig. 5: An illustration of the feature encoding process.[4]

The header byte consisting the number of core and the types of classes is also stored with the corresponding template. A header byte has two bits for the number of cores, two bits for number of delta, three bits for the class of Fingerprint and one bit for Iris segmentation information.

D. *Matching*

Whenever a Fingerprint and Iris image comes in the real time for authentication, the entire process is followed and the fused template is generated. First the header is compared with the header present in the master file. If it matches then the real time generated fused template is then given as input to the hamming distance [4]. This is then compared with each feature vector in master file. If two patterns are completely independent, the HD between them should be equal to 0.5, since independence implies that the two strings of bits are completely random so that 0.5 is the ability to set every bit to 1 and vice versa.

$$HD = \frac{\left\| (codeA \otimes codeB) \cap maskA \cap maskB \right\|}{\left\| maskA \cap maskB \right\|} \cdots\cdots (2)$$

If the two patterns of the same biometric descriptor are processed, then their distance should be zero. The subject with the lowest hamming distance is considered as the subject with maximum match.

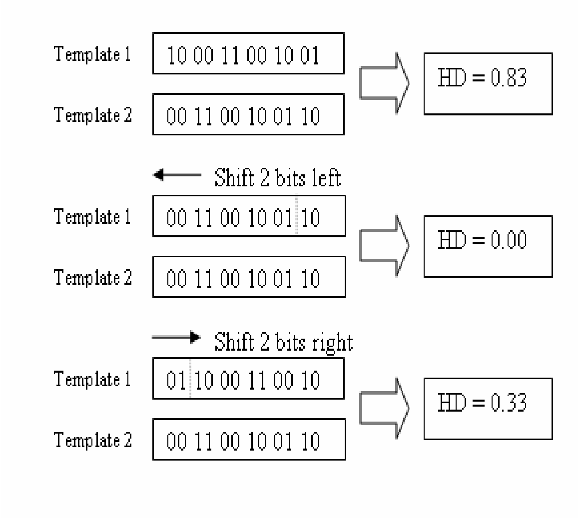

Fig. 6: An illustration of the shifting process.[4]

To avoid false results caused by the rotation problem, a template is shifted to the right and left with respect to the corresponding template [4], and for each shift operation, the new HD is then calculated. Each shift corresponds to a rotation of 2◦. The code A and code B is the final fused biometric template. They are EXORed and the result is then AND with the masks. Among all obtained values, the minimum distance is considered (corresponding to the best matching between the two templates). Due to this process of multiple matching the accuracy is increased and the FAR is reduced.

IV. Experimental Result

A. *Recognition Analysis Of Multimodal System*

To evaluate the performance of the proposed approach, several tests have been conducted considering the appropriate number of Fingerprint and Iris images. The proposed multimodal biometric authentication system achieves interesting results which are underlined here. we have obtained the results for 50 users each having 5 sample images for Iris and Fingerprint respectively. Our experimental trials confirm that the optimized threshold increases the recognition performance. The obtained

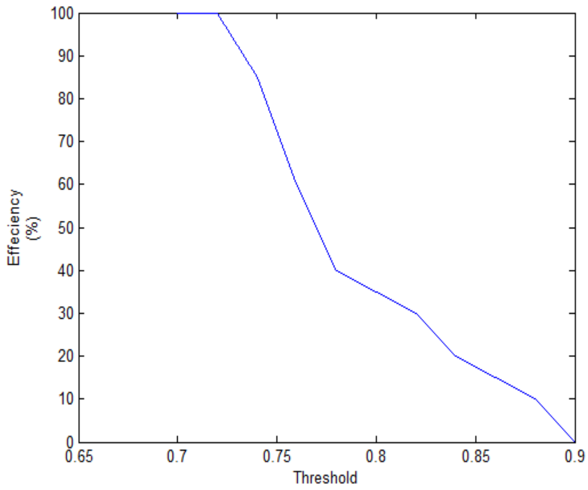

Fig. 7: FAR curve for multimodal biometric system

fusion technique carries out an enhanced system showing interesting results in terms of FAR and FRR. Gradually, the proposed fusion strategy using log Gabor filter has been applied and the results obtained has reduced execution time by half. With the proposed approach, the following results have been obtained: FAR = 0% and FRR = 4.3%.

B. *Execution Time Analysis*

The biometric multimodal systems using Iris and Fingerprint images have been implemented using the MATLAB environment on a general-purpose Intel P4 at 3.00GHz processor with 2-GB RAM memory. Table II shows the average software execution times for the preprocessing and matching tasks. The Fingerprint preprocessing time can change, since it depends either on singularity-point detection, maximum curvature point detection, the number of images accounting for different classes of Fingerprint in master file.

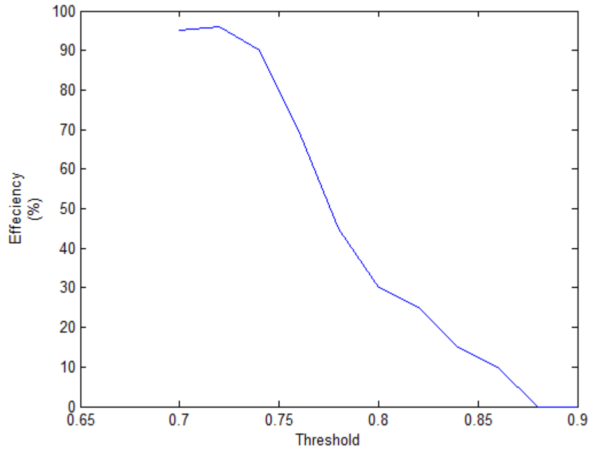

Fig. 8: FRR curve for multimodal biometric system

The blue colour indicates the execution time taken by other existing systems and the green colour indicates the execution time taken by the proposed system.

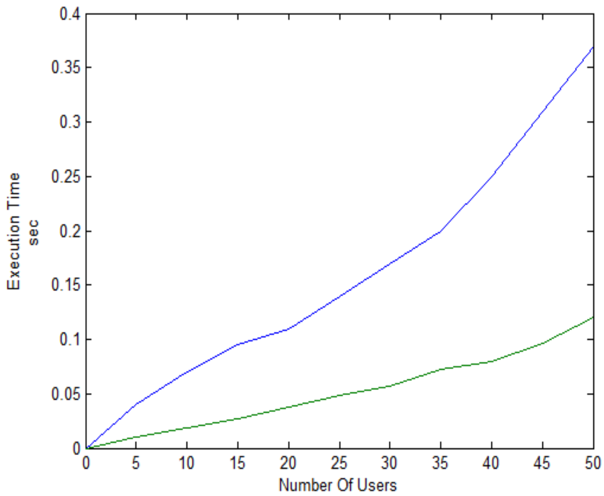

Fig. 9: comparison of software execution time for matching

Table II: software execution times for matching task

TASK	FINGERPRINT	FUSED	IRIS
PRE-PROCESSING	4.6		3.56
MATCHING PHASE		0.14	

V. Discussion

Multimodal biometric identification systems aim to fuse two or more physical or behavioural traits of information to provide optimal FAR and FRR indexes improving system dependability and accuracy of system. In contrast to the classical minutiae-based approaches, the proposed system performs Fingerprint matching using the segmented regions (ROIs) surrounding singularity points. This choice overcomes the drawbacks related to the Fingerprint minutiae information: the frequency-based approach should consider a high number of ROIs, resulting in the whole Fingerprint image coding, and consequently, in high-dimensional feature vector. Using the template level fusion technique for extracting the feature vectors and is finally stored in a master file stored according to the core-delta classification results. Along with this the Iris preprocessing aims to detect the circular region surrounding the feature, generating an Iris ROI as well. For best results, we adopted a Log-Gabor-algorithm-based codifier to encode both Fingerprint and Iris features, thus obtaining a unified template. Successively, the HD on the fused template has been used for the similarity index computation.

The improvements are described and discussed, which were introduced by adopting the fusion process at the template level as well as the related comparison against the unimodal biometric systems and the classical matching-score-fusion-based multimodal systems. In the frequency-based approach, it is very difficult to use the classical minutiae information, due to its great number. In this case, the frequency-based approach should consider a high number of ROIs, resulting in the whole Fingerprint image coding, and consequently, in high-dimensional feature vector.

For an ideal authentication system, FAR and FRR indexes are equal to 0. To increase the related security level, system parameters are then fixed in order to achieve the FAR = 0% point and a corresponding FRR point. In conclusion, we can say that when a fusion strategy is performed at the feature-extraction level, a homogeneous template is generated, so that a unified matching algorithm is used, at which time the corresponding multimodal identification system shows better results when compared to the result achieved using other fusion strategies.

VI. Conclusion

The approach used here increases the efficiency as well as the speed of the entire system. The already developed systems take a large computational time when applied on large population. This is due to the large database. This system proposes a novel way to increase the speed of the matching stage that will prove beneficial when the system is used on large population. This is done on the basis of the singularity points present in the Fingerprint. After fusing the Iris and Fingerprint the final template is stored in a group formed on the basis of the number of cores and delta.

Table III: FAR and FRR for the proposed system

Traits/Bio. Features	Approach	False Acceptance rate (FAR) (%)	False Rejection Rate (FRR) (%)
FUSION	FREQUENCY BASED	0	4.3

This means that all the templates that have one core will be stored together and the templates having two cores will be stored together. This process will decrease the FAR and the matching stage requires less time compared to other large population system. Ideally the system should be five times faster than the other systems but we have tested it to get a system that is two to three times better according to the computational cost. This change in ideal and real situation is because some singularity points can be found more often with the subjects.

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