Fusion of Face and Palmprint for Personal Identification Based on Ordinal Features*

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1. Introduction

Unimodal biometric systems, relying on the evidence of a single source of biometric information for authentication, have been successfully used in many different application contexts, such as airports, passports, access control, etc. However, a single biometric feature sometimes fails to be exact enough for verifying the identity of a person. By combining multiple modalities, enhanced performance reliability could be achieved. Due to its promising applications as well as the theoretical challenges, multi-modal biometrics has drawn more and more attention in recent years [1].

Face and palmprint multimodal biometrics are advantageous due to the use of non-invasive and low-cost image acquisition. We can easily acquire face and palmprint images using two touchless sensors simultaneously. Existing studies in this approach [2, 3] employ holistic features for face representation, and results are shown with small data sets (less than 100 subjects) were reported. Note that holistic features are sensitive to global variation, such as illumination and inaccurate alignment.

It is believed that the human vision system uses a series of levels of representation, with increasing complexity. A recent study on local appearance based object recognition [4] shows that features of intermediate complexity are optimal for basic visual task of classification. We consider a class of simple local features, that of ordinal relationship. Ordinal features are defined based on the qualitative relationship between two image regions and are robust against various intra-class variations. Ordinal features have been used for recognition of palmprints [5] and faces [6].

In this paper, we present a face+palmprint multimodal biometric identification method and system to improve the identification performance. Effective classifiers based on ordinal features are constructed for faces and palmprints, respectively. Then, the matching scores from the two classifiers are combined using several fusion strategies. Experimental results on a middle-scale data set have demonstrated the effectiveness of the proposed system.

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2. Ordinal Features

Ordinal features come from a straightforward concept that we often use. For example, we could easily rank or order the heights or weights of two persons, but it is hard to answer their precise differences. For computer vision, the absolute intensity information associated with an face can vary because it can changes under various illumination settings. However, ordinal relationships among neighborhood image pixels or regions present some stability with such changes and reflect the intrinsic natures of the object.

An ordinal feature encodes an ordinal relationship between two concept. Figure 1 gives an example in which the average intensities between regions A and B are compared to give the ordinal code of 1 or 0. Ordinal features are efficient to compute. According to the spatial relationship between image regions, Ordinal measure can be classified into two categories, local ordinal measure [5] and non-local ordinal measure [6].

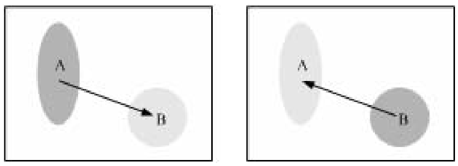

Figure 1. Ordinal measure of relationship between two regions. An arrow points from the darker region to the brighter one. Left: Region A is darker than B, i.e. $A \prec B$. Right: Region A is brighter than B, i.e. $A \succ B$.

3. Multimodal Biometric System Using Ordinal Features

Figure 2 shows the block diagram of the proposed multimodal biometric system based on the fusion of face and palmprint at the matching score level. Firstly, effective face and palmprint ordinal features are extracted for matching. By comparing with the templates stored in the database, the matching scores of each classifier are generated. For these two modalities, the classifiers are constructed using the methods proposed in our previous works [5, 6]. Then, the scores output from the two classifiers are combined using several fusion strategies to give a unique matching score. Finally, a decision about whether to accept or reject a user is made.

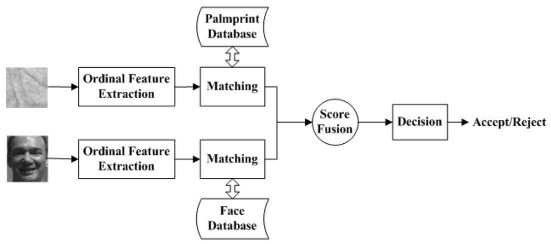

Figure 2. Block diagram of face and palmprint multimodal biometric system.

In our multimodal biometric system, the fusion is performed at the matching score level. There are two approaches for consolidating the scores obtained from different matchers. One is to formulate it as a combination problem and use simple fusion rules, such as sum, product, max and min rule, to combine the two matching scores and compare the result to a threshold. To ensure a meaningful combination of the scores from different modalities, the scores must be first transformed to a common domain prior to combining them. This is known as score normalization. The following normalization techniques are used: simple Min-Max, Z-Score and Hyperbolic tangent (Tanh). The other approach is to formulate it as a classification problem and treat the matching scores of different modalities as a feature vector and use linear discriminant analysis (LDA) to classify the vector as being genuine or an impostor.

4. Experiments

We evaluate the proposed multimodal system on a data set including 7560 pairs of images from 378 subjects. We randomly pair face and palmprint to obtain a multimodal dataset for each of these 378 subjects. Each pair contains 20 face images and 20 palmprint images. We divide the dataset into two partitions. The first 3780 pairs of images, including 189 subjects, are used for training and the rest for testing. Therefore, there are totally 35,910 intra-class (genuine) samples and 7,106,400 extra-class (impostor) samples in both training and testing set.

As for palmprint matching [5], a training procedure is actually not required. Each of palmprint image was directly used to obtain a characteristic. While for face matching [6], each of the image was filtered by 24 ordinal filters. Local subwindow of ordinal features are used to construct weak classifier based on Hamming distance for AdaBoost Learning. Finally a strong classifier, consisting of 2014 weak classifiers, is obtained. For comparison, the holistic feature based (i.e., PCA-based here) method [3] is also evaluated using the same set of training and test images.

The comparative experimental results are shown in Table 1. Two measurements are employed. One is the equal error rate (EER), the other is the d' (d-prime). Where d' is a statistical measure of how well a biometric system can discriminate between different individuals. The larger the d' value is, the better a biometric system performs at discriminating between individuals. The results suggest that the multimodal biometrics can offer substantial performance gain. In addition, as we analyzed, local features, for instance ordinal features here, are experimentally illustrated to be superior to the holistic features. Moreover, they are not only good for improving the performance of face and palmprint classifiers but also good for the fusion schemes.

Table 1. Comparison of accuracy measures for different classifiers

Algorithm	Score normalization	Proposed method		PCA-based method	
		EER (%)	d'	EER (%)	d'
Face	-	1.160	4.403	14.88	1.971
Palmprint	-	0.160	6.081	3.66	3.970
Sum rule	Min-max	**0.028**	**7.391**	**2.03**	4.115
	Z-Score	0.032	7.364	2.65	3.672
	Tanh	0.032	7.372	2.70	3.674
Product rule	Min-max	0.067	5.771	3.27	3.113
	Z-Score	0.091	4.036	8.19	1.956
	Tanh	0.032	7.282	2.72	3.648
Max rule	Min-max	0.220	5.449	3.45	**4.146**
	Z-Score	0.056	6.280	2.98	3.584
	Tanh	0.056	6.290	2.96	3.586
Min rule	Min-max	0.150	6.751	3.66	2.072
	Z-Score	0.160	5.555	3.66	2.798
	Tanh	0.150	5.559	3.67	2.798
LDA rule	-	0.044	7.124	2.18	3.926

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