Using Genetic Algorithms to Improve Matching Performance of Changeable biometrics from Combining PCA and ICA Methods

MinYi Jeong, Jeung-Yoon Choi, and Jaihie Kim
Biometrics Engineering Research Center (BERC)
School of Electrical and Electronic Engineering
Yonsei University
Republic of Korea
(myjeong, jychoi, jhkim@yonsei.ac.kr)

Abstract

Biometrics is personal authentication which uses an individual’s information. In terms of user authentication, biometric systems have many advantages. However, despite its advantages, they also have some disadvantages in the area of privacy problems. Changeable biometrics is solution to problem of privacy protection. In this paper we propose a changeable face biometrics system to overcome this problem. The proposed method uses the PCA and ICA methods and genetic algorithms. PCA and ICA coefficient vectors extracted from an input face image were normalized using their norm. The two normalized vectors were transformed using a weighting matrix which is derived using genetic algorithms and then scrambled randomly. A new transformed face coefficient vector was generated by addition of the two weighted normalized vectors. Through experiments, we see that we can achieve performance accuracy that is better than conventional methods. And, it is also shown that the changeable templates are non-invertible and provide sufficient reproducibility.

1. Introduction

The idea of maintaining security by the use of knowledge-based authentication and token-based authentication has been used to restrict access in many applications. Biometric systems [1] refer to personal authentication methods that use individual information from a given person’s fingerprints, face, iris, palmprints or voice. Biometric systems provide a greater degree of security than traditional authentication methods. However, biometric systems have identity theft problems in that a person’s private information is revealed in biometrics which are non-revocable. Privacy problem occurs because biometric information is unique and cannot be easily changed as in traditional authentication methods.

Changeable biometrics [2] aims to provide a solution by an alternative to problems of biometric systems. Changeable biometrics use transformed biometric data instead of the original biometric data for identifying a person. When templates of the biometric data are found to be compromised, it can be transformed and a new template can be regenerated. For changeable biometric systems, transformed biometric data should not be easily converted back to the original biometric data even if the transformation method and the transformed biometric data are known. This is called non-invertibility. Changeable biometrics should be able to generate numerous different templates of transformed biometric data from the original data. This is called reproducibility. And, after transformation, the recognition rate must not be much lower than the original recognition rate. Ideally, the methods should provide better recognition rates.

Several researches have been done on changeable biometric systems for the face [3]. Ratha et al. [4] proposed a morphing method for changeable biometrics. New biometric data are generated by a new morphing function when the transformed biometric data are compromised. For changeable biometrics authentication, Savvides et al. [5] proposed a method using random kernels and MACE (Minimum Average Correlation Energy) filters. They create a transformed training image using a face image and a random kernel, and the training images are used to create the MACE filter. A test image is convolved with the same random kernel and the convolved test image is cross-correlated with the MACE filter. Teoh et al. [6][7] proposed a method called BioHashing. In this method, an extracted feature vector is projected onto a random vector basis. The random basis is found using the Gram-Schmidt procedure. And, a value of 0 or 1 is determined using an arbitrary threshold. Kang et al. [8] proposed a changeable face biometric by combining PCA and a Password-Based Key Derivation Function (PBKDF) method. The transform function is created from a PBKDF and PCA coefficients are...
transformed by this transform function. The biometrics features are implemented by the transform function and stored in an authentication system. Jeong et al. [3] proposed generation of changeable face biometrics template by combining two different appearance based methods. This method generates transformed templates by addition of the coefficients of the normalized and scrambled PCA and ICA coefficients.

In existing works on changeable biometrics, less emphasis has been placed on the performance of these methods. In this paper, we attempt to provide privacy protection along with enhanced recognition accuracy of a changeable biometric authentication system.

The organization of this paper is as follows. In Section 2, we describe the proposed method for changeable face biometrics. In Section 3, experimental results from using the proposed method are shown. And, in Section 4, the conclusion and future work are presented.

2. Changeable biometrics for appearance based face recognition

We propose changeable face biometrics by combining two coefficients using appearance based method [9, 10, 11], specifically PCA (Principal Component Analysis) [10] and ICA (Independent Component Analysis) [11], but other appearance-based methods can be applied in the same way. The main idea of the proposed method is to generate transformed coefficients by addition of the scrambled coefficients of the weighted PCA and weighted ICA coefficients. We refer to Jeong et al. [3] for our proposed method. This method consists of combining two different coefficients, and satisfies the condition of changeable biometrics, along with maintaining the matching performance, but no efforts were made to improve the recognition rates. In this paper, to increase matching performance, we propose generation of a weighting matrix which is added to Jeong’s method. Fig. 1 shows the overall block diagram of the face recognition system using the proposed method.

2.1. Normalization

In the first step, using PCA and ICA, an n-dimensional PCA coefficient vector \( \mathbf{P}=[P_1, P_2, P_3, \ldots, P_N] \) and ICA coefficient vector \( \mathbf{I}=[I_1, I_2, I_3, \ldots, I_N] \) are extracted from an input face image. The range of PCA and ICA coefficient values are quite different. Therefore the two coefficient vectors are normalized using their norm as follows:

\[
p = \frac{\mathbf{P}}{||\mathbf{P}||} = [p_1, p_2, p_3, \ldots, p_N],
\]

\[
i = \frac{\mathbf{I}}{||\mathbf{I}||} = [i_1, i_2, i_3, \ldots, i_N],
\]

where \( ||\mathbf{P}|| \) and \( ||\mathbf{I}|| \) denotes the L2 norm of vector \( \mathbf{P} \) and \( \mathbf{I} \).

2.2. Weighting the normalized coefficient vectors

Here, we propose a weighting method for performance enhancement. In our algorithm, the fitness values are the EER (Equal Error Rate) results of each of the input PCA and ICA algorithms. Then, in terms of training, weighting vectors for the PCA and ICA coefficients are obtained by genetic algorithms [12, 13, 14]. Genetic algorithms are stochastic search techniques guided by the principles of evolution and natural selection. A genetic algorithm applied to an optimization problem is an iterative procedure to heuristically search the optimal solution of the
problem. It combines survival of the fittest among feasible solutions, and a randomized formation exchange to form a search algorithm. This method therefore searches the weighting vector for higher performance, so that the matching performance obtains a minimized EER by finding an optimized weighing matrix using the genetic algorithm.

First, we create a vector that consists of arbitrary initial numbers as a population from random values, then evolves through succeeding generations. The size of this initial vector is \( n \), where \( n \) is the size of the basis dimension. The initial vector is then multiplied by a previously trained coefficient set (PCA or ICA). This vector is the weighting vector of the first stage. Using the first stage weighting vector, performance of training data is evaluated by the objective function. The weighting vector is updated in accordance with the methods of genetic algorithm such as inheritance, mutation, natural selection, and crossover.

In this way, the updating weighting vector is generated by an optimized new value, and performance is evaluated using this new weighting vector. An optimized weighting vector which minimizes the error rate is found by the fitness evaluation after many repetitions. Finally, an optimized weighting vector is saved in the database and it is used as a weighting vector multiplied by each coefficient (PCA or ICA coefficient) for changeable biometrics. We define weighted coefficient vectors as follows:

\[ a_p = [\alpha_1 \times p_1, \alpha_2 \times p_2, \cdots, \alpha_n \times p_n] \]
\[ b_i = [\beta_1 \times i_1, \beta_2 \times i_2, \cdots, \beta_n \times i_n] \]

This phase is completed through sufficient experiment using the training database, similarly to creating the appearance based method basis. Therefore, an optimized weighting vector need not be re-processed for updating even if a new member is added.

2.3. Scrambling the weighted normalized coefficient vectors

Next, each weighted coefficient vector is randomly scrambled, where the scrambling rule is determined by a user ID. We define the two scrambling functions \( S_{ID}^{PCA}(\cdot) \) and \( Z_{ID}^{ICA}(\cdot) \). \( S_{ID}^{PCA}(\cdot) \) is a function for scrambling the weighted normalized PCA coefficient vector \( p \), and \( Z_{ID}^{ICA}(\cdot) \) is a function for scrambling the weighted normalized ICA coefficient vector \( i \). The scrambled PCA and ICA coefficient vectors are given by:

\[ (a_p)^* = S_{ID}^{PCA}(a_p) \]
\[ (b_i)^* = Z_{ID}^{ICA}(b_i) \]

When the transformed coefficient vector is compromised, new transformed coefficient vectors can be generated by replacing the new scrambling rule. Therefore, this method satisfies sufficient reproducibility.

2.4. Addition between weighted normalized coefficient vectors

Finally, the transformed face coefficient vector is generated by adding the weighted scrambled PCA and ICA coefficient vectors as follows:

\[ c_{ID} = (a_p)^* + (b_i)^* \]

One of the conditions for changeable biometrics is that transformed biometric data should not be able to be converted back to the original biometric data even if an attacker knows both the transformed biometric data and the transforming method. Because the PCA coefficient vector \( p \) and the ICA coefficient vector \( i \) are not stored in the proposed method, an attacker cannot know the PCA coefficients nor the ICA coefficients. It is difficult to recover the PCA and ICA coefficients from the transformed coefficients \( c_{ID} \). Therefore, this method satisfies the non-invertible condition.

3. Experiments

In this section, experimental analysis is presented in terms of matching performance. In our experiments we used the AR Face database [15] to evaluate matching performance. We used 672 frontal facial images for a total of 6 different images per subject without occlusion and illumination changes. Each image consisted of a 56 by 46 array of pixels. The number of images used for training and testing was both 336 for each of the 56 subjects, respectively. Fig.2 shows example images from the AR database.
We used the Euclidean distance for a dissimilarity measurement and EER for recognition accuracy. We show the recognition rate as the number of dimensions is changed from 300 to 20 at intervals of 20. In this experiment, we compared the performance using PCA, ICA, Jeong’s method [8], and the proposed method. The experimental results of Jeong’s method and the proposed method have multiple instances for each simulation because the scrambling function is randomly changed. Therefore we conducted a total of 100 experiments for each case, and averaged the recognition rate for experimental results. We used an evaluation function in the Genetic Algorithm Optimization Toolbox (GAOT) [16] to search for the optimal weighting matrices.

Fig. 4 shows EER results as the number dimensions of the coefficient vector varies. The experimental results show that EER of the proposed method is better than conventional PCA, ICA based methods or Jeong’s method. Also Fig. 5 shows the ROC curve in 120 dimensions in the case of the best EER result. These results show the effectiveness of the matching performance driven transformation of the proposed method.

4. Conclusion

In this paper, we proposed a changeable biometric system for face recognition. The main idea is to scramble weighted PCA and ICA coefficient vectors and to find an addition of the two vectors. Weighting values for PCA and ICA coefficients are generated by genetic algorithms. Experimental results show that this method is shown to improve recognition accuracy compared with conventional methods. By changing the scrambling method in the transform function, we can generate numerous face templates for changeable biometric systems. And, since this method is non-invertible because the transformed template is generated by the addition of two vectors, the original PCA and ICA coefficients cannot be recovered from the transformed coefficients. Therefore, the proposed method also satisfies the condition that changeable biometric systems protect privacy and security.

ACKNOWLEDGEMENTS

This work was supported by the Korea Science and Engineering Foundation (KOSEF) through the Biometrics Engineering Research Center (BERC) at Yonsei University.

References


