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Fusion in Multibiometric Using Fuzzy Logic Review

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Abstract— Biometric is a technology for verification or identification of individuals by employing a person's physiological and behavioural traits. Although these systems are more secured compared the traditional methods such as key, smart card or password, they also undergo with many limitations such as noise in sensed data, intra-class variations and spoof attacks. One of the solutions to these problems is by implementing multibiometric systems where in these systems, many sources of biometric information are used. This paper presents a review of multibiometric systems including its taxonomy, level of fusion and fusion in multibiometric system using fuzzy logic is called fuzzy fusion.

Keywords— biometric, multibiometric, biometric fusion, level of fusions, fuzzy logic, fuzzy fusion

I. INTRODUCTION

A biometric system is essentially a pattern-recognition system that recognizes a person based on a feature vector derived from a specific physiological or behavioural characteristic the person possessed for authentication or identification purposes [2]. It differs from classical user authentication system which is based on something that one has (e.g., identification card, key) and/or something that one knows (e.g., password, PIN). Hence, a number of physiological and behavioural traits can be utilized in the biometric systems such as fingerprint, iris, face, hand geometry, palm print, finger vain structure, gait, voice, and signature. Depending on the context of applications, biometric systems may operate in two modes i.e. verification or identification [3,1]. Biometric verification is the task of authenticating the test biometric sample with its corresponding pattern or model according to the claim given by user. Whereas, biometric identification is the task of associating a test biometric sample with one of number of patterns or models that are available from a set of known or registered individuals [4]. Authentication systems with one biometric trait may not be sufficient for the application in terms of properties such as universality, uniqueness, permanency, collectability and acceptability. Unimodal biometric systems may not achieve 100% accuracy on account of the limitations such as the noise in the sensor data, intra-class variations, inter-class similarities, lack of universality, interoperability issues, spoof attacks and other vulnerabilities. Mutibiometric systems can improve limitations faced by unimodal biometric systems. For example, the multibiometric system can address the non-universality problem encountered by biometric systems. If a person cannot be enrolled in the fingerprint system, this person can aid the problem using other biometric traits such as voice, face or iris. The multibiometric systems can also reduce the effect of noise data. If the quality biometric sample obtained from one sources is not sufficient, the other samples can provide sufficient information to enable decision-making. Another advantage of multibiometric over single biometric systems is that, they are more resistant to spoof attacks since it is difficult to simultaneously spoof multiple biometric sources. The multibiometric systems are able to incorporate a challenge-response mechanism during biometric acquisition by acquiring a subset of the trait in some random order [6]. Multibiometric systems also have major drawbacks compared with single biometric systems. For example, the cost for the implementation of multibiometric systems is more expensive since these systems require many sensors.

II. MULTIBIOMETRIC SYSTEMS

A multibiometric system performs recognition based on the evidences obtained from multiple sources of biometric information. Multibiometric systems can be classified into six categories which are multi-sensor, multi-algorithm, multi-sample, multi-instance and multi-modal systems [7].The scenario of multibiometric systems is depicted as in Fig.1.

Multi-sensor systems: In multi-sensor systems, different sensors are used for capturing different representations of the same biometric modality to extract diverse information. For example, Chang et al. [8] acquire both 2D and 3D images of the face and combine them at the data level as well as the match score level to improve the performance of a face recognition system [7].

Multi-instance systems: Multi-instance systems involve fusion of information from multiple instances within the same biometric trait. For example, evidence from the left and right irises or the left and right index fingers can be combined for the recognition of an individual [10].

Multi- algorithm systems: In multi- algorithm systems use one biometric trait but use two or more different matching algorithms. For example, In Lu et al. [12] where three different feature extraction schemes which are Principle Discriminate Analysis (PCA), Independent Component Analysis (ICA) and Linear Discriminate Analysis (LDA) have been combined to improve a face recognition system.
Multi-sample systems: In multi-sample systems use single senor but multiple samples of the same biometric trait. For example, along with the frontal face, the left and right profiles are also captured. Multiple impression of the same finger, and multiple samples of a voice can be combined. Multiple samples may overcome poor performance. But, it requires multiple copies of sensors, or the user may wait a longer period of time to be sensed or a combination of both[13].
Multi-modal systems: In multi-modal systems use the evidence of multiple biometric traits to extract the biometric information of an individual. These different biometric traits can come from a variety of modalities [14]. The multi-modal system is reliable due to the presence of multiple independent biometrics.For example, a biometric system may use face and voice for person authentication. Multimodal systems have several advantages. Better recognition rates can be achieved combining different modalities. Higher performance improvement can be expected by using physically uncorrelated traits (e.g., fingerprint and iris) than using correlated traits (e.g., voice and lip movement). They provide very high protection against spoofing as it is quite difficult for an imposter to spoof more than one biometric trait simultaneously [15].

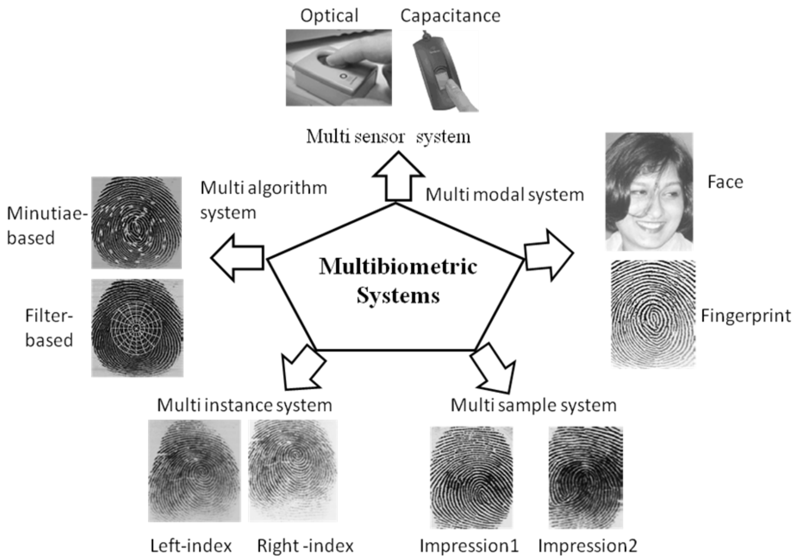

Fig.1 The different types of multibiometric systems[1].

III. LEVEL OF FUSION IN MULTIMODAL BIOMETRIC SYSTEM

Multimodal biometric fusion combines the distinguished aspect from different biometric features to support the advantages and reduce the limitations of the unimodal biometric. The fundamental issue of information fusion is to determine the type of information that should be fused and the selection of method for fusion. The goal of fusion is to devise an appropriate function that can optimally combines the information rendered by the biometric subsystems [15].
In multimodal biometrics, the fusion scheme can be classified as sensor level, feature level, match score level, rank level, and decision level as shown in figure (2). The process can be subdivided into two main categories: prior-to-matching fusion and after matching fusion [16]. Figure (3), shows these fusion levels possibilities at each module[5]. The fuzzy fusion method can be employed in both level prior-to-matching and after matching stage.

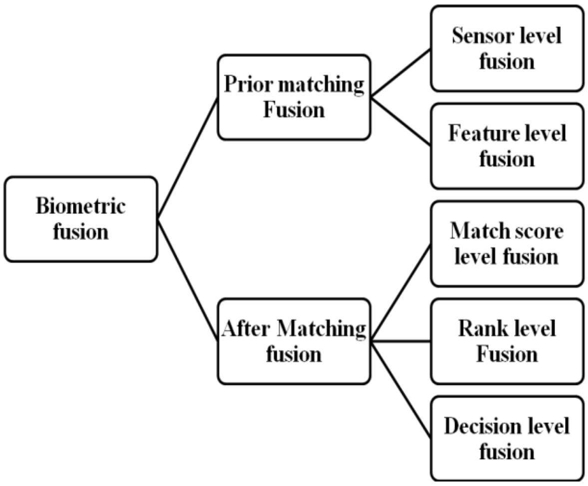

Fig.2 Biometric fusion classification.

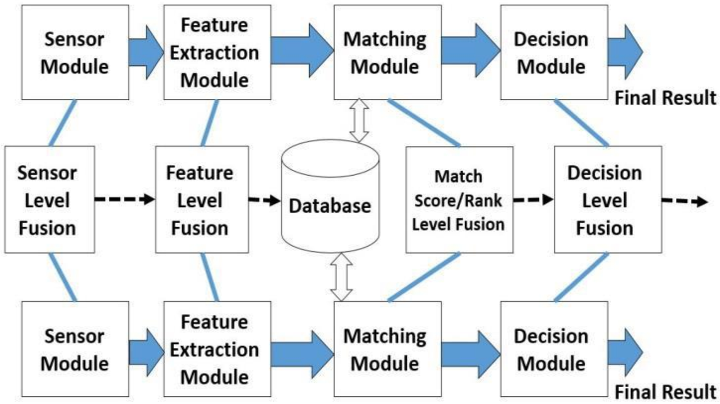

Fig.3 Prior-to-matching and after matching fusion levels related to biometric system modules [5]

A. Prior to Matching Fusion

Fusion in this category integrates evidences before matching. Fusion prior to matching can be achieved with two methods:

Sensor Level Fusion

Sensor level fusion is defined as "the consolidation of evidence presented by multiple sources of raw data before they are subjected to feature extraction" [9]. Sensor level fusion can be performed in two conditions i.e. data of the same biometric trait is obtained using multiple sensors; or data from multiple snapshot of the same biometric traits using a single sensor [17, 18]. This level of fusion is also known as data level fusion or image level fusion.

Feature Level Fusion

Fusion at this level can be applied to the extraction of different features from the same trait or different multi traits. 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 [19, 20].

After Matching Fusion

Fusion in this category integrates evidences of after matching module. Most multimodal biometric systems have been developed using these fusion methods as the information needed for fusion is easily available compared to fusion prior matching methods. Fusion after matching can be achieved with three different ways:

Match Score Level Fusion

In score level fusion, different biometric matchers provide match scores indicating the degree of similarity between the input and template enrolled in the database for each biometric trait. These match scores are consolidated to reach the final recognition decision. Fusion at score level provides the best trade-off between the available information content and convenience of fusion. This is also known as fusion at measurement level or confidence level. Density, transformation, and classifier based score fusion are different methods to achieve this fusion level [21].

The matching scores cannot be used or combined directly; because these scores are from different modalities and based on different scaling methods. Score normalization is required, by converting the scores into common similar domain or scale. This can be carried out with different methods.

Rank Level Fusion

Rank level fusion consolidates multiple ranking lists obtained from several biometric matchers to form a final ranking list which would aid in establishing the final decision [15]. Sometimes, only the final ranked outputs from a biometric system are available. Furthermore, in some biometric systems, the matching scores from the matchers are not suitable for fusion. Thus rank level fusion is a feasible solution in such systems [22]. This type of fusion is relevant in identification systems where each classifier associates a rank with every enrolled identity.

Ho et al. [23] describe three methods to combine the ranks assigned by different matchers. Those are the highest rank method, the borda count method, and the logistic regression method.

Decision Level Fusion

Decision level fusion method consolidates the final decision of single biometric matchers to form a consolidated decision. When each matcher outputs its own class label (i.e., accept or reject in a verification system, or the identity of a user in an identification system), a single class label can be obtained by employing techniques, such as, "AND"/"OR", majority voting, weighted majority voting, decision table, Bayesian decision and Dempster-Shafer theory of evidence[15]. Many biometric systems can only output the final decision, thus decision level fusion is very appropriate for biometric systems. The available information for this fusion method is binary (yes/no in most cases), which allows very simple operations for fusion.

IV. FUZZY FUSSION

Fuzzy logic based fusion, often called fuzzy fusion, uses fuzzy logic. The fuzzy fusion method can be employed in both before matching or after matching stages. When this fusion method is applied in before matching stage, usually it is to reduce the size of the dataset for comparison or matching. This fusion can also be employed in after matching stage to increase the recognition performance and to obtain the level of confidence of the final outcomes.

The method is based on fuzzy logic [24], which is the classic and most widely applied technology in computational intelligence. The fuzzy logic approach enables imprecise information is processed in a way that resembles human thinking, e.g. big versus small, high versus low.

V. LITERATURE REVIEW

Fuzzy fusion method has been widely used in many applications, including automatic target recognition, biomedical image fusion and segmentation, gas turbine power plants fusion, weather forecasting, aerial image retrieval and classification, vehicle detection and classification, and path planning.

In 1999, Solaiman et al. [26] proposed a fuzzy-based multisensor data fusion classifier which was applied to land cover classification. The authors used a Fuzzy Membership Map (FMM) to combine information gathered from multiple sensors. Due to the use of fuzzy concepts, their proposed classifier was ideally suited for integrating multisensor and a priori information and also results in confidence maps.

In 2001 Km et al. authors developed a new vehicle classification algorithm using fuzzy logic [27]. In the algorithm, authors used vehicles' weight and speed to classify different vehicles using fuzzy rules. With their experimental results, they showed that the proposed classification algorithm using the fuzzy logic significantly reduces the errors in vehicle classification.

A 2010 paper [28] proposed a data fusion method based on fuzzy set theory and Dempster-Shafer evidence theory for automatic target recognition. The authors represented both the individual attribute of target in the model database and the sensor observation as fuzzy membership function and constructed a likelihood function to deal with fuzzy data collected with each sensor. At the end, sensor data from different sources was fused based on the Dempster combination rule [29].

In another research on applying fuzzy fusion in the medical imaging research domain, Chaabane and Abdelouahab in 2011 [30] proposed a system of fuzzy information fusion framework for the automatic segmentation of human brain tissues. Their method consisted of the computation of fuzzy tissue maps in both images by using Fuzzy C-means algorithm. Reported results from experiments were encouraging and underlined the potential of the data fusion in the medical imaging field.

In 2010 S. Vasuhi et al.[31] Proposed system based on decision level fusion of fingerprint and voice is found to be highly accurate. The proposed work is successful in overcoming the drawbacks of individual sensors. The level of security is the most important criterion for the biometric sensor, its threshold or match scores will be chosen high value or low FAR. Experiments show that the proposed approach for fuzzy logic authentication is feasible and effective.

In 2013 M. Abdolahi et al.[34] 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%.

VI. CONCLUSIONS

Multibiometric systems are expected to alleviate many limitations of biometric systems by combining the evidence obtained from different sources using an effective fusion scheme. In this paper, description regarding multibiometric system, level of fusions, fuzzy logic fusion. From the study, it reveals that, performance of multibiometric systems can be further improved if an appropriate fusion strategy is used. Review on use of fuzzy logic fusion for multibiometric system concludes that fuzzy logic fusion enhances the results of the recognition, and authentication using fuzzy logic is feasible and effective.

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