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A description of multimodal biometric system using Iris and fingerprint traits

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***Abstract*— Multibiometric systems imitate the unification of two or more unimodal biometric systems. Such systems are predicted to be more sound due to the residence of multiple independent pieces of evidence. Hence they sign in at unparalleled levels of security. In this paper, multimodal biometrics which is a combination of iris and fingerprint is presented. Comparing to other biometrics, iris recognition is having low false acceptance rate. Various fusion techniques of iris and fingerprint with advantages and limitations are discussed**
Key words: Unimodal Biometrics, Multimodal Biometrics, Iris Recognition, Finger Print Recognition.

I. INTRODUCTION

Human verification was carried out using password or ID cards but they can be easily forgotten, guessed or stolen. Biometric refers to identification of individual by using physical or behavioral characteristics. Biometrics is an emerging technology for personal identification. These cannot be misplaced, guessed, forgotten, or forged. But biometrics used in real world is unimodal. The unimodal biometric rely on single source of information. The unimodal biometrics faces variety of problems such as noisy data, intra class variation, non-universality and spoofing. Face recognition is affected by position, happiness, sadness, amount of light. In finger print recognition, 2% of population does not have legible finger prints and therefore cannot be enrolled in to biometric recognition system. If the biometric sensed is noisy like a scar on finger print or iris is shaded with eyelids, the resultant matching score is not reliable. Each biometric technique has strength and weakness. The disadvantage with one biometric is physical characteristics of a person may not be always available. These problems tend to increase false accept rate (FAR) and false rejection rate (FRR). Some of the limitations can be overcome by including multiple source of information**.**

Multimodal biometric refers to combination of two or more biometric traits. The main aim of multimodal biometric is to reduce the error as low as possible and to improve recognition rate. Multiple biometric are difficult to spoof [1] False acceptance rate in finger print is 1 in 100,000. Pregnant and other medication may affect hand geometry. Voice can be easily mimicked by people who are expert in mimicking. DNA loses accuracy because it does not make out differentiation between monozygotic twins [2-5].Some of the multimodal applications are Biometric door lock security systems are used at those places where you have important information and stuffs. In such places multi biometric electronic door lock security systems that are based on finger print and iris recognition may be used for security purpose.

Biometric system operates in two modes namely enrollment and identification. All users' biometric features and other useful information is stored in data base in the form of a template with user identity in enrollment mode. In authentication mode, once again biometric data is captured and compared with templates corresponding to claimed identity

Biometric modalities are captured at sensor module and given as input to feature extraction module. Features are extracted after preprocessing from different modalities and then further given as input to matching module for comparison. Extracted features are compared with templates which are stored in the database in matching module and further it is processed in decision module. In decision module it is accepted or rejected [3].Multimodal biometric system can operate in three modes namely Serial, Parallel and Hierarchical modes.

A. Serial mode

Processing of different inputs in sequence, multiple traits need not be acquired simultaneously. Decision can be done before acquiring all traits and this reduces recognition time. eg. Bank ATMS

B. Parallel mode

Information about multiple modal are used simultaneously to perform recognition.eg. Military

C. Hierarchical mode

Individual classifiers are into tree like structure Fig1 and Fig 2 shows serial and parallel modes of multimodal biometrics [6-8].

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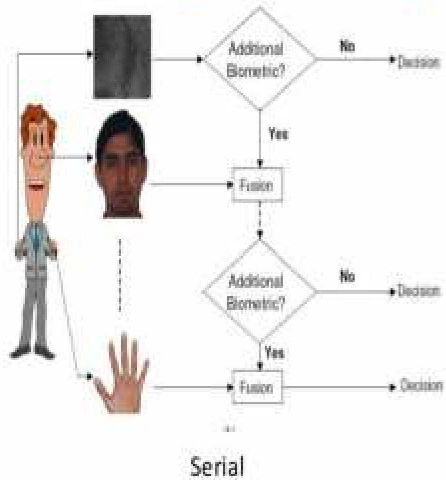

Fig 1- Serial Mode

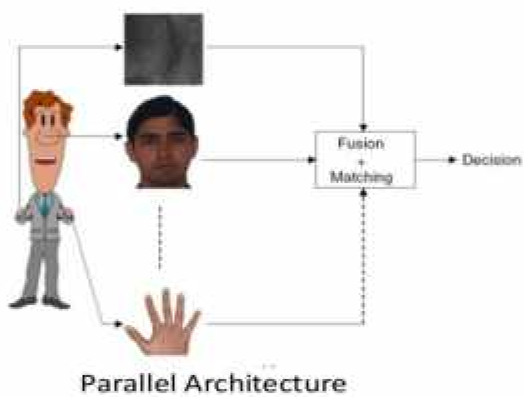

Fig 2- Parallel Mode

In this paper, Section 2 provides explanation of iris recognition which includes image acquisition, image localization, normalization, unwrapping encoding and matching. Explanation of fingerprint recognition which includes image acquisition, binarization, thinning, and minutiae extraction is presented in Section 3. The sections 4 and 5 describe various fusion techniques, and databases.

II. IRIS RECOGNITION

Personal identification using iris is non-invasive technique and it is considered to be reliable among all biometric methods. It is also considered that the probability of finding two people with identical iris is almost zero and even left eye and right eye of person are not identical. False acceptance rate of iris is 1 in 1.2 million. Many biometrics are having 16 to 20 distinct characteristics whereas iris is having 266 unique spots. The feature of iris remains stable for one year of age throughout life. The colored part of the eye is iris. The iris is a protected internal organ of the eye. It is the only internal organ which is externally visible. The function of iris is to control the amount of light entering through the pupil. The iris formation begins during the 3rd month of life [9-10].Iris Recognition Process consists of various steps such as 1.Image acquisition 2.Image localization 3.Normalization 4..Unwrapping 5.Encoding 6 Matching. Iris recognition process is shown in the followingfigure [11-12].

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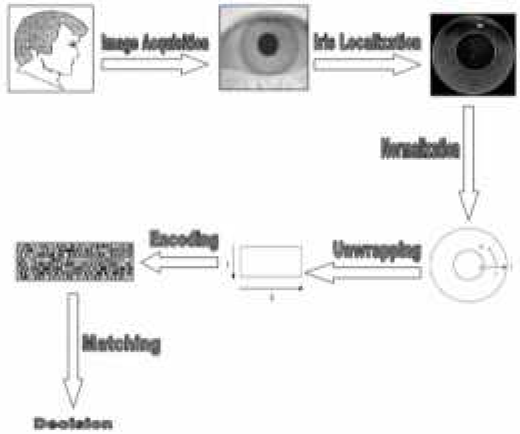

Fig 3- Iris Recognition Process

A. Image Acquisition

The major challenge of automated iris recognition is to capture a high-quality image. Noisy free images minimize chances of misidentifications. The Daugman system captures iris images of diameter between 100 and 200 pixels from a distance of 15-46 cm using 330mm lens. The operator should self-position in front of the camera. The system is provided with live video feed back using a miniature liquid crystal display placed in line with the cameras optics via a beam splitter. This helps the operator to see what are the images captured and accordingly the position is adjusted. In this process images are continually captured. From these images sufficient quality image is selected and forwarded to further processing [11-12].

B. Image Localization

An image acquired not only contains the region of interest but also some unuseful parts like eyelid, pupil etc. Because of non-uniform illumination brightness is not uniformly distributed. Before the image is used for recognition it should be preprocessed first. Different approaches have been proposed to detect iris boundaries. In 1993, John Daugman proposed integro- differential operator on raw image to isolate iris.[13-14]

C. Normalization

In order to allow comparison between irises, extracted iris should be transformed into fixed dimensions. Removing dimensional inconsistencies caused due to stretching of the iris caused by pupil dilation . Normalization process will produce irises with fixed dimensions so that two photographs for the same iris taken under different lighting conditions will have same characteristics. Rubber sheet model devised by Daugman remaps each point within the iris region to a pair of polar coordinates where the radius r is in the interval [0,1] and the angle is in the interval [0,2π]. Then normalized image is unwrapped into a rectangular region. Daugman Rubber sheet model takes into account the pupil dilation, imaging distance, and non-concentric pupil displacement and it does not consider rotational inconsistencies. This problem is discussed in matching process by shifting the iris templates. Fig 4 shows Daugman rubber sheet model for normalization

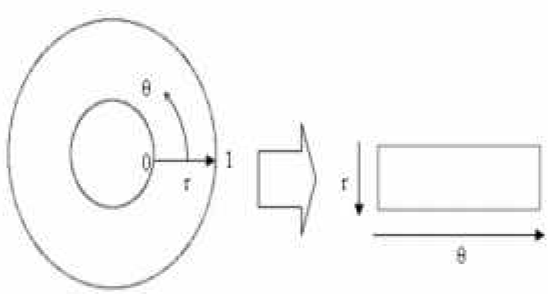

Fig 4- Daugman Rubber sheet model

D. Feature Extraction

It is a key process. Size of normalized image is 64x512and the image is divided into basic cell regions. Each cell region has 64x32 pixel size. A standard deviation of pixels value is used as representative value of a basic cell region for calculation. If pixel value is greater than threshold make it 1. Else make it 0. By following above procedure 16 bit binary value is obtained and this iris code can be used for verification.

E. Matching Algorithm

Hamming distance method was introduced by Daugman can be used as matching algorithm.. It represents number of bits that are different in two patterns. Hamming distance is defined as

$$HD = \frac{1}{N}\sum_{j=1}^{N} X_j (XOR) Y_j$$

Where x and y are two bits to be compared and N is total number of bits which constitutes iris code. Exclusive OR operation gives value 1 if bit pattern of X is different from bit pattern of Y. The process is repeated for all bit patterns. The resulting bit patterns are accumulated and divided by N. By using the above formula HD value is computed and if its value is closer to 1 then two patterns are different. If HD value is closer to 0 then two patterns are identical. Threshold value should be properly chosen to make matching decision [15].

III. FINGER PRINT RECOGNITION

A finger print is a feature pattern of one finger. Each person finger prints are unique and permanent. It consists of ridges and furrows or valleys. The dark areas of fingerprint are ridges and white area is valleys. Because of low cost, accuracy, uniqueness made fingerprint recognition most popular. Finger print recognition can be done using minutiae based, ridge based, correlation based and gradient based. In this paper, minutiae based method is presented. Minutiae points are local ridge characteristics that occur either at a ridge ending or a ridge bifurcation [16-18]. Fig 5 and Fig 6 shows finger print image and different minutiae points.

Fig 5- Finger Print

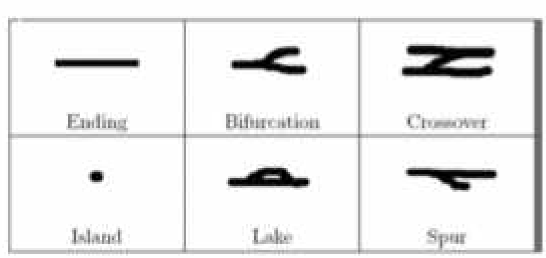

Fig 6- Common Minutiae Types

The following figure shows the phases fingerprint recognition process

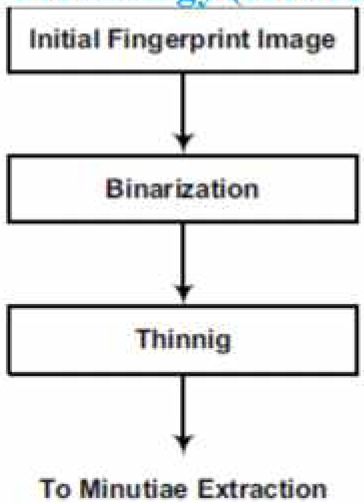

Fig 7- Fingerprint Recognition Process

A. Image Acquisition

Image is acquired using optical sensor. The finger is placed on glass prism and the prism illuminates light. The light gets reflected at valleys and absorbed at ridges. The reflected light is focused on CCD sensor[19].

B. Image Enhancement

It increases the clarity of ridge structure so that minutiae points can be easily extracted. The enhanced fingerprint image is binarized and submitted to thinning algorithm which reduces ridge thickness for location of endings and bifurcations.

1) *Binarization:* Gray scale image is converted into binary image. Local adaptive threshold is a good choice for converting gray scale image into binary image. To extract object in binary the following formula is used.

$$g(x, y) = \begin{cases} 1 & \text{if } f(x, y) > T \\ 0 & \text{if } f(x, y) \le T \end{cases}$$

F(x,y) is a value gray scale image, T is threshold and g(x,y) is binary image. Image is divided into series of equal blocks. Threshold is defined for each block. All pixels in the block are compared with threshold. Each block size is 16*16 and good threshold should be choosen. Threshold should be calculated for each block such that minimizing erroneous calculation ridge as valley or valley as ridge.

2) *Thinning Process:* A procedure for converting digital binary pattern to a connected skeleton of unit width is known as thinning process. This process increases the speed of minutiae extraction. A 3x3 window should be moved on the image in order to examine whether the pixel can be stayed in the image or not. Sequential and Parallel are two approaches for thinning. Parallel algorithm is faster than sequential for thinning process.

Algorithm runs two sub iterations continuously until image reaches stable state.[20]

Let A(P) be the number of 01 patters in the order set $P_2 \dots P_9$

Let B(P) be the number of non-zero neighbors of P

Do until image is stable (i.e. no changes made)

Sub-iteration 1:

Delete P from image if:

a) $2 \leq B(P) \leq 6$

b) $A(P) = 1$

c) $P_2 * P_4 * P_6 = 1$

d) $P_4 * P_6 * P_8 = 1$

Sub-iteration 2:

Delete P from image if:

a) and b) from above

c') $P_2 * P_4 * P_8 = 1$

d') $P_2 * P_6 * P_8 = 1$

C. *Minutiae Extraction*

Minutiae segmentation is needed to achieve high quality. Segmentation algorithm separates foreground fore ground from noisy back ground. Image enhancement algorithm keeps the ridge flow pattern without altering minutiae points and not including false information. This helps in extracting minutiae points efficiently. Crossing Number (CN) is widely used in minutae extraction. CN of a pixel is given by

$$C_n(P) = (\frac{1}{2})\sum_{i=1}^{8} | P_i - P_{i+1} |$$

Where Pi is a binary pixel value in the neighborhood of P with PI=0 or 1 and P1=P9. The Cn(P)=1 as ridge ending and Cn(p)=3 correspond to bifurcation. fig 8 shows minutiae points.\

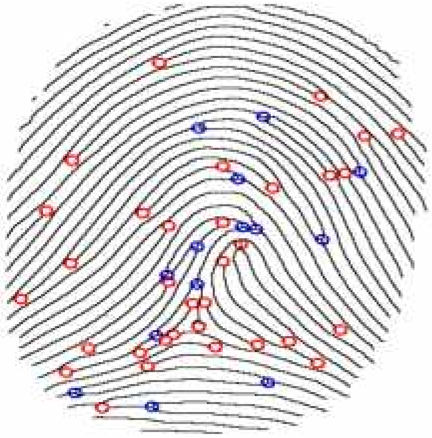

Fig 8- Minutiae Points

D. Minutiae Matching

The features extracted from the input finger are compared with those in template. The result of such process is called degree of similarity or matching score. The problem in matching is due to different impressions of the same finger. This variability is caused due to rotation in different acquisitions, partial overlap, skin conditions. Minutiae based matching technique is mostly used. In fingerprint matching, one minutiae from each finger print image is chosen and the similarity of two ridges associated with two minutiae points is calculated. If the similarity measured is larger than threshold, transform each set of minutiae to new coordinate system and its origin is from reference point and x-axis is coincident with direction of reference point. Elastic matching algorithm is used to count how many minutiae match in same position and same direction [21-22].

IV. FUSION LEVELS

The term fusion is a process of combining information from more than one source in recognition process. Fusion helps in getting much more information from each biometric modality. The two biometric traits Iris and Finger print are considered for fusion in this paper. There are five levels of fusion at which fusion can occur in multimodal. Fusion can be classified into two types. Pre-mapping fusion and post mapping fusion. Pre-mapping fusion is integration of information prior to matching level i.e. sensor level or feature level. Post mapping fusion is integration of information after matching [23-25].

A. Sensor Level

Combing biometric traits from different sensors like iris scanner and finger print scanner to form a composite biometric trait. It can be used when multiple cues are compatible. It can be used in cases fusing different speech signal simultaneously from different microphones. Fusion at sensor level is an emerging area. It produces more accurate results because of rich information available than fusion in later stages. First iris and finger print images are obtained from different sensors and decomposed using wavelet transformation and particle swarm optimization(PSO) to produce new image and finally decision accept or reject is taken. This cannot be used when data is incompatible.

B. Feature Level

In feature level fusion, different biometric traits are first preprocessed and feature vectors are extracted separately. All these feature vectors are combined to form composite feature vector. This composite vector is used in classification process. Due to rich information available in this level of fusion it is expected to perform better than score level and decision level fusion. But in many cases feature vectors are not compatible. It leads very high dimensionality, causes dimensionality problem and increases computational load [26-27].

Normalization: Due to difference in the extraction method, the order of magnitude and distribution between iris feature and finger print feature are different. So, normalization process is used. In order to eliminate, balance z-

Score normalization can be used. Let

$$A = (a_1^1, \cdots, a_m^1, a_1^2, \cdots, a_m^n)$$

be iris feature set. be d-dimensional iris feature of the jth iris training sample from the ith class. Let

$$B = (b_1^1, \cdots, b_m^1, b_1^2, \cdots, b_m^n)$$

be finger print image feature set. Let Ak is the kth row of iris feature set A. Compute

$$C_k = \frac{A_k - \overline{A_k}}{\sigma_k}$$

$\overline{A_k}$ is the mean value of AK. The normalized component is

$$X_k = \frac{C_k - C_{min}}{C_{max}}$$

Cmin and Cmax denote minimum and maximum value of Ck.Same process is repeated for finger print feature space. After normalization order of magnitude and distribution of two kinds of features are similar.[2].

C. Matching Score Level

Feature vectors from different modalities are processed separately and individual match score is found .Each match score is fused to form composite match score and this score is sent to decision module. The level of fusion is better because of simplicity. Logistic regression, highest rank, weighted sum, weighted product, bayes rule, linear discriminate analysis(LDA), K-nearest neighborhood are some of the techniques to combine match scores. Match score should be normalized. Some of the normalization techniques are Min-Max, Z-score, Double sigmoid, Tan-h. Many of the researchers are using match score level fusion technique because of less complexity [26.]. Fig9. shows score level fusion process.

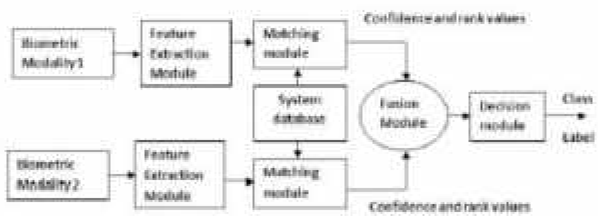

Fig 9- Score Level Fusion

Integrating Finger Print and Iris: The two biometric sensors captures the two biometric characteristics individually and converts each into raw digital format, which are further processed by feature extraction module individually to produce representation that is of the same format which is stored in the database. Again it is further processed by matching modules individually. The matching module generated by individual matchers is passed into fusion module to compute final match score by using the formula
MSfinal=MSIRIS+MSFINGERPRINT

Normalization: The output obtained from different matchers is not homogenous. This step is applied before raw data originating from different matches can be combined into fusion stage. For example if one matcher is yielding a score [100,500] and another matcher in the range [0,1]. Fusing two matches eliminates second matcher range. This problem can be overcome by using normalization. Normalizing the input of matching scores into same range and then combining normalizing scores. Normalization techniques like ,min-max ,z-score, median etc can be used.

Min-Max- It maps the raw scores to [0,1] range. Max(s) and Min(s) specify the end points of the score range.

N=s-min(s)/max(s)-min(s)

Finger prints are represented using minutiae features, the output of fingerprint matcher is similarity score . Before combining normalized scores it is necessary to combine to similar or dissimilar scores. Fusion methods like max rule, min rule, product rule, sum rule etc can be used. Finally two normalized matching scores are fused using sum rule to get final matching scores.
MSfinal=X* N1 iris +Y*Nfinger
X,Y are weights assigned to biometric traits. The final matching score is passed to decision module.

Weight assumption for individual biometric trait: Each biometric matcher produces a match score based on the comparison between input feature set and template stored in data base. The scores are weighted according to the biometric traits used for increasing the influence more reliable traits and reduce importance of less reliable traits.

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D. Rank Level Fusion Module

Very few researches are concatenated using rank level. To combine different rank orderings plural voting method can be used. Plural voting method considers elements which are at the top of ranked list [28].

E. Decision Level Module

Each biometric data is processed independently fusing the outputs of different modalities to make final decision. i..e accept or reject. Majority voting scheme can be used to make final decision. Fusion at decision level contains least information. The decision fusion is used when only the final decision output of the output is known. But this stage is not powerful. Fig 10 shows various steps in decision level.One problem that appears with decision level fusion is the possibility of ties. An important combination scheme at the decision level is the serial and parallel combination, also known **as** *"AND"* and"OR" combinations. Figure 11 shows the block diagram. The AND combination improves the False Acceptance Ratio (FAR) while the OR combination improves the False fusion.[39]

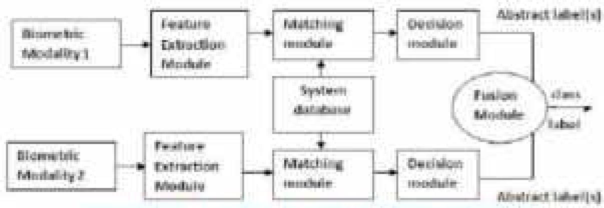

Fig 10-Decision Level

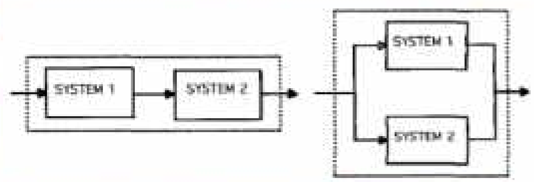

Fig 11- Serial and Parallel Decision Combinations

V. DATABASES

Many researchers are putting efforts in fusing multimodal biometrics. Fusion combines two or more biometrics traits, which improves matching accuracy. There are different approaches for biometric fusion. One approach is to use heterogeneous database i.e one biometric trait from one database and other trait from another database. But this approach is not reflecting the performance of multimodal users. The other approach is to use homologous database. It means different biometrics from the same person. Only few multimodal databases are available publicly. But most of them consists two traits they are BANCA and XM2VTS which includes face and voice. BIOMET which includes face, voice, fingerprint, hand and signature, BIOSEC includes fingerprint, ace, iris and voice. But these databases have some limitations. SDUMLAHMT is a homologous database which includes face images from 7 angles, finger print images, gait videos, iris images etc.[29]

VI. CONCLUSION

The purpose of multimodal biometrics is to reduce the error and to improve recognition accuracy. The time taken by Multi modal biometrics is greater than unimodal biometrics. But it is still used in places where security is main important. By using appropriate fusion techniques it improves recognition rates. In this paper, a multimodal biometric recognition system based on fusion of two biometric traits iris and fingerprint is discussed. .Various fusion level techniques are discussed. Fusion at score level works better than other techniques because of easy implementation. These two traits are the most widely accepted biometrics in most

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applications. There are also other advantages in multimodal biometric systems, including the ease of use, robustness to noise, and the availability of low cost.

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