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Selection of optimized features and weights on face-iris fusion using distance images

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ABSTRACT

The focus of this paper is on proposing new schemes based on score level and feature level fusion to fuse face and iris modalities by employing several global and local feature extraction methods in order to effectively code face and iris modalities. The proposed schemes are examined using different techniques at matching score level and feature level fusion on *CASIA Iris Distance* database, Print Attack face database, Replay Attack face database and IIIT-Delhi Contact Lens iris database. The proposed schemes involve the consideration of Particle Swarm Optimization (PSO) and Backtracking Search Algorithm (BSA) in order to select optimized features and weights to achieve robust recognition system by reducing the number of features in feature level fusion of the multimodal biometric system and optimizing the weights assigned to the face-iris multimodal biometric system scores in score level fusion step. Additionally, in order to improve face and iris recognition systems and subsequently the recognition of multimodal face-iris biometric system, the proposed methods attempt to correct and align the location of both eyes by measuring the iris rotation angle. Demonstration of the results based on both identification and verification rates clarifies that the proposed fusion schemes obtain a significant improvement over unimodal and other multimodal methods implemented in this study. Furthermore, the robustness of the proposed multimodal schemes is demonstrated against spoof attacks on several face and iris spoofing datasets.

1. Introduction

Currently, the identification and verification of human beings based on physical or behavioral characteristics is a trend in places with high security needs. In general, most biometric systems in the real time applications use a single biometric characteristic; unimodal biometric is suffered due to different factors such as lack of uniqueness, non-universality and noisy data [1]. For instance, variations in terms of illumination, pose and expression lead to degradation of face recognition performance [1]. Performance of iris recognition can be degraded in non-cooperative situations [2]. In order to solve the problem raised by the single trait, multimodality that is extracting information from multiple biometric traits can be applied as a remedy and ultimately causes to improve the performance of biometric systems.

In this study, face and iris biometrics are used to fuse the information because of many similar characteristics of these two modalities. Information fusion for multimodal biometric systems can be performed at four different levels: sensor level, feature level, matching score level and decision level fusion [1]. Due to the ease in accessing and combining the scores, matching score fusion level is more popular among all fusion levels and involves three different categories. The first category is Transformation-based score fusion where normalization of matching scores into a common domain is needed prior to combining due to incompatibility of different modalities feature set. Classifier-based score fusion is the second category that concatenates the scores from different systems. In fact, the scores from different classifiers are treated as a feature vector where each matching score is considered as an element of feature vector. Finally, the third category is Density-based score fusion that requires an explicit estimation of genuine and impostor matching score densities leading to an increase in implementation complexity [3]. Current researchers' studies [3,4] can be used as an evidence to state that employing score fusion techniques such as Sum Rule and Weighted-Sum Rule with a proper score normalization method leads to an unprecedented improvement on unimodal biometric systems performance. On the other hand, feature level fusion [43,44] considers the original feature sets of different modalities and therefore contains richer information

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about the raw biometric data compared to matching score level fusion and may lead to performance improvement. However, concatenating the feature sets may cause high dimensionality problem and produces noisy or redundant data; consequently affecting the performance [5]. In this respect, feature selection can be considered as a solution to enhance the performance of biometric systems by selecting an optimized subset of features from the original feature set based on a certain objective function.

In this study, effect of several techniques in different fusion levels is investigated on the proposed schemes using face and iris modalities. Local and global feature extraction methods namely subpattern-based PCA (spPCA) [6], modular PCA (mPCA) [7], Local Binary Patterns (LBP) [8], Principal Component Analysis (PCA) [9] and subspace Linear Discriminant Analysis (LDA) [10] are employed on face images in this study. For iris recognition, a publicly available library implemented by Masek and Kovesi [11] is applied to extract iris features. In order to evaluate the proposed schemes, *CASIA Iris Distance* [12] database, Print Attack face database [38], Replay Attack face database [39] and IIIT-Delhi Contact Lens iris database [40] are used. *CASIA-Iris-Distance* images were captured by a high resolution camera, so both dual-eye iris and face patterns are included in the image region with detailed facial features for multimodal biometric information fusion [12]. The Print-Attack Replay Database consists of 200 video clips of printed-photo attack attempts to 50 clients, under different lighting conditions and 200 real-access attempt videos from the same clients [38]. On the other hand, Replay-Attack Database consists of 1300 video clips of photo and video attack attempts to 50 clients, under different lighting conditions [39]. IIIT-Delhi Contact Lens iris database consists of 6570 iris images pertaining to 101 subjects. Both left and right iris images of each subject are available in this database. Iris images are captured using two iris sensors namely; Cogent dual iris sensor and VistaFA2E single iris sensor [40]. In this study, as a unimodal system, all five local and global methods are applied on face images of the database and both left and right irises of the corresponding face image are considered to extract iris features by using Masek & Kovesi iris recognition system. As a multimodal biometric system, the proposed scheme involves consideration of all face and both left and right iris scores along with Particle Swarm Optimization (PSO) [13] and Backtracking Search Algorithm [41] to select the optimized subset of features and weights. In order to enhance the accuracy of face and iris unimodal and multimodal systems, face images are detected and aligned based on the center position of both left and right eyes. Indeed, by using the center positions, angle of head roll and iris rotation can be measured to align the face images and rotate back the iris patterns. Prior to fusion, tanh normalization [14,15] is applied on the face and iris scores to transfer the scores into a common domain and range. The fusion of the two modalities, face and iris, is then tested with a well known combination method namely Weighted Sum Rule [5]. The proposed schemes are also tested on several spoofing attacks to show the robustness of the multimodal fusion schemes. In general, spoofing attacks [45–47] include cheating on biometric traits in order to have unauthorized access to the biometric system. Since it is not needed to have any specific knowledge on the system for spoofing, such as the feature extraction or matching algorithm used, the chance of having a spoofing attack on the biometric system is high. Therefore, constructing a robust multimodal system against spoof attacks is very important for the security of biometric systems. There are several ways to spoof face images such as: (i) face spoofing through photograph, (ii) face spoofing through video or (iii) 3D face model or mask of a genuine user. The most common, the cheapest and the easiest way to spoof face images is face spoofing through photograph or video. Spoofing attacks through photograph, known as 'photo-attacks' consist of submitting a photograph of a legitimate user to the face recognition system displayed in hard copy or on the screen of a portable computer or smart phone [45–47]. On the other hand, there are different methods to spoof iris images also. Some of the ways for iris spoofing can be stated as (i) iris spoofing through pupil dilation, (ii) iris spoofing through textured contact lenses and (iii) iris spoofing through print attack [48].

The proposed face-iris multimodal scheme is presented and compared with the existing unimodal and multimodal biometric systems in this study using Receiver Operator Characteristics (ROC) curves and Genuine Acceptance Rate (GAR). GAR at false acceptance rate (FAR 0.01%) is used to demonstrate the verification performance and recognition rate is also used to show the identification performance.

The contribution of our work is to use left and right iris patterns with optimized features of local and global based facial feature extraction methods using PSO and BSA to remove redundant data for the fusion of face-iris multimodal system with tanh score normalization and Weighted Sum Rule fusion method where the weights are also optimized using PSO and BSA. The proposed scheme can be used practically in person identification and verification systems using facial images. The iris information from left and right eye can be extracted from the face image of the same individual and the fusion of face-iris multimodal system can be performed to improve the performance of the individual face and iris recognition systems. In fact, recognition is performed on fusion of face and both of the eyes' iris patterns and therefore the verification becomes undisputable.

The organization of the paper is as follows. Section 2 describes unimodal biometric systems. Section 3 has an overview on the fusion of face and iris biometrics at feature level and score level fusion. The proposed schemes are explained in Section 4 while Section 5 is devoted to the database details, experiments and results. Finally, Section 6 draws some conclusions.

2. Unimodal biometric systems

Face and iris biometrics are considered in this study to construct the structure of the unimodal and consequently multimodal system. Generally, face recognition and iris recognition are considered as one of the most attractive areas for biometric schemes in the past few years [30–36]. These biometrics are briefly described in the following subsections.

2.1. Face biometrics

The common processing steps for unimodal face system are image preprocessing, training, testing and matching. The illumination effects of face images are reduced by applying histogram equalization (HE) and mean-and-variance normalization (MVN) [16] on facial images in preprocessing step. The facial features are then extracted in the training and testing stages to be examined by different techniques in matching score level fusion, feature level and/or combination of both fusion levels. Finally in the last step, in order to compute the matching score between train and test feature vectors, Manhattan distance measurement is applied.

The face databases used in different experiments of this study include several variations in images. Pose variations, illumination variations, facial expressions, distance images and occlusions due to glasses, mustache and beard are the variations that appear in the facial images. The availability of these variations on the facial databases used in this study is demonstrated in Table 1. In addition, identification accuracies of the state-of-the-art methods used in this study such as PCA, LDA, spPCA, mPCA and LBP are shown in that comparative table on the facial databases used in this study. Identification accuracies of the state-of-the-art methods are also