Overview of Fusion Techniques in Multimodal Biometrics

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Abstract: **Security means restricting unauthorized persons from some data. Biometric recognition is automated recognition of individual based on the physiological and behavioral characteristics. Unimodal biometrics are facing problems like noisy data, intra class variation, inter class variation, spoofing attack etc. These limitations can be solved by using multimodal biometrics. Comparing to unimodal , multimodal biometric systems are performing better. A multimodal biometric system is a combination of two more biometric traits to increase the security. In this paper two unimodal biometrics iris and fingerprint are used as multimodal biometrics. Comparing to other biometrics, iris recognition is having low false acceptance rate. We discuss various fusion techniques of iris and fingerprint with advantages and limitations. An effective fusion scheme is necessary for combining information from various sources. Fusion at the rank level is the new approach. The fuzzy fusion is based on match score and rank information.**

Key Words- biometrics; fusion; fuzzy.

I. INTRODUCTION

Controlling access to prohibited areas is an important activity of national and international security. Security can be provided using biometrics. Bios means life and Merton means measuring, biometric is defined as measuring and analyzing persons unique characteristics. Person can be identified using behavioural or physical or soft biometrics. Some of the physical characteristics include face, iris, ear, hand geometry etc. Voice, gait, signature, key strokes are behavioural characteristics. Gender, weight, height, age etc are soft characteristics. Choice of choosing biometric depends on application. The below Fig1 shows various biometric traits.

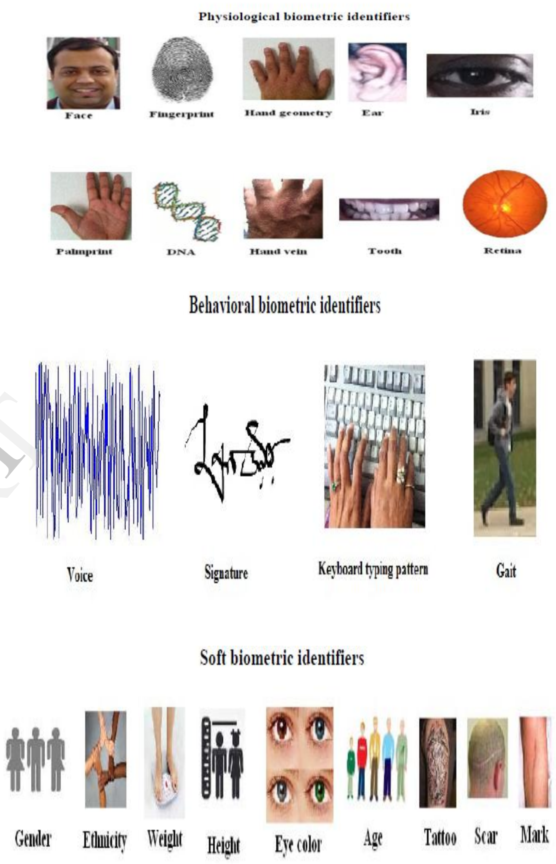

Fig1:Various Biometrics

Many advanced biometric systems are facing numerous problems. Noisy data: biometric data affected by noise at time of acquisition. Noisy data results in poor recognition performance. Ex. capturing voice biometric trait during heavy rain. Non-universality: If all members of the population can be enrolled in the biometric system then biometric trait is said to be universal. For example, a blind person cannot present his iris or retina biometric trait in front of sensors. Lack of individuality: Biometric obtained from different subjects are similar, as a result false recognition rate can be higher. For example facial appearance of father and son can be similar. Privacy: biometric trait is a link between a person and his identity.

The acquired biometric trait is violating a person's right to privacy.

Applications: Multimodal biometrics is combination or two or more biometrics. This is increasing accuracy in recognition rate. Some of the multimodal applications are Biometric door lock security systems are used at those places where you have important information and stuffs. In that kind of places multi biometric electronic door lock security systems that are based on finger print and iris recognization. Law enforcement, smart cards, Airport security, ATMs, driving license, pass ports, Aadhar cards, cellular telephones. [20]

II. OVERVIEW OF MULTIMODAL BIOMETRIC SYSTEMS

Biometric system is optimal if it is distinctiveness, universality, permanence, acceptability, collectability and security. But unfortunately there is no single biometric system which satisfies these properties. The solution is to use multimodal biometric system. Multimodal biometric systems are which uses more than one behavioural or physical characteristic. The advantage of multimodal biometric traits compared to token based or password is, these traits cannot be lost, stolen or shared. Biometric systems mainly consist of four Modules. Sensor module: acquires biometric data from sensors. Ex- fingerprint sensors, camera etc. The feature extraction module: extracts the features from acquired biometric traits. These feature sets are stored in the database as a template. In the matching module the feature set extracted are compared with the template stored in the database. The decision is taken at decision module based on degree of similarity. Biometric system operates in two modes enrolment and identification. All users' biometric features and other useful information are stored in data base in form of a template with user identity in enrolment mode. In authentication mode, once again biometric data is captured and compared with templates corresponding to claimed identity.

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 consist 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. [24]

III. 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 considered to fuse in this paper are Iris and Finger print**.** 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.[25][31][18][15][21][36][30][25][26][27] .Choosing appropriate fusion techniques depends on the necessity of application. Fuzzy fusion can be implemented in any levels. The different levels of fusion in Fig 2.

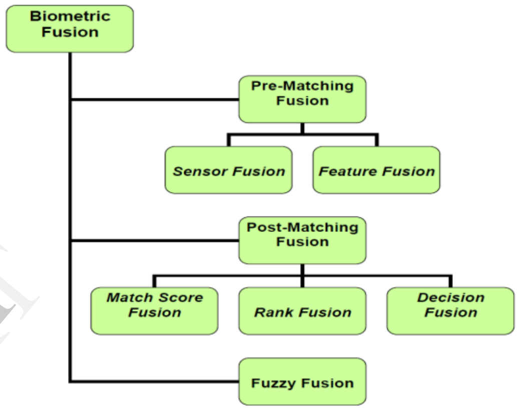

Fig2: Fusion Levels

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 pre-processed 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

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dimensionality leads to curse of dimensionality problem and increases computational load. [31][17][20][35]

(a) 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. a_j^i be d-dimensional iris feature of the j^{th} iris training sample from the i^{th} class. Let

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

be finger print image feature set. Let A_k is the k^{th} 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 A_K. σ_k is the SD of A_K. The normalized component is

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

C_{min} and C_{max} denote minimum and maximum value of C_k. The normalized feature set is $X = (X_1, \cdots, X_d)$. Same process is repeated for finger print feature space. After normalization order of magnitude and distribution of two kinds of features are similar.[31]. Fig 3 show feature level fusion.

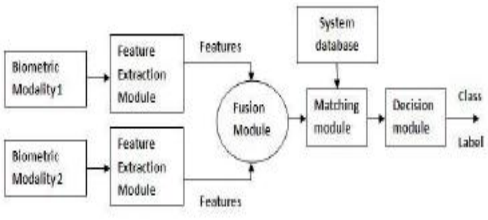

Fig 3:feature level fusion

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 neighbourhood 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. [30][20]. Fig4. Shows score level fusion

(a) 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.

$MS_{final} = MS_{IRIS} + MS_{FINGERPRINT}$

(b) 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. So, in this paper we are converting to similar score.

$N^1_{Iris} = 1 - N_{Iris}$

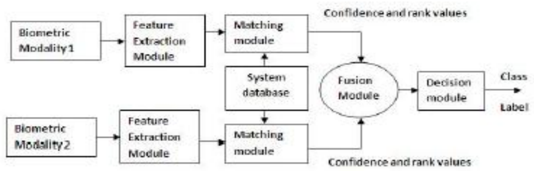

Fig4: score level fusion

Fusion methods like max rule, min rule, product rule, sum rule etc can be used. Sum rule: Finally two normalized matching scores are fused using sum rule to get final matching scores.

$MS_{final} = X * N^1_{iris} + Y * N_{finger}$

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X, Y is 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.

D. Rank Level Fusion Module:

Very few researches are concatenated using rank level. To combine different rank orderings plural voting method can be used. In plural voting method it considers elements which are at the top of ranked list. [38]. In the level fusion multiple ranking lists are consolidated to form a final ranking list. In few cases only ranked outputs are available. This level fusion can be used when individual matchers output is a ranking of the candidates in the template database sorted in a decreasing order of match scores. The systems assign a higher rank to a template that is more similar to the query. Highest Rank fusion: The ranking is obtained by sorting the identities according to their highest rank. The following steps can be employed in highest rank fusion method.

1.Get ranking lists from biometric classifiers.

2.for all ranking lists find out rank of each identity utilizing the following equation

$$R_c = \min_{i=1}^{n} R_i$$

Where n is number of ranking lists i.e number of biometrics used.

3. Sort R_C in ascending order and replace with corresponding identity.

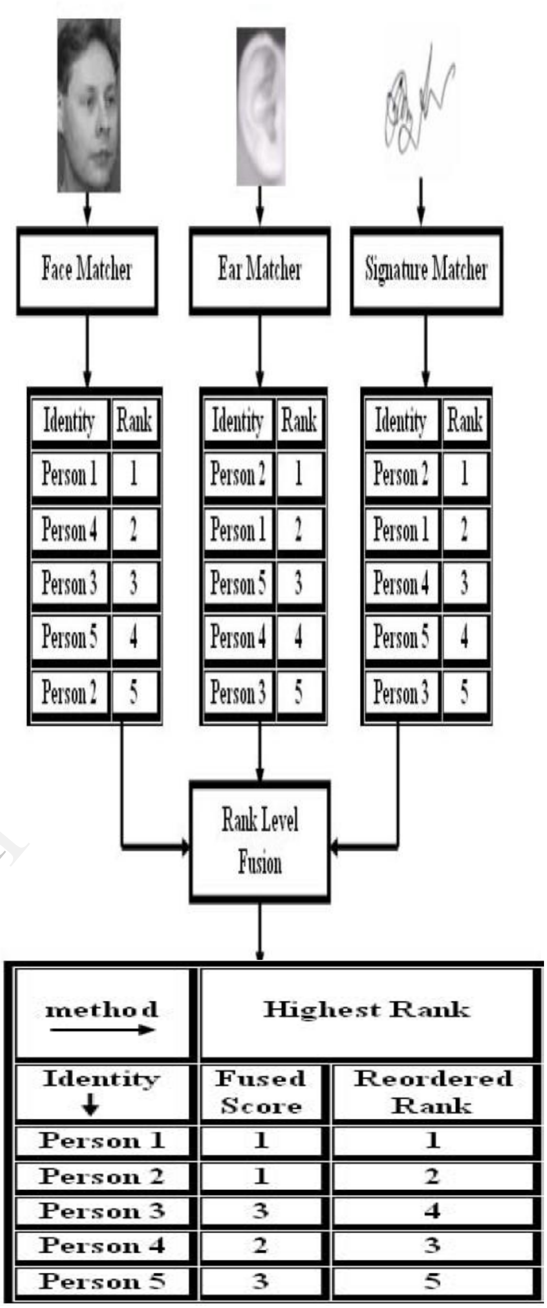

Fig5: Rank level fusion

E. Decision level module

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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 5 shows 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**

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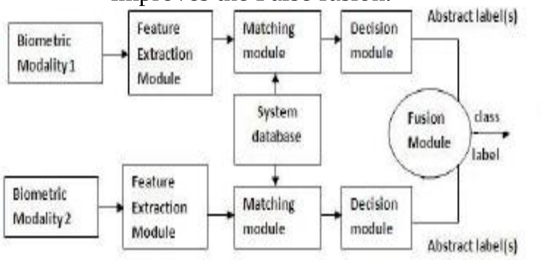
"AND" and "OR" combinations. Fig 6 shows the block diagram. The AND combination improves the False Acceptance Ratio (FAR) while the OR combination improves the False fusion.



[39]

Fig6: Decision level

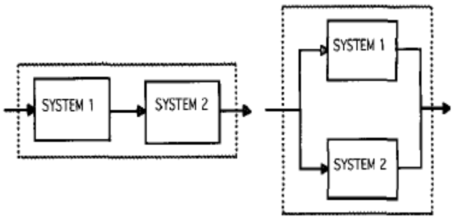


Fig7: Serial and Parallel Decision Combinations

Many researchers believe that score level fusion offers best performance and it is easy to implement but this requires normalization. Inappropriate choosing of normalization can degrade the system performance. Pre matching fusion methods are less extensively used .The most important thing in multimodal biometrics is fusion. The fig 7 shows how the information decreases in each level of fusion.

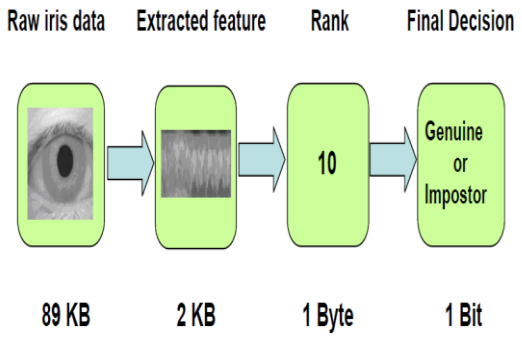


Fig 8: Example of how information available for fusion decreases in every level

Year	Modalities Used for Fusion	Authors	Fusion	Fusion Approach
1998	Face and fingerprint	Hong and Jain [Honj98]	Match score	Product rule
2000	Face, voice and leap movement	Frischholz and Dieckmann [FriD00]	Decision	Weighted sum rule, Majority voting
2003	Face, fingerprint and hand geometry	Ross and Jain [RosJ03]	Match Score	Sum-rule, decision tree and linear discriminant function
2003	2D and 3D faces	Liu and Chen [LiuC03]	Sensor	Face mosaic
2004	Face and palmprint	Feng et al. [FDHZ04]	Feature	Feature concatenation
2005	Face, fingerprint and hand geometry	Jain et al. [JaNR05]	Match score	Simple-sum-rule, max-rule and min-rule
2009	Fingerprint, face and hand geometry	Nandakumar et al. [NCDJ09]	Match score	Likelihood ratio
2009	Hand biometrics (palmprint, fingerprint, finger geometry)	Yu et al. [YXZL09]	Decision	AND rule, OR rule, majority voting
2010	Fingerprint and face	Rattani et al. [RKBT10]	Feature	Delaunay triangulation
2010	Face and palmprint	Raghavendra et al. [RaRK10]	Sensor	Particle swarm optimization
2010	Two palmprint images	Kumar and Shekhar [KumS10]	Rank	Borda count, weighted Borda count, maximum rank, nonlinear weighted rank

Table1: Some biometric systems

In the above table1 shows some comparisons of fusions

F. Fuzzy logic based fusion is another fusion approach. This fusion can be employed before matching or after matching. when this is applied before matching it reduces the size of dataset for comparison. If it is employed matching recognition performance can be increased. It is based on fuzzy logic. The idea of fuzzy set was Introduced in 1965 by professor Lotfi A.Zadeh. It uses fuzzy sets. Fuzzy sets: fuzzy set is a set which have member ship value between 0 to 1 unlike the crisp set where the members have only two membership value i.e 0 or 1.Fuzzy rules: some of the applications of fuzzy rules are pattern recognition, information retrieval, robotics, automation etc. Fuzzy rule base consist of fuzzification, inference and defuzzification. In fuzzification fuzzy variables and membership functions are defined. In inference step fuzzy rules have been developed. The fuzzy conclusion is converted into a discrete one in defuzzification method. The fig9 shows fuzzy logic steps.

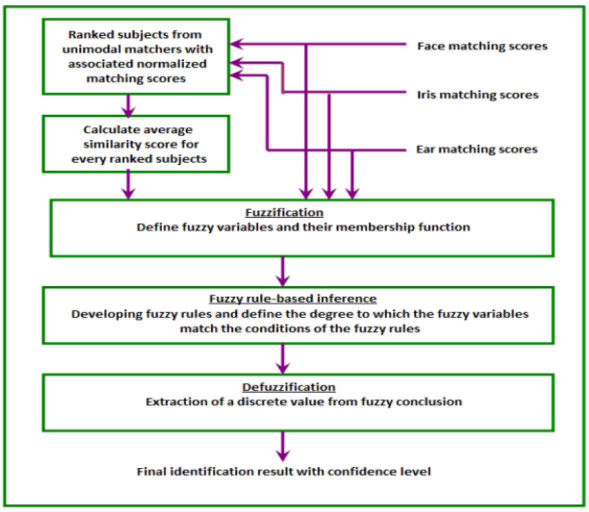


Fig9: Fuzzy logic steps

1. If AS = 'H', FS = 'H', IS = 'H' and ES = 'H', then 'SI'
2. If AS = 'H', FS = 'H', IS = 'H' and ES = 'M', then 'SI'

3. If AS = ‘H’, FS = ‘H’, IS = ‘M’ and ES = ‘H’, then ‘SI’
4. If AS = ‘H’, FS = ‘H’, IS = ‘M’ and ES = ‘M’, then ‘SI’
5. If AS = ‘H’, FS = ‘M’, IS = ‘H’ and ES = ‘H’, then ‘SI’
6. If AS = ‘H’, FS = ‘M’, IS = ‘H’ and ES = ‘M’, then ‘SI’
7. If AS = ‘H’, FS = ‘M’, IS = ‘M’ and ES = ‘H’, then ‘WI’
8. If AS = ‘M’, FS = ‘H’, IS = ‘H’ and ES = ‘M’, then ‘WI’
9. If AS = ‘M’, FS = ‘H’, IS = ‘H’ and ES = ‘L’, then ‘WI’
10. If AS = ‘M’, FS = ‘H’, IS = ‘M’ and ES = ‘H’, then ‘WI’

Fig10: Examples for some fuzzy rules

IS is iris matcher score FS is finger matcher score

IV. CONCLUSION

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 we discussed a multimodal biometric recognition system based on fusion of two biometric traits iris and fingerprint. Various fusion level techniques are discussed. Fusion at score level works better because of easy implementation These two traits are the most widely accepted biometrics in most applications. There are also other advantages in multimodal biometric systems, including the ease of use, robustness to noise, and the availability of low cost. I introduced new rank level fusion and fuzzy fusion approaches. Fuzzy fusion which improves the response time.

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