A Systematic Analysis of Face and Fingerprint Biometric Fusion

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Abstract: **This paper presents various techniques used for extracting the features of face and fingerprint biometrics. More reliable recognition and performance can be achieved if both face and fingerprint modalities are fused together. The problem in multimodal biometric fusion is that the features of each modality are extracted with different algorithm which makes it difficult to fuse them together. The work presented in this paper focuses on the bimodal biometric system having Gabor filter algorithm for feature extraction as it is capable of extracting the features of both face and fingerprint biometrics. Along with this various techniques used for the fusion of two unimodal modalities have been discussed and it has been found that feature level fusion is best among all as accuracy up to 99.25% can be achieved using Gabor filter. Also the performance characteristics of all the techniques are shown on the basis of FAR (False Acceptance Rate) and FRR (False Rejection Rate) values.**

Keywords: **PCA (principal component analysis), LDA (linear discrminant analysis), ICA (independent component analysis), OPTA (one pass thinning algorithm), Gabor filter, FAR and FRR.**

I. INTRODUCTION

For various reasons like security threats, spoof attacks the area of authentication has got a lot of attention from research community. The demand for practical and reliable authentication systems with ease of access is ever growing. Traditional authentication systems such as token based access, ID cards or passwords do not provide a good discrimination between fake users and authenticate users. Biometric traits can act as a remedy to this problem as these cues cannot be shared or spoofed easily and every person has uniquely discriminating biometric properties [6]. Biometric modalities are attributed to physiological or behavioral characteristics of a person. Currently used biometric traits can be accounted as face, fingerprint, palm print, iris etc. The biometric system is of two types- Unimodal biometric system and Multimodal biometric system.

Unimodal Biometric system depends on single Biometric trait. Single Biometric trait is used for person's identification or verification. However, the performance of a unimodal biometric system is dynamic because of presence of noise and distortions in input signal, variations in background conditions and acquisition devices. For example, face recognition systems suffer heavily due to slight changes in illumination conditions A unimodal biometric authentication system may suffer a spoof attack easily due to their inherent usage of a single information source [16].

Multimodal Biometric system uses multiple physical or behavioral characteristics for person's identification. Multimodal biometric system can be used to overcome the limitations caused by unimodal biometric systems (such as face and fingerprint of a person). Such systems are more reliable due to the presence of multiple, independent pieces of affirmation. These systems are also able to meet the performance requirements imposed by various applications. Multimodal Biometric uses different levels of fusion [6].

A. *Levels of Fusion:* Multimodal biometric systems integrate information presented by multiple biometric indicators. The information can be combined at various levels. Fig. 8 illustrates the three levels of fusion when combining two (or more) biometric systems. These are as follows:-

1) *Fusion at the feature extraction Level:* A feature vector is computed from the data obtained from each biometric modality. If the features extracted from one biometric indicator are independent of those extracted from the other, it is sensible to concatenate the two vectors into a single new vector, provided the features from different biometric indicators are in the same type of measurement scale [16].

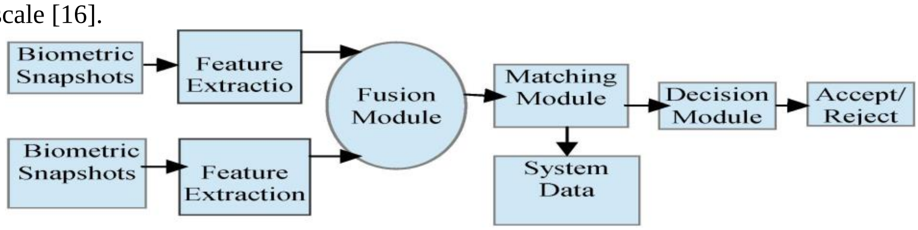

Fig 1: Fusion at the feature extraction level [16]

2) *Fusion at the matching score (confidence or rank) level:* Each biometric matcher provides a resemblance score indicating the closeness of the input feature vector with the template feature vector. Methods such as weighted averaging may be used to combine the matching scores reported by the multiple matchers [6]-[16].

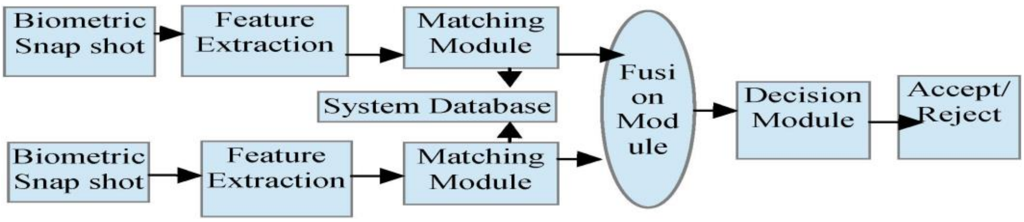

Fig2: Fusion at matching score (confidence or rank) level [16]

3) *Fusion at the decision (abstract label) level:* Each biometric system makes its own recognition decision based on its own feature vector. The final recognition decision is made on the basis of majority vote scheme [6]-[16].

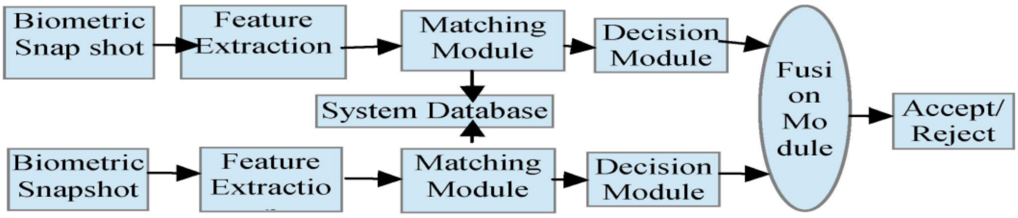

Fig3: Fusion at decision (abstract label) level [16]

Also, a carefully designed combination scheme, that has been trained and tested on a large amount of data, is expected to perform better than the best of the individual ingredient modalities. A combination of uncorrelated modalities (e.g., fingerprint and face) can provide better performance than a combination of correlated modalities (e.g., different fingerprint matchers). Also fingerprint and face modalities have high accuracy in terms of-Accuracy, Convenience, less cost, High practical implementation.

II. RELATED WORK

Literature review is broadly classified into three categories which are as follows:

A. *Face feature extraction algorithm review*

In 2002, G. G. Yen et al. presented genetic algorithm for automatic facial feature extraction.The experimental results shows that the proposed method can automatically extract features from various video images in the presence of a certain amount of artificial noise and faces with different angles of orientation. They proposed that the algorithm can be improved so that it can be applied to real world problem and also to extract features on faces containing either beard or mustache.

In 2002, M. S. Bartlett et al. used independent component analysis (ICA) method for the feature extraction of face images for face recognition. The experimental results express that both ICA representatives were better for representation based on PCA to recognize faces and changes in expression. Also, a classifier used for the combination of two ICA representations gave the best performance.

In 2007, S. Chartier et al. presented in their paper, a new model bidirectional associative memory (BAM) fine architecture that can eventually create its own set of perceptual features. The resulting model was successful for processing of noisy inputs, while being able to achieve principal component analysis (PCA) tasks such as feature extraction and dimensionality reduction. Simulations show that the model performs well as compared to existing neural PCA and ICA algorithms.

In 2010, S. Balakrishnama et al. stated that LDA is one of the most commonly used techniques for data classification and dimensionality reductions. Also LDA can easily handle the situation where the within-class frequencies are unequal and their performance has been analyzed on randomly generated test data. In PCA, the shape and location of the original data set does not alter when converted into a different space, whereas LDA does not change the location, but only allocate more class separability and produces a decision between the given classes.

In 2011, A. Bouzalmat et al. proposed that Compared with the methods such as principal component analysis (PCA) and linear discriminant analysis (LDA), Gabor features contain more inferior information and are thus more robust against variations in illumination, pose and expressions. Also provides decreased FAR and FRR.

B. *Fingerprint Feature Extraction Algorithm Review*

In 1999, C. lee et al. presented a Gabor filter algorithm for directly extracting fingerprint features from gray level images as it does not require any preprocessing of the original images obtained at the sensor level. Also Gabor filter is insensitive to varieties in sensors, skin and able to deal with the degraded images. Recognition can be improved to 97.2%.

In 2002, J. Yang et al. presented a fingerprint feature extraction method in which minutiae are extracted directly from original gray-level fingerprint images and does not require pre processing techniques such as binarization and thinning. Their algorithm improves the performance of the existing ones first; they preprocess the fingerprint images by making use of Gabor filter. Secondly, compute the orientation field which is very crucial in order to detect the ridgelines in the fingerprint images. Third, they determined the starting pixels to trace ridgelines, once a starting pixel in a ridge has been found, the minutiae are achieved.

In 2011, D. Arpit et al. presented a novel ridge tracing approach for extraction of fingerprint features directly from gray scale images. With this method, they made use of information collected during the tracing process to better handle noisy regions. Their experimental results have been compared with other feature extraction algorithms, which clearly show that their approach makes a ridge tracing more robust to noise and makes the extracted features more reliable.

C. *Fusion of extracted features on the basis of various levels*

In 2007, A. Rattani et al. presented the fusion at feature extraction level for face and fingerprint biometrics. The proposed approach is based on the fusion of the two modalities by extracting independent features from the two modalities, and making the two point sets compatible for concatenation. The experimental results show that fusing information from independent sources (face and fingerprint) at the feature level fusion increases the performance as compared to score level and decision level. Computational complexity is more due to different techniques used for extracting features.

In 2013, A. Deshmukh et al. have proposed a multimodal biometric authentication system on Feature level fusion of face and fingerprint images using Gabor filter bank. They have used LDA and PCA framework in their work to avoid that introduces a good discriminating ability. Experimental results of feature level fusion have been showcased against unimodal biometric recognition. The recognition accuracy of 99.25% has been achieved in their work.

In 2014, Telgad R L et al. have proposed the combination approach of Bimodal Biometric system using face and fingerprint images to fusion of score level. The features extracted in the system are used for matching using Euclidian distance matcher. Fingerprint recognition is obtained using minutiae matching and Gabor filter method. And also face features are extracted using PCA for measurement shrinking. Then the matched scores are formalised and fusion of score level is developed in this system.

In 2015, Xiaoxue Y et al. have proposed a multimodal biometric authentication system on decision level fusion of face and fingerprint images using OPTA for fingerprint and Gabor filter for face. The experimental result demonstrates that the established system work safely with the low false acceptance rate FAR and acceptable false rejection rate FRR.

D. Comparison with other feature extraction methods

In this section the Gabor filter based feature extraction is compared to the KFA, LDA, PCA, and KPCA as shown in Table 1 for the face features, Table 2 for the comparison between Gabor filter and minutia based feature extraction for the fingerprint features, and Table 3 presents the results for the fusion of the face and fingerprint modalities using Gabor filter algorithm compared with other forms of feature extraction algorithms.

Table I: Feature Extraction Performance For Face Images

Sr. no.	Author	Algorithm used	Performance
1.	G. G. Yen et al. (2002) [4]	Kernel fisher analysis(KFA) and genetic algorithm	82.35%
2.	M. S. Bartlett et al. (2002) [5]	Independent Component Analysis	83.45%
3.	S. Balakrishnama et al. (2010) [10]	Linear Discriminant Analysis (LDA)	91.18%
4.	S. Chartier et al. (2007) [7]	Principal component analysis (PCA)	97.01%
5.	A. Bouzalmat et al. (2011) [13]	Gabor filter	97.35%

Table II: Feature Extraction Performance For Fingerprint Images

Sr. no.	Author	Algorithm used	Performance
1.	J. Yang et al. (2002) [3]	Minutia based	97.76%
2.	C. lee et al. (1999) [2]	Gabor filter	98.87%

Table III: Feature Extraction Performance For The Face And Fingerprint Fusion.

Sr. No.	Author	Levels of Fusion	Algorithm Used	Far And Frr Values
1.	Telgad R L et al. (2014) [16]	Score level fusion	Fingerprint=minutae matching Face=Gabor filter	FAR=1.03 FRR=4.1
2.	Xiaoxue Y et al. (2015) [17]	Decision level fusion	Fingerprint=OPTA Face=Gabor filter	FAR=0.85 FRR=3.52
3.	A. Rattani et al. (2013) [15]	Feature level fusion	Fingerprint and face=Gabor filter	FAR=0.35 FRR=0.75

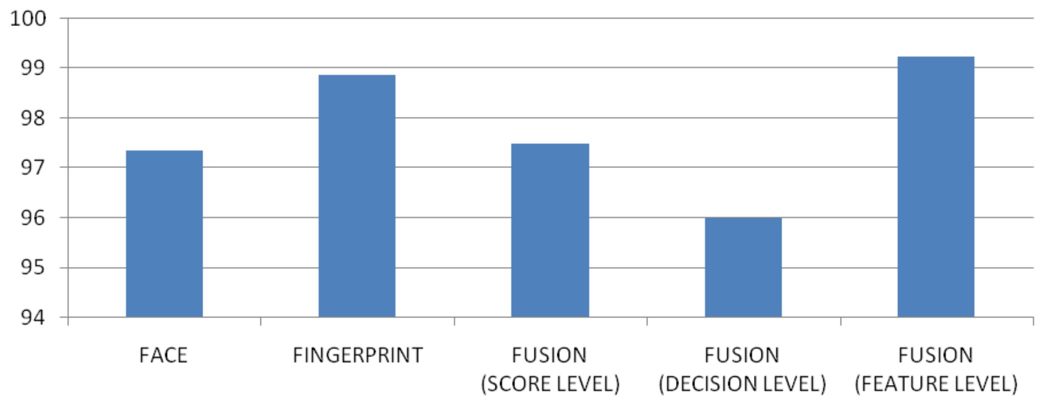

Fig 4: Comparison of face and fingerprint along with their fusion at different levels in terms of accuracy.

From Fig. 4 it can be concluded that comparing with what other researchers have done, the method of fusing face and fingerprint modalities at feature level together using the Gabor filter technique for their feature extraction look more promising.

III. CONCLUSION

From the literature it can be concluded that Gabor filter for feature extraction gives more robust and discriminate information of both face and fingerprint modalities even if the images are degraded as they are invariant to translation, rotation and variation. Face and Fingerprint represent the most widely used and accepted biometric traits, very less methods are present for feature level fusion of these modalities in the literature. The reason is radially different nature of face and fingerprint images. Although there are other methods which also perform better with different characteristics in feature extraction of face and fingerprint images, each of these algorithms cannot be used in extracting both face and fingerprint features at the same time. With fusion of Gabor features for face and fingerprints at feature level, reduces down the values for both FAR and FRR to 0.35% and 0.75% which is lower than decision level and score level fusion.

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