Multimodal Biometric Systems : A Brief Study

Himanshu Purohit, Pawan K Ajmera

Abstract: Multimodal Biometrics is a combination of different biometric modalities for individual's identification. In contemporary commercial unimodal biometric systems, most uses a single trait for authentication. So it is called unimodal system. Some of the drawbacks of unimodal biometrics such as intra- class variations, restricted degrees of freedom, spoof attacks and non-universality are eliminated by fusion based biometrics systems for unique personal identification. Various methods of fusion and data integration strategies can be utilized to combine information in multimodal systems. This paper presents a brief study on past research and development in the field of multimodal biometric technology in terms of fusion level, techniques for dimensionality reduction and normalization methods.

Index Terms: Unimodal; multimodal; biometric; fusion.

I. INTRODUCTION

Biometrics is used for person authentication in advance systems, devices and applications. The biometric systems are crucial in many domains like public distribution, security, defense and education. In biometric system, permission to get a service is managed by identification routine. Any physiological or behavioral trait can serve as a biometric identifier as long as it fulfills the requirements of: Universality, Distinctiveness, Permanence and Collectability. The popular physical traits for identification are: face, iris, retina, fingerprints, palm-prints, hand vein and hand geometry and common soft biometric behavioral characteristics like gait, voice, signature and typing rhythm are also used [1].

The biometric system operates in following manner: First registration phase and then authentication phase:

1. Registration: The biometric information of user is extracted by a sensor and after preprocessing, template is secured in a database. It can be successful enrollment or unsuccessful enrollment.

2. Authentication: by some method user claims identity (1-k) or system verifies (1-1) the claimed user identity against stored templates.

(a) *Fingerprint*: It consist of regular texture pattern composed of ridges and valleys. The ridge bifurcations and endings are known as minutiae and its distribution patterns are distinctive among each finger. The grouping of these features used to compare two fingerprints.

(b)*Face*: The spatial relationship among the location of features such as eye, nose and lips etc. are generally used by face recognition systems. It has higher user acceptance and provides acceptable levels of recognition performance in controlled environments.

(c)*Iris*: It is a secure and covered organ with stable and unique texture and spoofing is very difficult.

(d)*Palm Print*: The human palm print can be used in authentication because of unique friction ridges and flexion creases. Just like fingerprint, palm print system uses minutiae and creases for matching in authentication.

(e)*Gait:* Walking style of each individual is unique, and it can be fused with other traits for biometric authentication.

(f)*Signature:* The offline or online signature verification can be used for biometric system.

Similarly other traits such as voice, finger knuckle, DNA have their own characteristics and are useful for biometric system design. This article has a review of fusion models of different modalities, dimensionality reduction techniques and their performance.

II. TYPES OF BIOMETRIC SYSTEMS

The biometric system classification is possible in different categories such as multi-sensor, multi-instances, multi-modal, multi algorithm, and multi-presentation. It can be define as unimodal or multimodal systems. The later has following four modules: Sensors, Feature Extraction, Matching and Decision module. The extracted and preprocessed information from different traits can be fused at different levels such as at sensor, feature, score and decision or at rank level.

A. Unimodal Biometric Systems

The unimodal biometric system uses single biometric modality for authentication. The main challenges Faced by UBS are: Noisy data, Non-universality, Intra-class variation, Inter-class similarities and Spoof attacks. In UBS main modules are human interface, information acquisition, comparison module, and decision making module. Unimodal biometric systems (UBS) ***cause*** higher False Acceptance Rate (FAR) and False Rejection Rate (FRR). The Uniqueness and reliability of extracted data are important aspects that have direct impact on FAR and FRR values [2]

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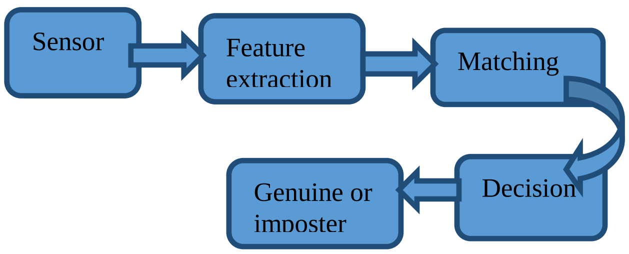

Fig.1. Unimodal Biometric Architecture

B. Multimodal Biometric System

Multimodal biometric system (MBS) is a system where fusion of multiple traits such as palm vein, voice, iris and ear features is done for authentication. The combinations of feature vectors are fused at different levels of system design for improvement of accuracy and high FRR. The structure of MBS is modified version of UBS; it consists of additional fusion and multiple sensor modules.

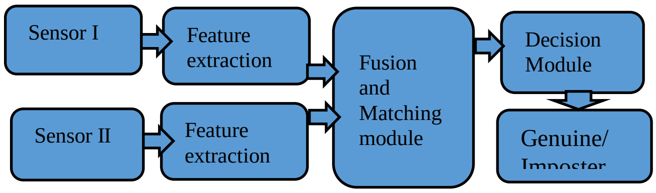

Fig.2. Multimodal Biometrics Architecture

The fusion based system can be classified as pree matching fusion or post matching fusion model. The feature and sensor level are *fusion before matching* based system, whereas score, rank and decision comes under fusion *after matching* [3].

Some of the shortcomings of unimodal biometric systems can be overcome by multimodal systems. The multimodal biometric system provides more accurate and reliable results at the cost of increased complexity and high computation time.

III. DIFFERENT LEVELS OF FUSION

Mixing of preprocessed extracted feature vectors from multiple traits is called fusion. The Compatibility among feature vectors is important for fusion. The raw data may contain noise with real biometric information. So selection of efficient matching algorithm is crucial aspect for biometric system design. With biometric traits, other information such as password, code or hardware token can also be fused to get additional encryption. As per Jain et al soft identifiers such as sex, ethnicity and physical parameter can also be incorporated in recognition process [3]. Following are the different fusion levels of MBS

A. Sensor-level Fusion

This is a primary level of fusion where outputs of different sensors are directly concatenated for fusion. Discrete wavelet based and graph matching are main methods of this category.

B. Feature-level Fusion

In feature level fusion, after initial processing separately extracted feature vectors from each trait are fused to form a single feature vector for authentication process.

The extracted feature at this level contains real insight of intact information better than any other level, so in recognition process, feature level fusion shall outperform rest. The main issue here is compatibility among different feature vectors. The principal component analysis (PCA) and other correlation enhancement techniques are used to improve compatibility among feature vectors. PCA is one of the most popular methods, usually preferred in feature level fusion [2].

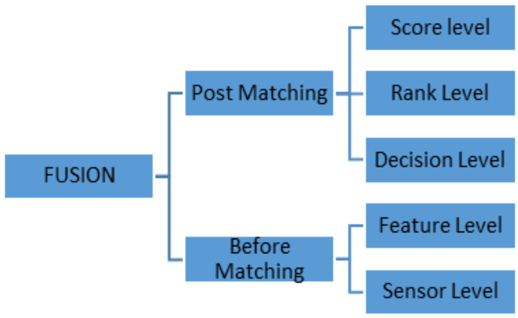

Fig.3. Fusion level classification

C. Score-level Fusion

In this case, individual scores which are generated from the matching of features with already stored templates, are fused together to make final decision. The min max, average, highest score method are common methods to compute scores. Support vector machine and relevance vector machine are main methods of this category [3].

D. Rank-level Fusion

This method overcome compatibility issue among features sets as it is based on performance ranking. The Boarda count, highest rank method and logistic regression are most popular algorithms for rank calculation [4].

E. Decision-level Fusion

Post independent recognition of each trait, final decision is made by some overall decision making criteria. Human interface wise it is the top most level of fusion in comparison to other levels.

IV. METHODS OF FUSION

There are three main categories for classification of fusion methods for multimodal biometrics, such as: Estimation based, Classification based and Rule based methods.

A. Estimation based Fusion Methods

It includes particle fusion approach and Kalman filter. With certain statistical significance, Kalman filter enables the execution of real time of dynamic low level data and gives state estimates of the system from the fused data.

Particle based approach or Sequential Monte Carol method are simulation based methods. It involves prediction and update steps.

B. Classification based Fusion Methods

This is a supervised category as it is based on learning or training process. It includes many classification techniques to classify the observation of multimodal into well-defined different classes. The Baysian inference, neural

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network, Dempster-Shafer theory, Maximum entropy, support vector machine and dynamic Baysian theory are main methods. Bayesian and Neural network method are applicable to both feature level and decision level fusion methods.

C. Rule Based Fusion Method

In unsupervised methods of fusion, training process is not involved as learning rules are better suitable for physical application for well-defined targets. Sum rule, Max rule, Product rule and Min Max are example of rule based methods. The product rule yield fewer results then sum rule.

Majority of the work published in multimodal biometrics field, is in the score level fusion category as it is comparatively easier to implement. The feature level fusion contains maximum information, so feature vector size would be large but it will generate more reliable authentication process. The large size of feature sets is a data management problem and it can be managed by dimensionality reduction techniques.

V. DIMENSIONALY REDUCTION TECHNIQUES

The real information signal such as speech, voice, video, images have high dimensionality. Handling large size data would be complex and costly mode, so it is important to reduce dimensionality of data to manageable size by transformation or some mathematical process. The transformation from high dimension random variables to low dimensional random variables is known as dimensionality reduction process. These are mainly classified into linear and non-linear categories.

Linear methods are based on linear mapping of high dimensional data to low dimensional data in such a way that variance in new representation is maximized. The example of linear methods is linear discriminant analysis (LDA), Principal component analysis (PCA), independent component analysis (ICA) and singular value decomposition (SVD).

The non-linear data can be handled by nonlinear methods only. In table below main methods are given for non- linear dimensionality reduction category.

TABLE I. NON-LINEAR METHODS of DIMENSIONALITY REDUCTION [18]

Sr. no.	Non Linear Methods
1	Simon's Mapping
2	Self-Organizing Map
3	Principal Component Analysis
4	Auto Encoders
5	Gaussian Process Latent Variables Models
6	Curvilinear Component Analysis
7	Curvilinear Distance Analysis
8	Demographic Dimensionality Reduction
9	Kernel Principal Component Analysis
10	Locally-Linear Embedding
11	T-Distributed Neighbor Embedding (T-SNE)
12	Manifold Sculpting

VI. RELATED WORK

In recent years many researchers have started working in the multimodal system design. The MBS can operate in different scenarios like multiple sensors, multiple biometrics, multiple instances and multiple algorithms for same biometrics etc. [5]. In this section a literature survey on feature level fusion based methods is presented.

TABLE II. SUMMARY OF WORK DONE IN BIOMETRIC FUSION [17]

Sr. No.	Traits	Researchers	Type
1.	Face & Fingerprint	Davide Maltoni	Post matching
2.	Face & Acoustic	Paliwal	Post matching
3.	Face & Palm Print	Philips	Before matching
4.	Voice & Face	Bengio	Post matching
5.	Voice & Face	Kitter	Post matching
6.	Fingerprint & Signature	Ching	Post matching
7.	Face & Palm Print	Feng	Before matching
8.	Face & Iris	Rose	Post matching
9.	Signature & Iris	Wang	Before matching
10.	Face & Finger Prints	Jing	Before matching
11.	Fingerprint & Face & Hand Geometry	A Jain	Post matching
12.	2D Face & 3D Ear	Mahoor	Post matching
13.	Face & Finger Veins	Imran l	Post matching
14.	Face & Palm print	Linlin al	Post matching
15.	Face & Eye	Kawuolak l	Before matching
16.	Iris & Finger print	Ujwalla	Before matching
17.	ECG & Acoustic	Bugdol	Before matching
18.	Finger Print & Face	Ghate	Post matching
19.	Iris, Palm Print & Face	Ren-He	Before matching
20.	Multiple combination	Saif	Before matching
21.	Finger Print & Iris	Jain	Post matching

The bimodal biometrics has been proposed by Ross and Jain in 2003 [2]. Fusion of Iris and Fingerprint has been a major attraction for researchers and they have

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tested variety of approaches and it is available in the literature. Ross et al has cross verified feature level fusion scheme on face and hand geometry, which are considered as weaker biometric traits [4]. For FAR close to 0.01%, 15 % improvement has been noticed in the GAR. Besbes et al., proposed a multimodal biometric fusion based system using Fingerprint and Iris [6]. It was a mixed approach where Fingerprint minutiae extraction and Iris template encoding were used. In this study no experimental results were presented.

Islam et al., fused Ear and Face traits for MBS. It was based on local 3D feature and PCA. Experimental results outperformed unimodal system in terms of scale variations and computation [7].

M. Haghighat et al have proved that discriminant correlation analysis (DCA) of feature level fusion is better than canonical correlation analysis method [8].

Ujwalla G. et al, in the year 2013 developed a novel method which was based on feature level fusion using SVM classifier. Their focus was on was on Iris-Fingerprint multimodal biometrics, where Haar wavelet was used for feature extraction. The design was tested on CASIA iris database and real fingerprint database [9].

Ren-He Jeng et al presented a new feature level fusion mechanism which was based on shuffle coding for authentication. Their work addresses two distinct methods, such as feature scaling and hashing to standardize the range of independent features of data. It was proved experimentally that shuffle coding scheme can effectively fuse vectors from more than two modalities into single fusion code sequence [10].

The security and compact representation of fused biometrics is very crucial. The proposed method has been claimed as near perfect for verification [11]. In a short review Celik in 2017, has discussed the work done by M. Haghighat et al. in brief [12]. Apart from complex MBS, wearable devices are also good platform to be equipped with simple sensors and biometric devices. Uhl et al, have developed a wearable biometric system that is worn on the arm and authentication is made when the user is recognized by the device [13].

In their work, Xiaona et al. have proposed an algorithm, based on kernel canonical correlation analysis (KCCA) and tested it for ear and face biometrics. [14]. In a complex approach Bharti et al, have presented a different way, where features from different images of veins (finger, palm or dorsal) are extracted by applying Radon transform, Hilbert transform and Dual tree complex wavelet transform for respective veins. The Group search optimization was used for fusion and recognition is done using different classifiers. The outcome has shown lower equal error rate. The FAR of 0.011 % and EER of 0.014% were obtained [15]. In the year 2016 Muhatahir O. et al. have presented state of the art survey on biometric sensing systems [16].

VII. CONCLUSION AND FUTURE WORK

In this paper authors have done detail study of biometrics field, starting from history of unimodal system to latest multimodal biometric systems. The applications and need of biometric would be integral part of future generation of any technology. The main focus of this work is feature level fusion as this scheme provides maximum information for decision making. As compare to score level and other post matching schemes it gives better results. The classification of feature vectors would reduce the complexity of the feature fusion based system. There is huge scope of improvement in feature level fusion method and so authors would try to develop novel algorithm of fusion, feature extraction and its implementation on smart phone platform. The commercially available smart phone are yet not that much capable in terms of biometric authentication. The application can be modified and upgraded for distance voting and betterment of social security schemes such as ADHAR card in India.

REFERENCES

1 H. Purohit, Pawan K. Ajmera, “Fusion of Palm print with palm-phalanges Print and Palm Geometry”, AISC book series, Chapter 59,Volume 870, Springer Nature, 2019

2 A.K. Jain et al “An introduction to biometric recognition” IEEE Transctions on Circuit and Systems for Video Technology, vol.14, pp. 4-20, 2004.

3 A.K. Jain et al “Information fusion in biometrics” Pattern Recognition letters, vol.24, pp. 2115-2125, 2003

4 A. A. Ross et al , “Handbook of Multibiometrics”, (Springer Publisher) International series on Biometrics, Vol. 6, XXI, 198 p. 2006.

5 Monwar et al. , “Multimodal biometric system using rank level fusion approach”’ 2009.

6 F. Besbes et al, “ Multimodal biometric systems based on fingerprint identification and Iris recognitions,” in Proc., 3rd Intl. IEEE Conf. Inf. Comm. Technology: from theroy to application ICTTA pp.1-5 ,2008.

7 Islam et al, “Score level fusion of ear and face local 3D feature for Fast and expression- invariant Human recognition,” ICIAR 2009, LNCS 5627, pp. 387-396, 2009. Springer-Verlag Berlin Heidelberg 2009.

8 M. Hghighatet al, “ Discriminant Correlation anlaysis: real time feature level fusion for multimodal biometric recognition,” IEEE Transction on Information Forensic and Security, vol.4, pp. 1-11, Jun 2016.

9 U. Gawande, “A Novel algorithm for feature level fusion using SVM classifier for Multibiometrics- based person authentication”, Applied Computing Intelligence and Soft Computing, vol 2013

10 Ren-He Jenget al, “Two feature level fusion methods with Feaature scaling and Hasing for Multimodal biometrics,” IETE Technical review, DOI:10.1080/02564602.2016.1149039

11 Celik N, “ A short review of multimodal biometric recognition systems,” Journal of Biometrics and Biostatistics, vol. 8, issue 3. 2017

12 Rathgeb C et al, “ A survey on biometric cryptographics and cancelable biometrics,” EURASIP Journal on information Security, vol.8, issue 3, June 20, 2017

13 Xiaona Xuet al, “The study of feature level fusion algorithm for multimodal recognition,” IEEE Tranction on Information Forensics and Security, vol.7, no.1, pp.255-268, 2012

14 Bharathi Subramaniam et al, “ Multiple features and classifers for vein based biometrics recognition” Biomedical Research vol. special issue, 2017, www. Biomedres.info

15 M. O. Oloyede et al, “ Unimodal and Multimodal Biometric Sensing Systems : A review,” IEEE Access vol 4, pp. 7532-7558, September 2016

16. N. Sivasankariet al, “ A Review on Recent Techniques in Multimodal Biometrics”, International Conference on Computer and Informatics (IC3I) Coimbatore, India, 2016.