Bimodal biometric system: feature level fusion of iris and fingerprint

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Biometric systems try to impersonate the decisions that humans make for identification and matching. Many millions of people in almost every country are using some kind of biometric for different reasons. India's UID project Aadhaar uses an iris scan along with fingerprints to uniquely identify people and allocate a Unique Identification Number.

Today, all of the United Arab Emirates' land, air and sea ports of entry are equipped with biometric systems. Police forces across the US planned to start using BI2 Technologies' mobile MORIS (Mobile Offender Recognition and Information System) in 2012.

In recent years, biometric recognition is showing considerable improvement in reliability and accuracy, with some biometrics really offering reasonably good overall performance. A wide variety of biometrics underpins technologies that can identify and verify an individual for access control to secured areas and equipment.

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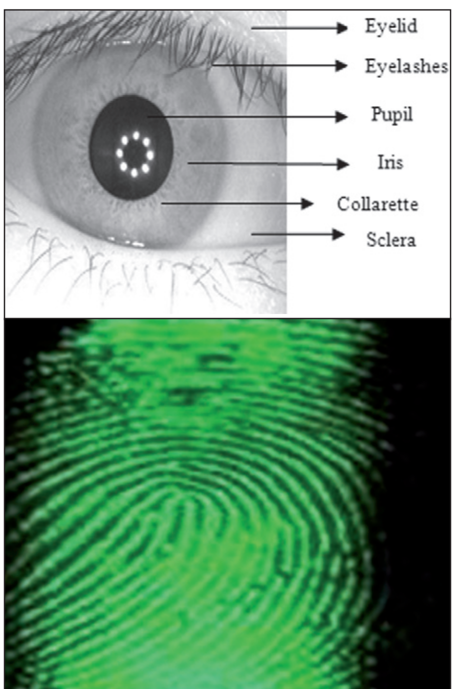
Due to factors such as non-universality, noisy input data, intra variability, limited degree of freedom, and other factors, a large number of advanced biometric systems are still facing a number of problems, which affect the performance, security, and convenience of using such systems.

It is not easy to obtain acceptable recognition using only single mode biometric techniques, especially when they are tested on large-scale databases or in high security areas. To overcome some of the problems of unimodal biometrics, multimodal biometric systems are used. Multimodal biometrics fusion techniques have attracted increasing attention and interest among researchers, due to improved recognition compared to unimodal biometric systems, as multimodal systems provide multiple pieces of evidence of the same identity.

Multimodal research

A lot of work has been done on combining different biometrics, by different researchers, for a variety of purposes, yet not much of that has been focused on the combination of fingerprint and iris, which are two of the characteristics that can reach the best recognition performance for high security applications.

Fingerprint recognition is the most consistent biometric modality in use. Iris is an externally visible yet protected organ whose unique pattern remains stable throughout life.



Combination of iris and fingerprint.

No individual biometric trait provides 100% recognition accuracy. A problem arises when a person is unable to provide an iris image due to problems with light exposure or eye disease. In such cases, an individual cannot be recognised using an iris pattern alone. Likewise, fingerprint recognition may be hampered by the presence of scars and/or cuts. Scars add noise to the image, which cannot be enhanced. With a noisy fingerprint image, the system is unable to extract the minutia points correctly leading to false recognition.

To overcome these limitations of unimodal biometrics, a combination of both iris and fingerprint biometrics would work well. This integrated approach also makes it difficult for an imposter to spoof both traits simultaneously.

In principle, the fusion of any modalities can be performed at three levels: pixel level, feature level, or decision level. So far, most research work on fusion has been done in the highest level, that is the decision level. As a commonly used decision level fusion rule, the "Sum rule" is demonstrated to be most effective in a series of combination schemes.

Feature level fusion is receiving most of the attention nowadays, due to its raw characteristics. A feature extraction method significantly reduces the information needed to represent the content of an image. Choosing the features to be extracted is guided by two concerns:

- The features should carry enough information about the image yet not require any domain specific knowledge to accomplish the processing.
- The computation should not be intensive, so that it will work with large image collections.

This article presents a novel algorithm based on feature level fusion using iris and fingerprint biometrics. Fusion at the feature level involves the integration of feature sets that correspond to multiple modalities. Feature level fusion of biometric traits is a challenging problem in multimodal fusion. However, good feature representation and an efficient solution to issue of dimensionality can ease feature level fusion.

Some of the challenges include:

- It is very hard to fuse multiple biometric at feature extraction level in practice.
- The feature sets are sometime found to be incompatible.
- The dimensionality problem.
- Poor feature representation may degrade the performance.
- Introduces additional processing complexities.

A combination of multi-algorithmic and multimodal approaches would seem to address the issues. The recognition process begins with the iris and fingerprint features being extracted from preprocessed images. There is no universally perfect feature extraction algorithm and a given technique may excel in one application yet underperform in another. Consequently, better and more consistent results can be obtained when multiple algorithms are employed for feature extraction of one modality. So a multi-algorithmic approach is used to extract the features from single modality.

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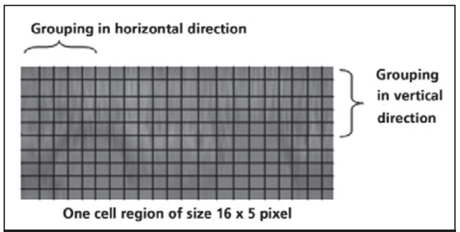
The fingerprint and iris images are preprocessed and then various feature extraction techniques are applied to obtain the feature vectors from the fingerprint and iris images. The deterministic feature sequence is extracted from the iris image by using the Haar wavelet and block sum technique.

The feature extraction from the fingerprint is again performed by two methods: minutiae and wavelet transform.

Fusion module

These four feature sets are then passed to a fusion module. The fusion module consists of three major steps – distance measures, normalisation and fusion – using a simple average sum rule. To determine the similarity of an unknown sample set to a known one, first a Mahalanobis Distance is applied. This is a statistical method that gauges similarity of an unknown sample set to a known one.

Now for these two images (query image and known image) and four feature sets



Block sum method.

(haar, block sum, wavelet and minutiae), the Euclidian distance is found. This distance is normalised and is fused by applying the average sum rule. This fused feature vector can then be trained for classification. These classifiers can be used for pattern recognition or data classification, through a training process. In general, classifiers can produce robust performance when a large amount of feature vectors are available. This classifier is used to declare the person as genuine or imposter.

Feature level fusion of iris and fingerprint

The concatenation of four feature vectors obtained from four different algorithms (two for iris and two for fingerprint) will naturally lead to a significant increase in dimension. The advantage behind the fusion of different modalities is to get a better representation of the subject through varying and complementary details. So, to address this obstacle, we need to find a scheme that keeps the complementary information and a reduced dimension feature vector. An algorithm for feature level fusion: Let Ii = Ii1, Ii2, ...Iin and Ij = Ij1, Ij2, ...Ijm represent the feature vectors of the iris by haar wavelet and block sum method. Then let Fi = Fi1, Fi2, ...Fin and Fj = Fj1, Fj2, ...Fjm represent the feature vectors of the fingerprint by wavelet transform and minutiae, respectively.

The application of Mahalanobis Distance will find the feature vectors stored in the database that are similar to the query image feature vectors. Mahalanobis Distance is an effective distance measure when it comes to pattern recognition problems. It uses the covariance between the variables and hence removes the problems related to scale and correlation. The dissimilarity between the iris and fingerprint of the same images is smaller compared to the images of different eyes and fingerprint.

Let MIi, MIj, MFi and MFj be the Mahalanobis Distance generated by comparing Ii, Ij, Fi and Fj (which we consider the query image feature vector) with the feature vectors of the rest of images stored in the database.

After obtaining these similar feature vectors, we again find the Euclidian distance between query image feature vectors and the most similar feature vectors stored in database, represented as EIi, EIj, EFi and EFj.

The normalised feature vectors NIi, NIj, NFi and NFj are obtained by applying Tanh (TH), to have all the vectors in same numerical scale. This distance is now fused to obtain a final fused vector, Zfusion = (NIi + NIj + NFi + NFj) / 4, using the average sum rule.

Acceptance and rejection

In this feature level fusion, two distance measures are important in distinguishing genuine and impostor pairs:

- Mahalnobis Distance
- Euclidian Distance

In a real application, a person can be identified as genuine user or an imposter. Thus there are two possible types of error: a genuine user is rejected by the system or imposters are accepted by the system. The two types of error rates are FAR (false acceptance rate), which is the number of false acceptances/number of impostor attempts – in most biometrics this error rate is high – and FRR (false rejection rate), which is the probability of rejecting an authorised user. EER (equal error rates) occur where FAR is equal to FRR.

For better performance of multimodal biometric recognition, the EER value should be low. To achieve this we have to select a logical threshold, so that the performance of the system can be adjusted.

The results in this research for integrated iris and fingerprint identification at feature level show a substantial performance improvement to those involving a single biometric.

About the author

Ujwalla Gawande received her BE degree in Computer Technology from KITS Ramtek, Nagpur in 2001 and M Tech degree in Computer Science and Engineering from GHRCE, Nagpur in 2007. She is currently working as a lecturer in Computer Technology department, Yeshwantrao Chavan College of Engineering, Nagpur. She received best paper award in ICSCI 2008. Her areas of interest are digital image processing, neural network and fuzzy logic, artificial intelligence, computer graphics. Mukesh Zaveri is based at the Department of Computer Engineering, Sardar Vallabbhai National Institute of Technology, Surat, Gujarat, India. Avichal Kapur is based at the Department of Electronics Engineering, Nagar Yuwak Shikshan Sanstha, Nagpur,