Multimodal Biometric system Fusion using Fingerprint and Iris with Fuzzy Logic

Mohamad Abdolahi, Majid Mohamadi, Mehdi Jafari

Abstract* — Single biometric systems have a variety of problems such as noisy data, non-universality, spoof attacks and unacceptable error rate. These limitations can be solved by deploying multimodal biometric systems. Multimodal biometric systems utilize two or more individual modalities, like face, iris, retina and fingerprint. Multimodal biometric systems improve the recognition accuracy more than uni-modal methods. In this paper, two uni-modal biometrics, iris and fingerprint are used as multi-biometrics and show using this biometrics has good result with high accuracy. Decision level is used for fusion and each biometric result is weighted for participate in final decision. Fuzzy logic is used for the effect of each biometric result combination.

***Index Terms*— fingerprint recognition, Iris recognition, , minutiae extraction, multi-biometric.**

I. INTRODUCTION

Single biometric systems have limitations like uniqueness, high spoofing rate, high error rate, non-universality and noise. For example in face recognition, it is affected by position, sadness, happiness and the amount of ambient light. It has been recently clear for most researchers that approximately two percent of the population does not have a legible fingerprint and therefore cannot be enrolled into a fingerprint biometrics system [1]. Today, using multiple biometrics is recommended for overcoming these limitations. Using multiple biometric indicators for identifying individuals, known as multimodal biometrics, has been shown to increase accuracy [2] and population coverage, while decreasing vulnerability to spoofing. The important part in multimodal biometrics is the fusion level of various biometric modalities. Four levels are proposed including sensor level, feature extraction, matching score, or decision levels [3]. In this research, decision level fusion is used. This approach has the advantage of utilizing as much information as possible from each biometric modality. Two modalities are used in these researches which are fingerprint and iris. In first sections a brief review for fingerprint and iris acquiring code is provided, and then the combination method of thestwo modalities and fusion method are introduced.

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II. RELATED WORKS

A number of studies have been done on multimodal biometrics and these works show that multi- biometric has more advantage than single- biometric. Brunelli and Falavigna [4] used hyperbolic tangent (tanh) for normalization and weighted geometric average for fusion of voice and face biometrics. Hong and Jain [6] proposed an identification system based on face and fingerprint, where fingerprint matching is applied after pruning the database via face matching. Kittler et al. [5] have experimented with several fusion techniques for face and voice biometrics. Ben-Yacoub et al [7] considered several fusion strategies, such as support vector machines, tree classifiers and multi-layer perceptron, for face and voice biometrics. The Bayes classifier is also used in many methods. Ross and Jain [8] combined face, fingerprint and hand geometry biometrics with sum, decision tree and linear discriminant-based methods. The authors report that sum rule outperforms others. Shubhangi and Manohar Bali proposed multimodal biometric system using face and fingerprint and combining ridge based matching for fingerprint and Eigen face [17].

III. FINGERPRINT RECOGNITION

A fingerprint is the feature pattern of one finger and it is believed that each fingerprint is unique. Each person has his own fingerprints with the permanent uniqueness. So fingerprints have being used for identification and recognition. A fingerprint is composed of ridges and furrows which are parallel and have same width.

Fig. 1. A fingerprint image acquired by an Optical Sensor

However, in fingerprint recognition, fingerprints are not distinguished by their ridges and furrows; they are distinguished by Minutia, which are features on the ridges. There is variety of minutia types on fingerprint image as in the below figure but two are mostly significant and in heavy usage: one is called termination, which is the immediate ending of a ridge and the other is called bifurcation, which is the point on the ridge from which two branches derive.

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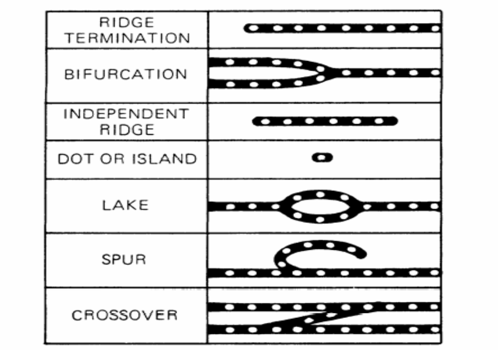
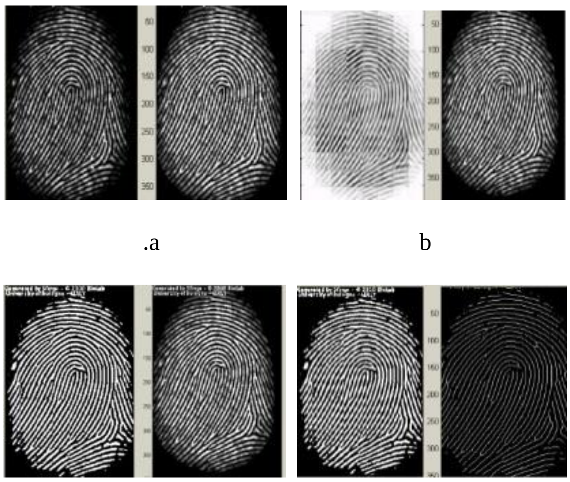


Fig. 2. Variety of minutia types on fingerprint image

Fingerprint identification system has three part that are image acquiring part, minutia extraction part and matching part. In image acquiring part, optical sensors are used. The main part is minutia extraction and this part has three sections: pre-processing, minutia extraction and post processing. Pre-processing section tries to enhance image quality with histogram enhancement and Fourier transformation and then convert the enhanced image to binary image and then ridges on fingerprint are making thin. Now fingerprint image is ready for minutia extraction.



.a b

.c d

Fig. 3. : Enhanced image with histogram (.a), Enhanced image with Fourier (b), Binary image (.c), thinning image (d)

The simple algorithm for minutia extraction is: if a pixel with 1 value has one neighbor with 1 value in its 8 neighbors, it is terminate and if it has three neighbors with 1 value it is bifurcation. Figure blow shows all operations:

0	1	0
0	1	0
1	0	1

0	0	0
0	1	0
0	0	1

Fig. 4. (a) Bifurcation (b) terminate

IV. FINGERPRINT METHOD IN THIS RESEARCH

In most identification methods both bifurcations and terminates are considered the same and they are stored as one features. So in these systems each minutia is determined, identified and stored with three parameters X, Y and its tangent angle. In these methods because of storing two decimal number X and Y and since a floating number for tangent have big database and also one pixel coordinate for each minutia is stored, acquiring numbers are changed and in comparing part, the result is changed with the change in minutia position due to rotating in our shifting finger. Usually in the previous methods for Pixel spatial problem, spatial pixel to a threshold is accepted so that this method reduces the accuracy of the system.

In this research, another method is used and solves the problem via simplest code and hence accuracy result is achieved. With using the proposed method, two 64 bits code is acquired, one for terminates and the other for bifurcations and by fusion them, a 128 bits unique code will be achieved.

In identification phase after obtaining 128 bits code from new fingerprint image, and comparing it against hamming distance with codes in database and finding the code with minimum difference, it is accepted consequently and saves the difference number for one input in our fuzzy logic engine.

V. IRIS RECOGNITION

Iris is a circular diaphragm which is located between cornea and lens of the human eye. The function of iris is to control the amount of light entering through the pupil. The average diameter of iris is 12 mm and pupil size can be 10% to 80% of the iris diameter. The iris consists of a number of layers; the lowest layer is the epithelium layer which contains dense color cells and determines the color of iris. Stromal layer consists of blood vessels and the external visible surface is a multi-layered iris that consists of two zones and each zone often differs in color. These two zones are divided by the collarets which make a zigzag pattern. The iris formation happens in the third month of embryonic life and unique patterns are formed during the first year of life. These patterns are random and do not depend on genetic factor and the only characteristic that is dependent on genetics is the pigmentation. Image processing techniques can be employed to convert iris pattern to unique code which can be stored in a database and allows comparisons between templates. The overall process for acquiring and storing iris features with iris images can be listed as follow:

1. Image acquisition: take photo of iris with good resolution and quality.
2. Segmentation: process the acquiring image for separation of iris from eye image.
3. Normalization,
4. Feature extraction and feature encoding,
5. Storing extracted codes in database and comparing acquiring iris images with codes in database.

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But in this research, another way is used for segmentation and extraction of iris region. In most previous methods iris edges are found with common edge detection algorithms, but here this algorithm is used:

Taking iris photo an important part in iris recognition and in most images tried to take images with maximum iris region with max opened eyes and no Latency lid on the iris. With using these iris images (CASIA standard database) a rectangle tangent is created to the periphery of the iris surrounding, remove out of rectangle, find an image with maximum part iris and an important advantage with iris in center of image.

With having this kind of image first the image size and center pixel can be found with dividing row and column to two and marked this pixel. Certainly the pixel is in the pupil region and its clear pupil is the darker part in eye, so it can move right to the pixel with a high amount of difference intensity and mark it, move left to the pixel with a high amount of difference intensity and mark it and find the center of these points. Do the same and find top and bottom and center of them. Now with these center and peripheral acquired points we can find the real pupil center with center point and maximum distance drawing a pupil circle performing the same task to find the iris region and extract iris from eye image. With Gabor filter features and iris code can be extracted.

After comparing extracted code of a new iris image with codes in database and hamming distance algorithm, the code with minimum difference can be found which can be accepted consequently and save the difference number for an input in our fuzzy logic engine.

VI. MULTI-BIOMETRIC

It is clear that some people have poor quality fingerprints, their face image depends on lighting, their voice can get hoarse due to cold, and also original image of iris projected on a lens can make different biometric authentication systems. All these disadvantages can be overcome with multi-biometric systems which combine the results of two or more biometric characteristics independent from each other. Uni-modal biometric systems perform identification based on single source of biometric information. These systems are affected by many problems like noisy sensor data, non-universality, lack of individuality, lack of invariant representation and susceptibility to circumvention. Because of these problems, the uni-modal biometric systems error rate is quite high which makes them unacceptable for security applications. Some of these problems can be alleviated by using two or more uni-modal biometrics as multi-biometric systems. The architecture of a multi-biometric system depends on the sequence through which each biometrics are acquired and processed. Typically these architectures are either serial or parallel. In the serial architecture, the result of one modality affects the processing of the subsequent modality. In parallel design, different modalities operate independently and their results are combined with appropriate fusion method. The proposed design in this paper is parallel design. There are several paper on different multi-biometric. S.Vasuhi & V. Vaidehi introduce a multimodal biometric system using two well-known biometrics fingerprint and voice [15]. They show using these two single- biometrics together as multi-biometric provides better result. Nageshkumar, M. Mahesh have worked on Palm print and face as multi-biometric [16]. Multi-biometric systems use five different methods for solving single biometric disadvantages:

Multi-sensor: using two or more sensors for obtaining data from one biometric. (Fingerprint image with two optical and alter sound sensors).

Multi-presentation: several sensors capturing several similar body parts. (Multi fingerprint image from multi finger of one person).

Multi-instance: the same sensor capturing several instances of the same body part. (Different position face image).

Multi- algorithm: the same sensor is used but its input is processed by different algorithm and compares the results.

Multi-modal: using different sensors for different biometrics and fusion the results. (Like fusion iris and fingerprint code as multi-biometric).

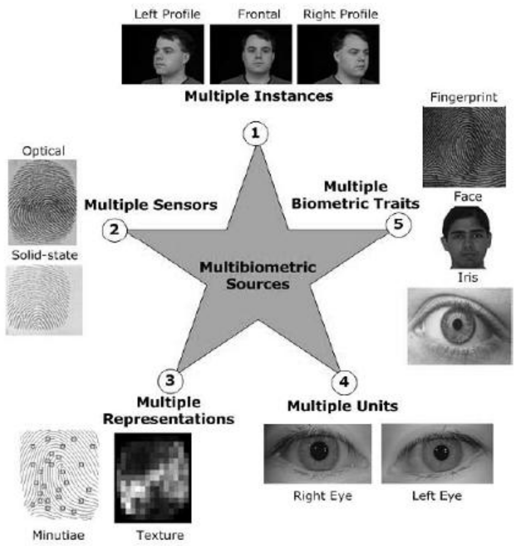

Fig. 5. Five different methods for solving single biometric disadvantages

The majority of works done on multi-biometric systems focus on methods that can fusion the single biometric results. For combining two or more uni-modal biometrics and making a multi-biometric system, two or more acceptance results must be combined as fusion. Four possible levels of fusion methods are used for integrating data from two are more biometric systems [9]. These are sensor level, feature extraction level, matching score level and decision level. Sensor level and feature extraction level are called pre-mapping **fusion** levels but matching score level and decision level are called post-mapping fusion levels.

A. Fusion at the sensor level

In this level raw data is acquired from sensing the same biometric characteristic with two or more sensors. Sensor level fusion can be done only if the multiple cues of the same biometric are obtained from multiple compatible sensors or multiple instances of the same biometric obtained using single sensor. An example is sensing a speech signal with two sensors. Another example, the face images obtained from several cameras can be combined to form a 3D

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model of the face. In sensor level fusion, the multiple cues must be compatible.

B. Fusion at the feature extraction level

Fusion at this level can be applied to the extraction of different features from the same modality or different multimodalities. Feature extraction level refers to combining different feature vectors that are obtained from multiple sensors for the same biometric trait or multiple biometric traits. When feature vectors are homogeneous, a single feature vector can be calculated with "and", "or", "xor" or other operations. When the feature vectors are non-homogeneous, we can concatenate them to form a single vector [11] [12].

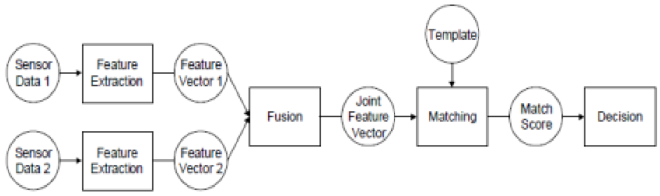

Fig. 6. Fusion at the feature extraction level

C. Fusion at matching score level

At this fusion method there are two approaches for consolidating the scores obtained from different matchers. One of them is to formulate it as a classification problem and the other is as a combination problem. In classification method, a feature vector is constructed by using matching scores output of individual matcher and then classified into two classes: "Accept" and "Reject". In combination method, each individual matching score are used to combine for generating a single scalar score for making the final decision.

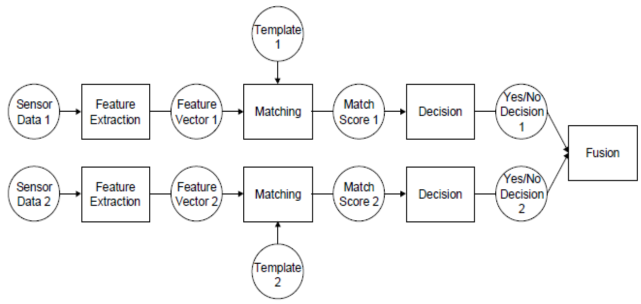

Fig. 7. Fusion at matching score level

D. Fusion at decision level

Integration of information at this level can take place when each biometric matcher individually decides on the best match. Methods like majority voting [13] and weighted voting [14] can be used at the final decision. In this approach, we use decision level fusion. At this kind of fusion, a separate decision is taken for each biometric type and then with weighting for each type result, final decision is accepted for final result. Thus, fusion at this level is the least powerful result [10].

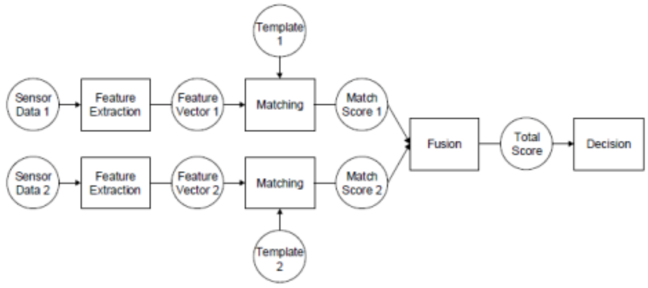

Fig. 8. Levels of fusion; FU: fusion module, MM: matching module, DM: decision module.

VII. MULTI-BIOMETRIC METHOD USING IN THIS PAPER

This paper presents a novel fusion strategy for personal identification using fingerprint and iris at the decision level fusion scheme. It is also shown that integration of fingerprint and iris biometrics can achieve higher performance than using each single biometric alone. A fuzzy logic method is used for fusion which is given better performance and accuracy. Hamming distance and fuzzy logic are used for comparing and deciding to verification.

A. Fuzzy logic (FL)

Fuzzy logic is a kind of soft computing, which mimics human decision making. In this paper, fuzzy logic decision fusion is used and gives reasonable results. The general block diagram for FL is shown in figure 7. Fuzzification is the process of each input convert to linguistic variable. One or more membership function with a degree of membership function is obtained from linguistic variables. The degrees of membership function based on predefined rules and rule weights are combined and the output is produced. Each rule can be given a weight to show the influence of the particular rule on the output.

Fig. 9. Fuzzy logic block diagram

B. Using fuzzy logic

In this paper, fuzzy logic is used for fusion at decision level. The fuzzy engine has two inputs, one of them named fig and the other iris. Fig considered as fingerprint results in identification and iris considered as iris result identification. The figure below shows them:

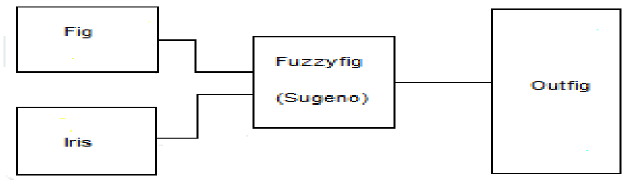

Fig. 10. Membership function

In the previous fusion methods, each single biometrics has same weight, but some biometrics have more features and more stability. It is better that biometric with more features will have more chance to participate. Iris has more features than fingerprint and also more stability. It is also more resistant against cheating and copying. So in this paper, iris has more weight in fusion with fingerprint and this is one of the reasons that we get better results.

C. Fusion by Fuzzy Logic Decision

Fuzzy logic enables us to process iambuses information in a way like human thinking, i.e. big versus small or high versus low. It makes intermediate values to be defined between true and false by partial set memberships. As an initial step, we consider fuzzy variables and fuzzy sets in a fuzzy inference system for iris and fingerprint images.
Using fuzzy logic for fusion at decision level has many advantages like soft inputs while the crisp outputs are achieved. Fuzzy system used in this paper with simplest way gives an excellent result. This system gives an acceptable percentage output for every acceptable range of inputs for which using a threshold for the best states are accepted.

D. Fuzzy Inference System

The fuzzy inference system adjusts the weighting for each biometric as affected by the differences between hamming code. There are two input fuzzy variables, one for fingerprint (fig) and one for iris (iris).). Each input variable has a fuzzy set that defines each variable. As seen in figure 12 trapezoidal membership function is used.
There is one output fuzzy variables (outfig), which corresponds to the weightings for iris and fingerprint verification.
This MF accept %100 input number 0 to 3 and input number 15 with %0. This means that input fingerprint with 3 bits difference accepted with %100 and fingerprint with 15 bits difference accepted %0 and normalize numbers 3 to 15 with %100 to %0. For example, fingerprint with 5 bit difference is accepted by %84 and with 10 bit difference by %44. Now we normalize these acceptation rates (%0 … %100) to (%0 … %20). This is because of weighting fingerprint code as 20. Triangular membership function is used for input.

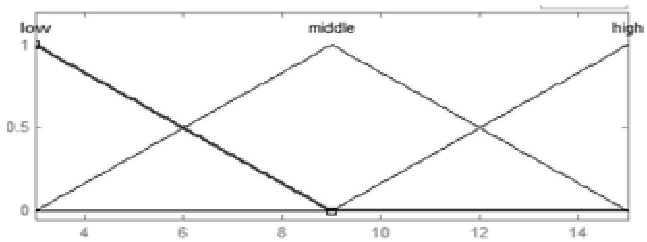

Fig. 11. Triangular membership function for fingerprint code

E. Fuzzy Rules

The conditions that comprise the fuzzy logic are formulated by two groups of fuzzy IF-THEN rules. One group controls the output variable finger (weighting for the fingerprint biometric) according to values of the input variables. The other group controls the output variable iris (weighting of iris biometric) according to the values of the input variables.
We could find the experimental numbers (3) for high level and (15) for low level acceptation. These numbers are the differences between acquired code and the code in database with hamming distance. Number (3) means that fingerprint code has three bits differences with the code in database and Number (15) means code with 15 bits differences. Numbers 0 to 3 are accepted as real and numbers 15 and up is not acceptable fingerprint code. Now normalize these acceptation rates(%0 … %100) to (%0 … %20). This is because of weighting fingerprint code as 20.
The other MF used for iris accepts % 100 input numbers 0 to 40 and input number 400 with %0. This means that input iris to 40 bits difference is accepted with %100 and iris with 400 bits difference is accepted %0 and normalizes numbers 40 to 400 with %100 to %0. Now normalize these acceptation rates (%0 … %100) to (%0 … %80). This is because of weighting iris code as 80. Triangular membership function and sugeno fazzification are used in this fuzzy system.

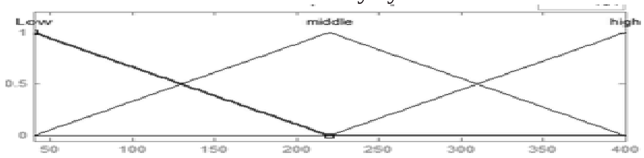

Fig. 12. Triangular membership function for iris code

The main properties in the fuzzy rules are:

If (fig is low) and (iris is low) then (OR is Very Low)
If (fig is low) and (iris is middle) then (OR is middle)
If (fig is low) and (iris is high) then (OR is Very Good)
If (fig is middle) and (iris is low) then (OR is Low)
If (fig is middle) and (iris is middle) then (OR is Good)
If (fig is middle) and (iris is high) then (OR is Very Good)
If (fig is high) and (iris is low) then (OR is Middle)
If (fig is high) and (iris is middle) then (OR is Very Good)
If (fig is high) and (iris is high) then (OR is Excellent)

It is also the same for iris code and the experimental numbers we found (40) for high level and (400) for low level acceptation. These numbers are the differences between acquired code and the code in database with hamming distance.
Number (40) means iris code has forty bits differences with the code in database and Number (400) means code with 400 bits differences. Numbers 0 to 40 are accepted as real and number 400 and up is not acceptable iris code.

VIII. EXPERIMENTAL RESULTS

In this section, Single biometric fingerprint is used and find results that is shown in table1. Then iris recognition is used and the result is obtained. Now if multi- biometric is used with fusion fingerprint and iris, better result is accepted.
Table 1 shows differences between two single-biometrics and multi- biometric. In the fingerprint part after converting fingerprint image to binary code, we can compare it with the codes in database with hamming distance and select the code in database with minimum difference. In iris part also do the same and choose the code in database with minimum difference. Fuzzy logic is used for final decision.

Table 1. difference between uni-modal and multi-modal results

Trait	FAR	FRR	Accuracy
Fingerprint	%3.5	%4	%96
Iris	%5	%5	%97.5
Fingerprint & Iris	%2	%2	%98.3

In experimental results, the fuzzy inference system gives an output and accepts the main output. If we have two inputs, 1 for fingerprint and 5 for iris, system gives accuracy %99.4.

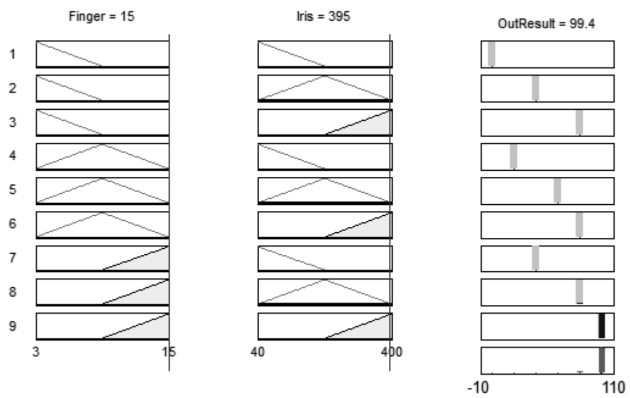

Fig. 13. Rule view of finger=1 and iris=5 and output=99.4%

Fingerprint and iris are two parts of body that have permanent features and do not depend on genetic factors. They are even having different features in twins. It is quite remarkable that even iris features in one person are different. Fingerprint is also different in twins and one's fingers. So if we use these two permanent biometric as multi-biometric certainly, we will have better results. There are some methods that fusion iris with other biometrics like face, retina, voice , … and also fingerprint with other biometrics, but fusion iris and fingerprint are more reliable. Table 2 considers and compares two other multi- biometric systems and shows that with fusion two single biometrics iris and fingerprint could give better result.

Table 2. difference between multi-modals results

Trait	Accuracy
Face& Iris	%96.2
FingerPrint&Face	%97.7
FingerPrint&Iris	%98.3

IX. CONCLUSION

Nowadays, biometric systems are widely used for authentication, but the uni-modal biometric system has some problem like noisy sensor data, non- universality, lack of individuality, lack of invariant representation and susceptibility to circumvention. So for overcoming these disadvantages, multi-modal biometric system are used. In this paper, a multi- modal biometric system (Fingerprint & Iris) is used after converting fingerprint and iris image to a binary code, with decision level fusion combining the results. Fingerprint code is weighed as 20% and iris code as 80%. Using fingerprint and iris as multi-modal gives better result than other modalities. Using fuzzy logic and weighted code gives flexible result. An efficient method in fingerprint encoding is used and the fuzzy logic framework incorporates iris and fingerprint code and achieves an additional improvement of 1.7%.

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