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Improved Recognition Performance with LDA and ICA Using Vertically and Horizontally Partitioned Facial Images

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Abstract: A comparative recognition performance of LDA- and ICA-based multiple classifier systems for face recognition is presented using vertically and horizontally partitioned facial images. A face image is partitioned into several vertical and horizontal segments and a multiple classifier based divide-and-conquer approach is used to combine these segments to recognize the whole face. The experiments demonstrate that vertical and horizontal partitioning result in a better recognition performance compared to the performance results of the holistic methods.

Key-words: LDA, ICA, multiple classier systems, appearance-based statistical methods, classifier combination, feature-based face recognition

1. Introduction

Linear Discriminant Analysis (LDA) and Independent Component Analysis (ICA) are widely used appearance-based statistical approaches for the solution of face recognition problem. LDA and ICA are mainly dimensionality reduction algorithms which are used for feature extraction to train classifiers [1-3]. LDA searches for those vectors in the underlying space that best discriminate data among classes. ICA is a method for transforming an observed multidimensional random vector into its components that are statistically as independent from each other as possible.

LDA is a dimensionality reduction technique, which is frequently used for feature extraction in classification problems [4,5]. The basic idea of LDA is to find a linear transformation such that the feature clusters are most separable after the transformation, which can be achieved through scatter matrix analysis. This is performed by maximizing the Between-class scatter matrix measure while minimizing the Within-class scatter matrix measure [4-6].

Independent Component Analysis (ICA) is an appearance-based statistical method which represents the data in terms of statistically independent variables [7,8]. The goal is to minimize the statistical dependence between the basis vectors and ICA can be distinguished from other methods since it looks for components that are both statistically independent and nongaussian [7-10]. LDA and ICA are well-known methods applied for the solution of pattern recognition problems. Face recognition is one of the well-known pattern recognition problems, which is still a very hot topic studied extensively by many researchers in literature [11-14]. In this study, a divide-and-conquer approach implemented over multiple classifier systems (MCSs) [15] is used to improve the computational efficiency and recognition performance of LDA and ICA methods on the face recognition problem [6]. FastICA method is used in this study for performing independent component analysis. MCSs combine the output information provided by two or more classifiers. The standard FERET database and the FERET Evaluation Methodology [16] are used to conduct experiments using holistic methods and the proposed approach.

The main idea of the presented approach is to use a divide-and-conquer methodology for the face recognition problem, where the face images are divided vertically and horizontally into equal-width segments and LDA or ICA are used for each face segment as a feature extraction method. Consequently, a multiple classifier system is established based on a particular distance measure and finally the outputs of multiple classifiers are combined using well-known multiple classifier combination methods to recognize the whole face. Results of horizontal partitioning are already published in [6], hence, only vertical partitioning methodology will be presented in this paper and experimental evaluation within this

framework and [6] are presented for comparison purposes.
The paper is organized as follows. The divide-and-conquer approach is presented in Section 2. Experimental results are given in section 3. Finally, section 4 concludes the paper.

2. The Divide-and-Conquer Approach

Appearance-based statistical methods require long training times and large storage spaces particularly for huge databases of facial images. The difficulties of the appearance-based face recognition algorithms are result of their holistic approach for feature extraction, which considers the features from all facial areas with equal importance. However, considering the vertical symmetry of facial images, feature extraction from smaller symmetric segments may yield several advantages. First, feature extraction from smaller facial segments is computationally simpler and results in faster recognition which is an important issue for large databases. Secondly, feature extraction from nearly symmetric segments helps to improve the recognition performance since information loss on a particular locality may be completed by similar information on the symmetric counterpart. Finally, feature extraction from smaller regions and using them as the main components of a multiple classifier system emphasizes their contribution in the recognition procedure.
In order to achieve these goals, a facial image is vertically divided into a number of segments and each facial part is processed independently by an individual classifier and individual classifier outputs within a MCS are combined to get an improved performance compared to holistic approaches.
In the implementation of the divide-and-conquer approach, a face image is divided into equal-width vertical segments as shown in Fig. 1. Then, features of each segment are extracted independent of each other using one of the appearance-based statistical methods. In this type of partitioning, the aim is to extract locally important characteristic features of a facial image from distinctive and nearly symmetric facial regions. All the training and testing face images are cropped as shown in Fig. 1. Cropping operation is applied in the same way for both the training and test images, so that all the images include only the head of a face after this operation. In other words, there is the forehead (without hairs) on top and the chin at the bottom of each face image (without the neck and shoulders). Fig. 1 shows four different vertical partitioning on a facial image as an example. That is, it demonstrated the division of a cropped facial image into equal-width 2 to 5 vertical segments.

After applying a dimensionality reduction algorithm on each segment of training and test images, Euclidean distance measure is used to find the distance between these image segments. For each test image, we compare the distances between the test image and all the training images. The training image that has the minimum distance to the test image is the image that mostly resembles to the test image. Consequently, a multiple classifier system is established based on the Euclidean distance measure and finally the outputs of multiple classifiers are combined using well-known multiple classifier combination methods to recognize the whole face.

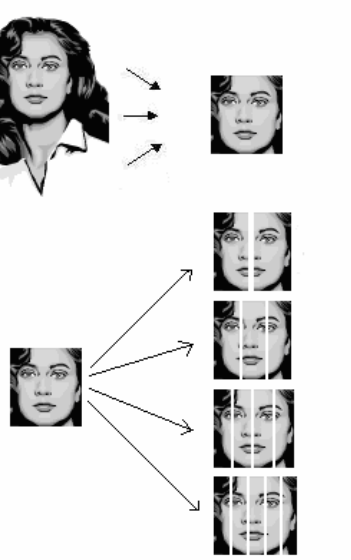

Fig. 1. Cropping an original image and division of a cropped face image into equal-width 2 to 5 vertical segments

In order to understand the theoretical gains achieved with the divide-and-conquer approach, computational and storage space efficiencies are evaluated in [6]. In addition to these, various experimental results on horizontally-divided face images are demonstrated in [6]. In the implementation of the horizontal divide-and-conquer approach, multiple classifiers with different number of individual classifiers and different output combination methods were considered. In this study, two, three, four and five individual classifiers, hence that number of equal-

width vertical facial segments is used. The output of each individual classifier is computed separately, followed by a multiple-classifier combination procedure which produces the final classifier or recognition output.

3. Experiments and Results

In order to test the performance of the proposed divide-and-conquer approach, experiments were done on the FERET database. LDA and ICA approaches were applied in the same way as explained in [6]. In these methods, *(n-1)* components are used, where *n* is the number of training face images; in other words, *n* is the number of gallery images which is 50 in our experiments. The Large Gallery Test of the FERET Evaluation Methodology was used in which a performance statistics known as "Cumulative Match" score was considered to represent the results. In this test, each algorithm reports the top 20 matches for each probe for 50 gallery images, in a ranked-ordered list. From this list, one can determine if the correct answer of a particular probe is in the top 20, and if it is, how far down the list is the correct match.

In this study, the face images used are cropped so that they only include the head of the individuals. The face images were scaled down to 45x35 pixels from the original size of 384x256 pixels. The gallery consists of 50 frontal images (two samples per person) in all the experiment sets.

In the experiments, the performance of the holistic LDA and ICA approaches and individual classifiers of the divide-and-conquer approach built on these methods are demonstrated. The recognition performance results of the holistic algorithms and the individual classifiers built on these methods are presented in Fig. 2 and Fig.3 for LDA and ICA, respectively. These figures demonstrate the performance of holistic LDA and ICA approaches and the performance of the combination of 2 to 8 vertical classifiers based on LDA and ICA approaches.

The experiments for LDA show that the recognition performance of the combination of vertical classifiers increases the recognition performance of the holistic LDA approach. The best recognition rates are obtained with the combination of seven vertical classifiers for LDA.

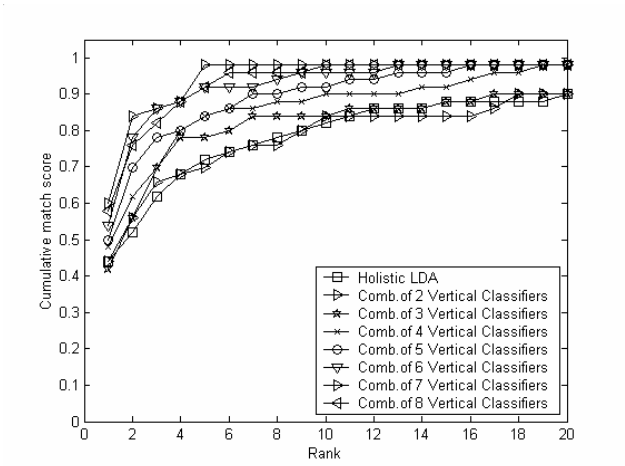

Fig. 2 Performance of the holistic LDA approach and the combination of vertical classifiers of LDA approach

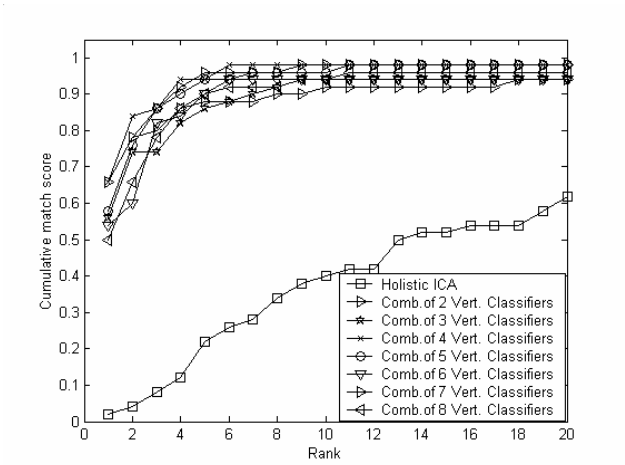

Fig. 3 Performance of the holistic ICA approach and the combination of vertical classifiers of ICA approach

The recognition performance of the combination of vertical classifiers on ICA shows a big improvement compared to the recognition performance of holistic ICA approach. The combination of seven vertical classifiers on ICA shows the highest recognition performance among the others. These figures demonstrate the combined recognition performance of LDA- and ICA-based individual classifiers using Borda Count multiple-classifier combination method.

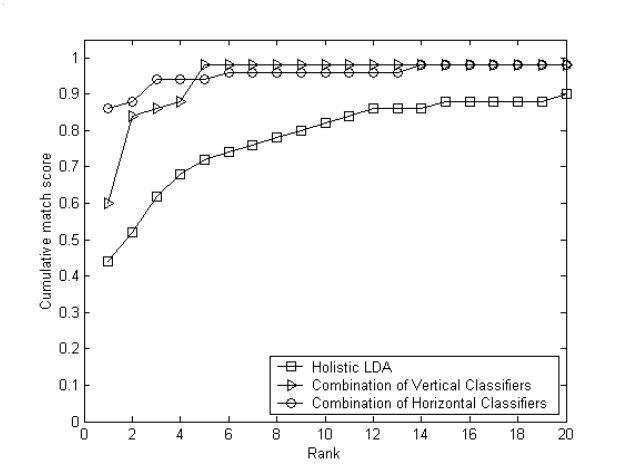

Fig. 4 Performance of the holistic LDA approach and the combination of horizontal and vertical classifiers

For comparison, the best recognition rates of the combination of horizontal classifiers on LDA and ICA, are obtained from [6]. These results are used in Fig.4 and Fig. 5 with the recognition performance of the combination of vertical classifiers and holistic approaches for LDA and ICA, respectively.

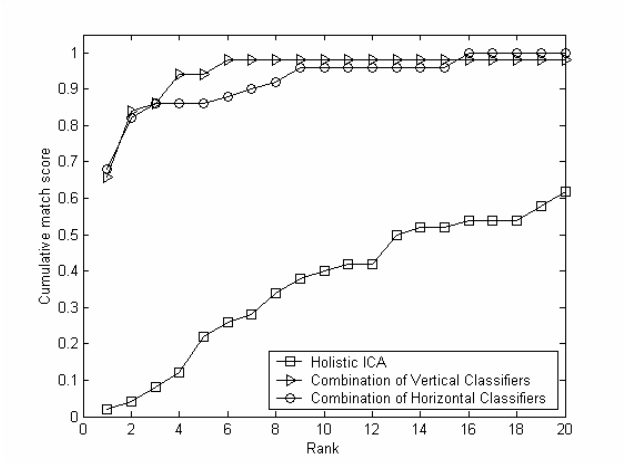

Fig. 5 Performance of the holistic ICA approach and the combination of five horizontal and two vertical classifiers

Fig. 4 demonstrates that the recognition performance of holistic LDA is increased when the combination of eight horizontal and seven vertical classifiers are used. The best recognition rate is obtained by horizontal partitioning for LDA. The recognition performance of holistic ICA is significantly increased when the combination of seven horizontal and seven vertical classifiers are used. The best improvement is obtained with the combination of vertical classifiers as shown in Fig. 5. In general, the recognition performances of all the combined classifiers are increased compared to the holistic methods' recognition performance.

The comparison of the holistic LDA and ICA approaches together with their best partitioning results are demonstrated in Fig. 6 and the best recognition rates for LDA and ICA are taken from Fig. 4 and Fig. 5, respectively. The best recognition rate for LDA is obtained by the combination of horizontal LDA classifiers and for ICA, by the combination of vertical ICA classifiers.

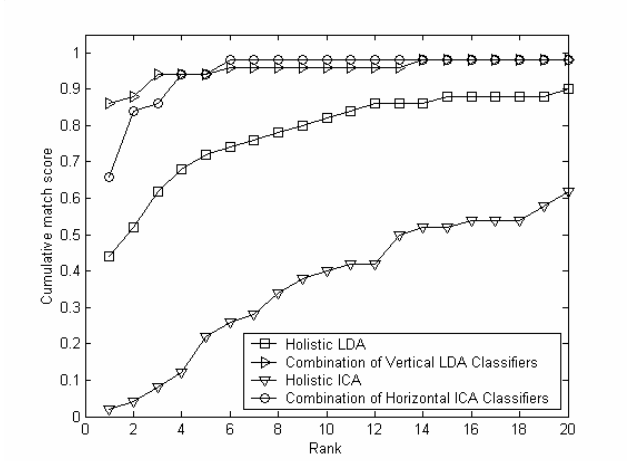

Fig. 6 Performance of the holistic LDA and ICA approaches compared with the best partitioning performance results

The recognition performance of the holistic LDA approach is better than the performance of the holistic ICA approach as shown in the above figure. The partitioning results improve the performance of both of the approaches and the best recognition rate is obtained by the combination of horizontal LDA classifiers. Additionally, vertical partitioning on ICA gives better performance compared to the recognition performance of the holistic LDA approach.

4. Conclusions

The recognition performance of LDA- and ICA-based multiple classifier system based on a divide-and-conquer methodology through vertically and horizontally partitioned facial images is presented.

The experiments demonstrate that the recognition performance of the holistic LDA and ICA methods are improved when the combination of horizontal and vertical classifiers are used**.** The best recognition rate for LDA is obtained by the combination of horizontal LDA classifiers and for ICA, by the combination of vertical ICA classifiers. It can be stated that, in general, the partitioning results improve the recognition performance of both of the approaches and the best recognition rate is obtained by the combination of horizontal LDA classifiers compared to the performance of the holistic approaches and the partitioning results.

References

1. Heisele, B., Ho, P., Wu, J., Poggio, T.: Face recognition: component-based versus global approaches. Computer Vision and Image Understanding, Vol. 91(1/2). (2003) 6-1.
2. Yang, M.-H., Kingman, D.J., Ahuja, N.: Detecting Faces in Images: A Survey. IEEE Transations on Pattern Analysis and Machine Intelligence, Vol. 24(1). (2002) 34-58
3. Gross, R., Matthews, I., Baker, S.: Appearance-based face recognition and light-fields. IEEE Transactions on Pattern Analysis & Machine Intelligence, Vol. 26(6). (2004) 449-465
4. Martinez, A.M. and Kak, A.C.: PCA versus LDA. IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol.23(2). (2001) 228-233
5. Jing, X.-Y., Zhang, D., Yao, Y.-F.: Improvements on the linear discrimination technique with application to face recognition. Pattern Recognition Letters, Vol. 24(15) (2003) 2695-2701
6. Toygar, Ö., Acan, A.: Multiple Classifier Implementation of a Divide-and-Conquer Approach Using Appearance-Based Statistical Methods for Face Recognition. Pattern Recognition Letters, Vol.25. (2004) 1421-1430
7. Hyvärinen, A., “Fast and Robust Fixed-Point Algorithms for Independent Component Analysis”, IEEE Transactions on Neural Networks, 1999, Vol. 10, No.3, pp. 626-634.
8. Comon P.,"Independent component analysis - a new concept?", Signal Processing, Elsevier, vol. 36, pp. 287--314, April 1994, Special issue on Higher-Order Statistics.
9. Liu C., Wechsler H.,"Comparative Assessment of Independent Component Analysis (ICA) for Face Recognition", Second Int'l Conf. on Audio-and Video-based Biometric Person Authentication, AVBPA'99, Washington D. C., March 22-24, 1999.
10. Baek K., Draper B.A., Beveridge J. R. and She K.,“PCA vs. ICA: A Comparison on The FERET Data Set”, International Conference on Computer Vision, Pattern Recognition and Image Processing in conj. with the 6th JCIS, Durham, North Carolina, March 8-14, 2002.
11. K.Chang, K.W.Bowyer, S.Sarkar, B.Victor, Comparison and combination of ear and face images in appearance-based biometrics, IEEE Trans. Pattern Analysis & Machine Intelligence,Vol.25, No.9,pp.1160-1165, 2003.
12. A.M. Martínez, Recognizing Imprecisely Localized, Partially Occluded, and Expression Variant Faces from a Single Sample per Class, IEEE Trans. Pattern Analysis and Machine Intelligence, Vol.24,No.6, pp.748-763, 2002.
13. J.Wu, Z.-H.Zhou, Face recognition with one training image per person, Pattern Recognition Letters, Vol.23,No.1, pp.1711-1719, 2002.
14. A.M.Martinez and A.C.Kak, PCA versus ICA, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol.23,No.2, pp.228-233, 2001.
15. J.Kittler, M.Hatef, R.P.W.Duin and J.Matas, On Combining Classifiers, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol.20,No.3, pp.226-239, 1998
16. P.J.Phillips, H.Moon, S.A.Rizvi, P.J.Rauss, The FERET evaluation methodology for face-recognition algorithms, IEEE Trans. Pattern Analysis & Machine Intelligence, Vol.22, No.10, pp.1090-1104, 2000.