Davide Maltoni
Anil K. Jain (Eds.)

LNCS 3087

Biometric Authentication

ECCV 2004 International Workshop, BioAW 2004
Prague, Czech Republic, May 2004
Proceedings

Springer

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Springer

Volume Editors

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Library of Congress Control Number: 2004108951

CR Subject Classification (1998): I.5, I.4, I.2.10, I.2, K.4, K.6.5, C.3

ISSN 0302-9743
ISBN 3-540-22499-8 Springer-Verlag Berlin Heidelberg New York

Springer-Verlag is a part of Springer Science+Business Media

springeronline.com

Printed in Germany

Typesetting: Camera-ready by author, data conversion by Boller Mediendesign
Printed on acid-free paper SPIN: 11303138 06/3142 5 4 3 2 1 0

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Preface

Biometric authentication is increasingly gaining popularity in a large spectrum of applications, ranging from government programs (e.g., national ID cards, visas for international travel, and the fight against terrorism) to personal applications such as logical and physical access control. Although a number of effective solutions are currently available, new approaches and techniques are necessary to overcome some of the limitations of current systems and to open up new frontiers in biometric research and development. The 30 papers presented at Biometric Authentication Workshop 2004 (BioAW 2004) provided a snapshot of current research in biometrics, and identify some new trends. This volume is composed of five sections: face recognition, fingerprint recognition, template protection and security, other biometrics, and fusion and multimodal biometrics. For classical biometrics like fingerprint and face recognition, most of the papers in Sect. 1 and 2 address robustness issues in order to make the biometric systems work in suboptimal conditions: examples include face detection and recognition under uncontrolled lighting and pose variations, and fingerprint matching in the case of severe skin distortion. Benchmarking and interoperability of sensors and liveness detection are also topics of primary interest for fingerprint-based systems. Biometrics alone is not the solution for complex security problems. Some of the papers in Sect. 3 focus on designing secure systems; this requires dealing with safe template storage, checking data integrity, and implementing solutions in a privacy-preserving fashion. The match-on-tokens approach, provided that current accuracy and cost limitations can be satisfactorily solved by using new algorithms and hardware, is certainly a promising alternative. The use of new biometric indicators like eye movement, 3D finger shape, and soft traits (e.g., height, weight and age) is investigated by some of the contributions in Sect. 4 with the aim of providing alternative choices for specific environments and applications. Improvements and new ideas are also presented for other popular biometrics like iris, palmprints and signature recognition. Multimodal biometrics has been identified as a promising area; the papers in Sect. 5 explore some insights into this topic, and they provide novel approaches for combinations at sensor, feature extraction and matching score levels.

May 2004

Davide Maltoni
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Face Recognition Based on Locally Salient ICA Information

Jongsun Kim, Jongmoo Choi, Juneho Yi

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Abstract. ICA (Independent Component Analysis) is contrasted with PCA (Principal Component Analysis) in that ICA basis images are spatially localized, highlighting salient feature regions corresponding to eyes, eye brows, nose and lips. However, ICA basis images do not display perfectly local characteristic in the sense that pixels that do not belong to locally salient feature regions still have some weight values. These pixels in the non-salient regions contribute to the degradation of the recognition performance. We have proposed a novel method based on ICA that only employ locally salient information. The new method effectively implements the idea of "recognition by parts" for the problem of face recognition. Experimental results using AT&T, Harvard, FERET and AR databases show that the recognition performance of the proposed method outperforms that of PCA and ICA methods especially in the cases of facial images that have partial occlusions and local distortions such as changes in facial expression and at low dimensions.

1 Introduction

Over the last ten years, canonical subspace projection techniques such as PCA and ICA are widely used in the face recognition research [2-4]. These techniques employ feature vectors consisting of coefficients that are obtained by projecting facial images onto their basis images. The basis images are computed offline from a set of training images. ICA is contrasted with PCA in that ICA basis images are more spatially local than PCA basis images. Fig. 1 (a) and (b) show facial image representation using PCA and ICA basis images, respectively, that are computed from a set of images randomly selected from the AR database. PCA basis images display global properties in the sense that they assign significant weights to the same pixels. It accords with the fact that PCA basis images are just scaled versions of global Fourier filters [21]. In contrast, ICA basis images are spatially more localized, highlighting salient feature regions corresponding to eyes, eye brows, nose and lips. This local property of ICA basis images makes the performance of ICA based recognition methods better than PCA methods in terms of robustness to partial occlusions and local distortions such as changes in facial expression. Thus, ICA techniques have popularly been applied to the problem of face recognition [3-6], especially for face recognition under variations of illumination, pose and facial expression. However, ICA basis images do not display

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perfectly local characteristics in the sense that pixels that do not belong to locally salient feature regions still have some weight values. These pixels in the non-salient regions contribute to the degradation of the recognition performance.

We propose a novel method based on ICA, named LS-ICA (locally salient ICA) where the concept of "recognition by parts" [18-20] can be effectively realized for face recognition. The idea of "recognition by parts" has been a popular paradigm in object recognition research that can be successfully applied to the problem of object recognition with occlusion. Our method is characterized by two ideas: one is removal of non-salient regions in ICA basis images so that LS-ICA basis images only employ locally salient feature regions. The other is to use ICA basis images in the order of class separability so as to maximize the recognition performance. Experimental results show that LS-ICA performs better than PCA and ICA especially in the cases of partial occlusions and local distortions such as changes in facial expression. In addition, the performance improvement of LS-ICA over ICA based methods was much greater as we decrease the dimensionality (i. e. the number of basis images used).

The rest of this paper is organized as follows. Section 2 contrasts ICA with PCA in terms of locality of features. Section 3 describes the proposed LS-ICA method. Section 4 presents experimental results.

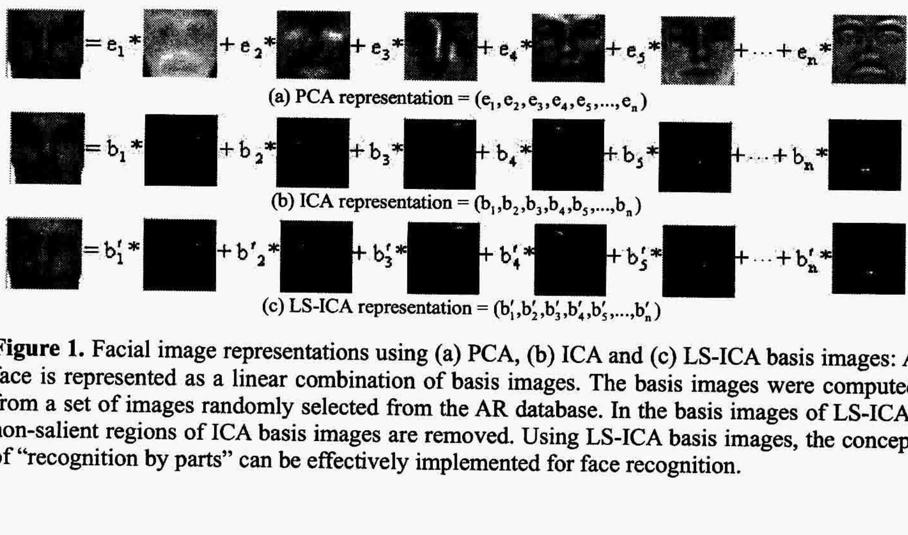

Figure 1. Facial image representations using (a) PCA, (b) ICA and (c) LS-ICA basis images: A face is represented as a linear combination of basis images. The basis images were computed from a set of images randomly selected from the AR database. In the basis images of LS-ICA, non-salient regions of ICA basis images are removed. Using LS-ICA basis images, the concept of "recognition by parts" can be effectively implemented for face recognition.

2 ICA Versus PCA

PCA and ICA are the most widely used subspace projection techniques that project data from a high-dimensional space to a lower-dimensional space [2, 4]. PCA addresses only second-order moments of the input. It is optimal for finding a reduced representation that minimizes the reconstruction error, but it is not optimal for classification. ICA is a generalization of PCA that decorrelates the high-order statistics in addition to the second-order moments. Much of information about characteristic local structure of facial images is contained in the higher-order statistics of the images. Thus ICA, where the high-order statistics are decorrelated, may provide a more powerful representational basis for face recognition than PCA, where only the second-order statistics are correlated. Figure 2 illustrates PCA and ICA axes for the same 2D distribution. PCA finds an orthogonal set of axes pointing in the directions of maximum covariance in the data, while ICA attempts to place axes pointing in the directions of spatially localized and statistically independent basis vectors [17].

As previously described, global properties of faces may be more easily captured by PCA than ICA. As shown in Figure 1, ICA basis images are more spatially localized and never overlap unlike their PCA counterpart [1]. Since spatially localized features only influence small parts of facial images, ICA based recognition methods are less susceptible to occlusions and local distortions than are global feature based methods such as PCA. We can compute ICA basis images using various algorithms such as InfoMax [3, 10], FastICA [5, 8] and Maximum likelihood [6, 7].

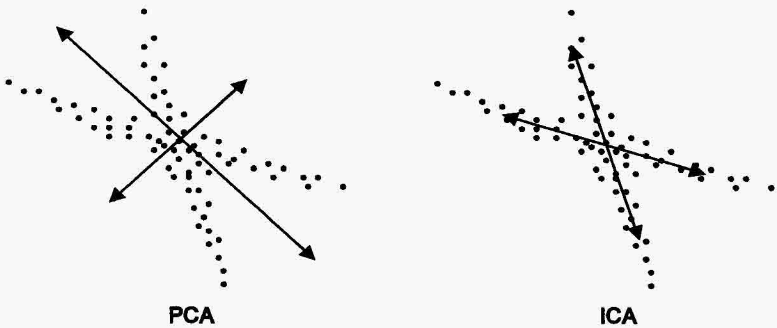

Figure 2. PCA and ICA axes for an identical 2D data distribution [17]

3 The LS-ICA (Locally Salient ICA) Method

The LS-ICA method features the use of new basis images made from ICA basis images that are selected in the decreasing order of class separability. Only salient feature regions are contained in the LS-ICA basis images. As in most algorithms that employ subspace projection, the LS-ICA method computes a projection matrix, off-line from a set of training images. Let W_{ls-ica} denote the projection matrix. The columns of W_{ls-ica} are LS-ICA basis images. During recognition, given an input face image $\mathbf{x}$, it is projected to $\mathbf{\Omega}' = W^T_{ls-sica}\mathbf{x}$ and classified by comparison with the vectors $\mathbf{\Omega}_T$'s that were computed off-line from a set of training images.

Figure 3 shows a block diagram of the method. First, we preprocess training images by applying histogram equalization and scale normalization, where the size of images is adjusted so that they have the same distance between two eyes. Second, we com-

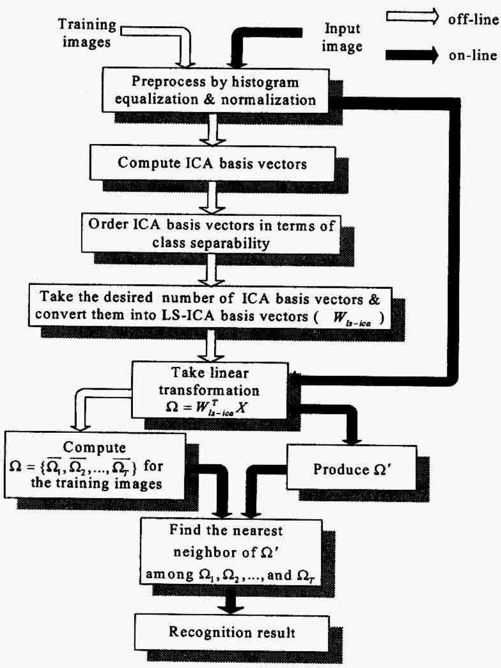

Figure 3. Algorithm overview

pute ICA basis images, using the FastICA algorithm [5, 8]. The FastICA method computes the independent components that become uncorrelated by a whitening process and then maximizes non-Gaussianity of data distribution by using kurtosis maximization [5]. We then compute a measure of class separability, r, for each ICA basis vector and sort the ICA basis vectors in the decreasing order of class separability [3]. To computer r for each ICA basis vector, the between-class variability $\sigma_{between}$ and within-class variability σ_{within} of its corresponding projection coefficients of training images are obtained as follows.

$$\sigma_{between} = \Sigma_i \left(M_i - M\right)^2 \quad (1)$$

$$\sigma_{within} = \Sigma_i \Sigma_j \left(b_{ij} - M_i\right)^2 \quad (2)$$

M and M_i are the total mean and the mean of each class, and b_{ij} is the coefficient of the j^{th} training image in class i. The class separability, r, is then defined as the ratio

$$r = \frac{\sigma_{between}}{\sigma_{within}}. \quad (3)$$