Neurocomputing 148 (2015) 294–309

Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

Sequential Subspace Estimator for biometric authentication

Obaidul Malek *, Anastasios Venetsanopoulos, Dimitrios Androutsos, Lian Zhao

Electrical and Computer Engineering, Ryerson University, Toronto, Ontario, Canada

ARTICLE INFO

Article history:
Received 7 August 2013
Received in revised form
26 February 2014
Accepted 30 June 2014
Communicated by M.-J. Er
Available online 17 July 2014

Keywords:
Biometric authentication
Image subspace
Kalman filter
PCA
Sequential estimator

ABSTRACT

The principal challenge in biometric authentication is to mitigate the effects of any interference while extracting the biometric features for biometric template generation. Most biometric systems are developed under the assumption that extracted biometrics and the nature of their associated interferences are linear, stationary, and homogeneous. The performance of biometric authentication deteriorates when the underlying assumptions are violated due to nonlinear, nonstationary, and heterogeneous noise. Therefore, a more sophisticated filtering method needs to be developed to deal with these challenges.

In this paper, a new Sequential Subspace Estimator (SSE) algorithm for biometric authentication is proposed. In the proposed method, a sequential estimator is being designed in the image subspace which addresses the challenges due to nonlinear, nonstationary, and heterogeneous noise. Furthermore, the proposed method includes a subspace technique that overcomes the computational complexity associated with the sequential estimator. The theoretical foundation of the proposed method along with the experimental results is also presented in this paper. For the experimental evaluation of the proposed method, we use facial images from two public databases: the "Put Face Database" and the "Indian Face Database". The experimental results demonstrate the superiority of the proposed method in comparison with its counterparts.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Biometric technology is a science that statistically analyzes human biological characteristics. Face and fingerprint physiologies have been used as the most reliable characteristics to authenticate a known or an unknown individual since the beginning of civilization. Over the last few decades, however, the concept of authenticating a known individual based on their behavioural characteristics such as gait and voice has also become popular [1]. Hence, biometric systems became measures of both human physiological and behavioural characteristics. These characteristics need to be unique and irrevocable for an individual. The fundamental architecture of the biometric is based on the extraction of these physiological and behavioural features, as well as their uses for its intended purpose. Biometric authentication is an automated computer-aided algorithm for authenticating an individual based on these features; thus checking the legitimacy of a known or an unknown individual. Depending on the application context, a biometric authentication system can operate in either an identification mode or a verification mode [1,2].

A biometric system often encounters situations that involve manipulation of a very large number of datasets (features). Robustness and performance of the authentication algorithm is largely dependent on the quality of information in these extracted features; its intra-class similarities and interclass variations. However, it is very likely that the subset of the extracted data is highly correlated and contaminated by the noise. Thus, it introduces computational complexity, redundancy and deteriorates efficiency and performance of the overall authentication system. In most cases, extracted biometric features and their associated interferences are considered as linear, stationary, and homogeneous. The performance of the system deteriorates when these underlying considerations are violated. Therefore, a vital issue of biometrics is the development of an efficient authentication algorithm that addresses the aforementioned deficiencies [2,3].

The most commonly used method for biometric authentication, especially for facial biometrics, is the Principal Component Analysis (PCA) [4]. Generally, it is a linear transformation under the supposition that an adequate number of independent and identically distributed (i.i.d) data is present in the received dataset. PCA is an optimal method under the assumption that the operating environment is linear, time-invariant, and homogeneous. But, in a realistic operating environment it is very likely that the data model is contaminated by nonlinear, nonstationary, and heterogeneous noise. This leads to a higher probability for the characteristics of the dataset to deviate from the underlying assumptions. In this situation, generated output from the PCA-based technique

* Corresponding author.

http://dx.doi.org/10.1016/j.neucom.2014.06.074
0925-2312/© 2014 Elsevier B.V. All rights reserved.

preserves misleading data which severely distorts the data model. This distorted data model in turn affects the detection, recognition, and authentication accuracy. Thus, a more complex system needs to be designed so the system can adapt to challenges due to noise contamination [5,6].

Typically, the other popular methods for biometrics authentication – Linear Discriminant Analysis (LDA), Maximum Likelihood Estimator (MLE), Bayesian Estimator (BE), Least Mean Square (LMS), Recursive Least Squared (RLS), and Wiener filters – are optimal for linear and time-invariant systems [6–10]. Thus, even integration of these estimators with PCA would be an inadequate solution to adapt to a nonlinear, nonstationary, and heterogeneous noise environment. A promising alternative is the sequential state estimator which has the capability of adapting to the diverse nature of noise. It is a recursive process and works based on prediction, adaptation (update or adjustment) and estimation [7,8]. However, the sequential state estimator is computationally inefficient for a higher dimensional dataset since it needs to compute the covariance matrix and perform a matrix inversion operation.

This paper addresses the predominant deficiency of the biometric system in this regard. It also systematically investigates a biometric authentication in a nonlinear, nonstationary, and heterogeneous noise environment. Importantly, this authentication method is made independent of the biometric traits. The performance of this approach is being tested on facial images from two public databases: the "Put Face Database" and the "Indian Face Database". In the experiment, the facial biometric features are extracted and analyzed to mitigate their noise levels before encoding and creating the biometric template. This template is then compared with other encoded facial images. More importantly, the noise associated with this feature is considered to be nonlinear, nonstationary, and heterogeneous due to position orientation, facial expression, and illumination effects.

In this paper, a new recursive sequential estimator algorithm in the image subspace is developed. This method addresses the challenges associated with the extracted features due to nonlinear, nonstationary, and heterogeneous noise. As well, a subspace technique is implemented to overcome the underlying computational complexity. The proposed subspace method transforms higher dimensional image space into a set of linearly independent image spaces (image subspace) so that the dimensionality of biometric features reduces from $N \times N$ to $M \times M$, where $M \ll N$. Using PCA analogy, this method distributes the principal biometric feature vectors to the image subspace. Moreover, in this recursive approach, the extracted data and the associated interferences update in every iteration using the biometric features (dataset) from the immediate previous state. The SSE approach is based on the minimization of noise and maximization of information contained in the received data, in MSE sense. Therefore, this method would be able to make a close approximation of the desired dataset, which would otherwise be contaminated by nonstationary and heterogeneous noise.

The remainder of the paper is organized as follows. Section 2 studies related works and prerequisites to the SSE algorithm. Section 3 introduces the problem formulation and briefly reviews PCA, MLE, Bayesian, and Wiener methods. Section 4 presents the detail analysis and methodology for the proposed solution. Experimental results and discussion are presented in Section 5. Finally, conclusions are drawn in the last section.

2. Previous work and prerequisites

Most authentication systems are based on linear, stationary, and homogeneous systems, though a few studies have addressed the challenges due to nonlinear, nonstationary, and heterogeneous noise. Zizhe et al. [5] developed a new algorithm in the nonlinear PCA domain termed the adaptive Strong Tracking Filter (STF). The authors showed that the model is a special case of Kalman Filter and Recursive Least Squared algorithms, and is immune to system model mismatch. The algorithm converges quickly and is robust at the cost of computational complexity. One study conducted by the National Science and Technology Council [9] proposed a Linear Discriminant Analysis (LDA) method for facial authentication. The author used LDA to maximize the inter-class and minimize the intra-class variations, since PCA performance deteriorates if a full frontal face can't be presented. However, this model was designed for linear and homogeneous systems and faces challenges if there are an inadequate number of data samples in the received dataset. Chan et al. [10] proposed a linear facial biometric authentication (identification and verification) system using PCA in conjunction with LDA. In that approach, the author used PCA for dimension reduction, while LDA was used to improve the discriminant ability of the PCA system in order to overcome the challenges associated with illumination and facial expression effects. The main problem with this model is that it is inadequate to deal with nonlinear, nonstationary, and heterogeneous noise.

Selvi et al. [11] presented a multimodal biometrics authentication based on fingerprint and iris biometrics. This approach is also useful in a linear and stationary operating environment. Here the author used a linear Wiener filter to improve the legibility of the fingerprint without affecting the ridge structure. Lakshmi [12] introduced another system fingerprint identification and encryption, and used a Wiener and a digital transformed filter to mitigate the noise. However, the author addressed the issues based only on a linear and homogeneous system. Nandini et al. [13] proposed a biometric authentication based on vein patterns. The author used the length of the vein and the angle of the bifurcation points as the key features. To enhance the quality of the vein pattern the authors used different filtering techniques including the Wiener and the Median filter. The experimental results were very promising, however, the algorithm is based on linear and homogeneous systems. Lu et al. [14] presented a new PCA algorithm in an uncorrelated multilinear PCA domain using unsupervised subspace learning of tensorial data. This system offered a methodology to maximize the extraction of uncorrelated multilinear biometric characteristics, but it is an iterative process and inadequate to deal with a nonstationary and heterogeneous system. Law et al. [15] presented a nonlinear dimensionality reduction algorithm under the assumption that high dimensionality data are available in the mainfold. Hence, dimensionality reduction can be achieved by mapping with respect to certain properties associated with the mainfold. The authors used the sequential processing method, which outperformed the computationally demanding approach, batch processing. Unfortunately, it is very likely to have misleading information due to a nonlinear, nonstationary, and heterogeneous operating environment, if the system is dependent only on the information contained in the mainfold. Suo et al. [16] developed a gender transformation algorithm based on hierarchy fusion strategy. In that approach authors used a stochastic graphical model to transform the attributes of a high-resolution facial image into a new image as the opposite gender with the same age and race. The main objective is to modify the gender attributes while retaining its facial identity. This is an interesting model, however the authors did not consider the associated heterogeneity due to the different race and age groups.

In addition, Carlos et al. [17] developed a new algorithm for covariance estimation for the Bayesian classifier. This method successfully addressed the challenges associated with the Bayesian Estimator due to limited numbers of sample data. However, this model was developed under the assumption that variation in the

Download English Version:

https://daneshyari.com/en/article/6866123

Download Persian Version:

https://daneshyari.com/article/6866123

Daneshyari.com