Overlapping on Partitioned Facial Images

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Abstract: The effect of overlapped classifiers on partitioning-based face recognition is presented. The features of facial images are extracted by appearance-based statistical dimensionality reduction algorithms for the recognition of horizontally and vertically partitioned facial images. The proposed approaches employ a divide-and-conquer strategy which aims to improve the recognition performance of holistic methods by emphasizing locally important features over horizontal or vertical segments. Additionally, computational complexity is also reduced significantly since feature extractions are performed over smaller facial regions. Analysis of the obtained results demonstrate that both vertical and horizontal partitioning achieve better recognition performance compared to the holistic counterparts. It is also observed that, for some of the statistical methods, overlapped feature extraction results in better recognition performance compared to disjoint partitioning approach. The proposed implementations achieved particularly superior performance for LDA- and ICA-based classifiers, for which the proposed approaches demonstrated the best so far published results.

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

1. Introduction

Appropriate feature extraction is an essential component of a successful face recognition algorithm [1-3]. For this purpose, statistical dimensionality reduction methods such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) and Independent Component Analysis (ICA) are demonstrated to be successful in several academic studies and commercial applications [4-7]. The success and popularity of these algorithms are mainly due to their statistics – based ability of automatically deriving the features instead of relying on humans for their definitions. These algorithms are widely studied within individual and multiple classifier systems through which our proposals implement a divide-and-conquer strategy for the solution of the face recognition problem.

PCA projects images into a subspace in order to find the principal components that best describe data among classes [8-11]. LDA searches for those vectors in the underlying space that best discriminate data among classes [10-12]. ICA is a method for transforming an observed multidimensional random vector into its components that are statistically as independent from each other as possible [13-17].

In this study, a divide-and-conquer approach implemented over multiple classifier systems (MCSs) [18-20] is used to improve the computational efficiency and recognition performance of PCA, LDA and ICA methods on the face recognition problem. MCSs combine the output information provided by two or more classifiers. The standard FERET database and the FERET Evaluation Methodology [21,22] are used to conduct experiments using holistic methods and the proposed approach.

In the implementation of the presented divide-and-conquer methodology for the face recognition problem, face images are divided vertically and horizontally into equal-width disjoint and overlapped segments and PCA, 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.

2 Feature Extraction

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 horizontally localized characteristics and vertical symmetry of facial images, feature extraction from smaller segments may yield several advantages. Firstly, feature extraction from smaller facial segments is computationally simpler and results in faster recognition which is an important issue for large databases. Furthermore, using these features as the main components of a multiple classifier system emphasizes their contribution to the overall recognition performance. From the proposed approaches point of view, feature extraction from nearly symmetric vertical segments helps to improve the recognition performance since information loss on a particular locality may be completed by similar information on the symmetric counterpart. In addition to this, when partitioning the face images into equal-width horizontal segments, distinctive features of the face such as the forehead, eyebrows and eyes, nose, mouth and the chin are placed into different horizontal segments. However, this approach may have variations for arbitrary face images such that two features may be placed into one segment or a distinctive feature may partly stay in two different segments.

3 Overlapping on Facial Segments

Feature extraction from horizontal or vertical facial segments is carried out using disjoint or overlapped strategies. In the former case, each segment is processed independently for the extraction of localized features while in the latter case, overlapping of the current and the previous segment is allowed to emphasize the significance of locally important features by repeated extraction. The amount of overlapping resulting in the best performance is determined experimentally.

According to the above mentioned descriptions, a facial image is vertically or horizontally divided into a number of overlapped or non-overlapped segments. Each facial part is processed independently by an individual classifier and individual classifier outputs within the associated MCS are combined to get an improved performance compared to holistic approaches.

In the vertical partitioning-based divide-and-conquer approach, firstly the face images are divided into equal-width disjoint (non-overlapped) vertical segments (or equal-width overlapped vertical segments) as shown in Fig.1. In this figure, the demonstration is done using 3 segments for which the difference of disjoint and overlapped partitioning is shown clearly.

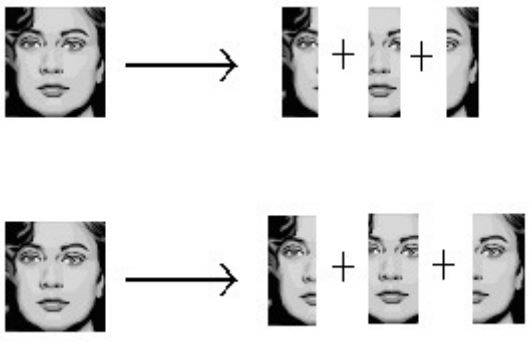

Fig. 1 Division of a cropped facial image into 3 equal-width disjoint vertical segments and 3 equal-width overlapped vertical segments

Fig.2 demonstrates disjoint and overlapped horizontal partitioning of a facial image using 3 segments. In all cases, the division process divides the face images into a number of segments and the features of each segment are extracted independent of each other using one of the appearance-based statistical methods. All the training and testing face images are cropped as shown in Fig.1 and Fig.2. 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).

After applying a dimensionality reduction algorithm on each segment of training and test images, Euclidean distance measure is used to find the distance between features of 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 it. Consequently, a multiple classifier system is established and the outputs of individual classifiers are combined using a well-known multiple classifier combination method to recognize the whole face. For a better understanding of the theoretical gains achieved with the divide-and-conquer approach, the

evaluation of computational and storage space efficiencies can be found in [6].

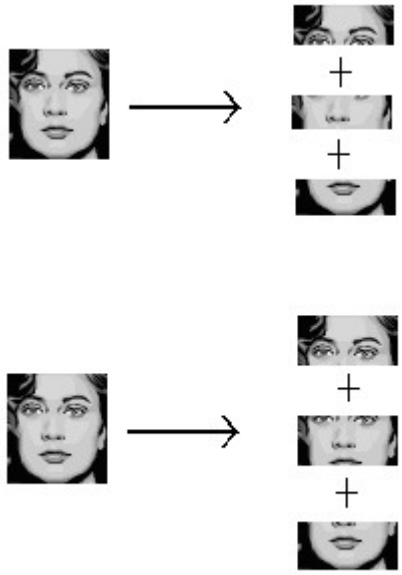

Fig. 2 Division of a cropped facial image into 3 equal-width disjoint horizontal segments and 3 equal-width overlapped horizontal segments

4 Experimental Results

In order to test the performance of the proposed divide-and-conquer approaches, experiments were done on the FERET database. PCA, LDA and ICA approaches were applied in the same way as explained in [6]. In these methods, the first *(n-1)* of the superior components are used, where *n* is the number of training face images which is 100 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 100 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 100 frontal images (two samples per person) in all the experiment sets.

In the implementation of the divide-and-conquer approach, multiple classifiers with different number of individual classifiers were considered using the Borda Count classifier combination method. For both non-overlapped and overlapped cases, 2 to 8 individual classifiers, hence that number of equal-width vertical and horizontal facial segments is used in this study. The output of each individual classifier is computed separately, followed by a multiple-classifier combination procedure which produces the final classifier or recognition output.

Comparative performance evaluations for disjoint and overlapped classifiers, for both vertical and horizontal partitioning for PCA, LDA and ICA approaches are demonstrated in Fig. 3, Fig. 4 and Fig. 5, respectively. In all these experiments, 2 to 8 vertical and horizontal classifiers on PCA, LDA and ICA approaches are experimented separately and the best recognition rates are used among these combinations of classifiers for each approach and category of partitioning.

Fig. 3 demonstrates the performance of the holistic PCA approach and the combination of disjoint vertical, disjoint horizontal, overlapped vertical, and overlapped horizontal classifiers using the divide-and-conquer approach on PCA method. It is clearly seen that the performance of the holistic approach is improved whenever the combination of non-overlapped and overlapped horizontal and vertical classifiers are used. However, the performance results are similar for overlapped and non-overlapped partitioning techniques. Therefore, it can be concluded that the combination of overlapped segments does not improve the performance significantly compared to non-overlapped segments on PCA method.

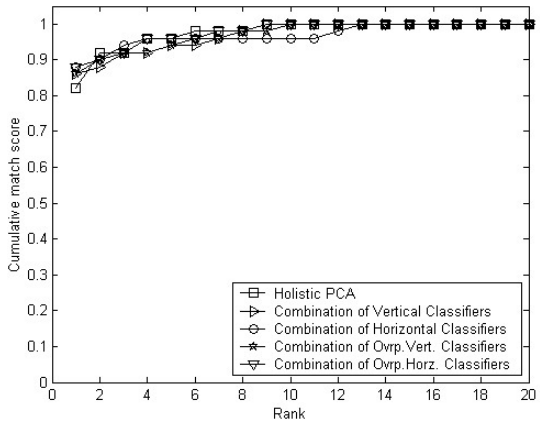

Fig. 3 Performance of the holistic and the combination of vertical, horizontal, overlapped vertical and overlapped horizontal classifiers of the PCA approach

All the partitioning techniques improve the performance of the holistic LDA method which is clearly seen on Fig. 4. It can be stated that overlapping on horizontal partitioning improves the performance compared to the holistic and other partitioning techniques on LDA method.

The recognition performance of the holistic ICA approach and the combination of overlapped and non-overlapped vertical and horizontal classifiers are presented in Fig. 5. The partitioning techniques significantly improve the performance of the holistic ICA and overlapped partitioning for both horizontal and vertical cases improve the performance of non-overlapped counterparts.

In general, partitioning improves the recognition performance in the appearance-based statistical methods PCA, LDA and ICA. That is, both vertical and horizontal partitioning techniques result in a better recognition performance compared to the performance results of the holistic methods. The horizontal and vertical overlapped partitioning results are improved in ICA compared to non-overlapped partitioning results and the best recognition results are obtained with overlapped horizontal partitioning in LDA while PCA recognition performance is not affected by overlapped partitioning.

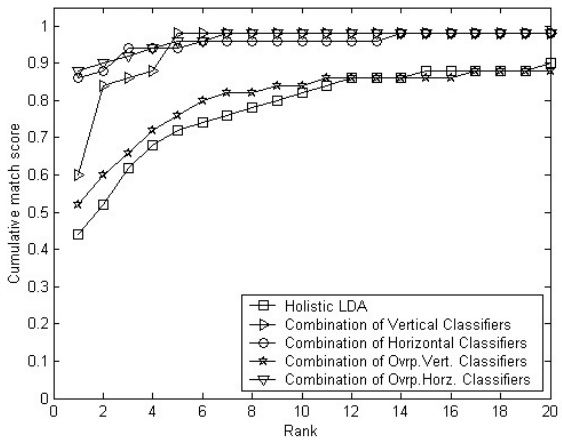

Fig. 4 Performance of the holistic and the combination of vertical, horizontal, overlapped vertical and overlapped horizontal classifiers of the LDA approach

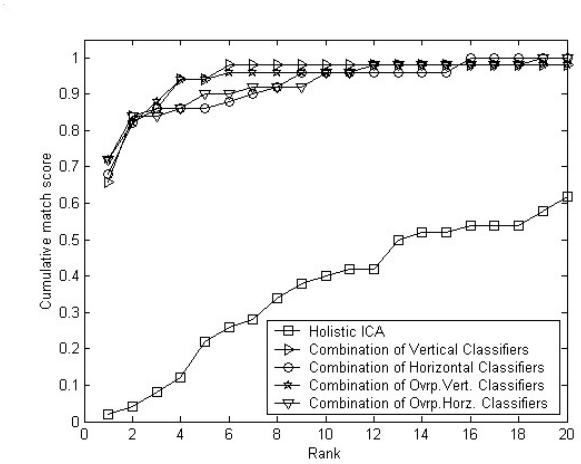

Fig. 5 Performance of the holistic and the combination of vertical, horizontal, overlapped vertical and overlapped horizontal classifiers of the ICA approach

In order to show the overall results and compare the three appearance-based statistical methods with each other, the holistic recognition performances of PCA, LDA and ICA approaches and the best overlapped or non-overlapped partitioning performance results are demonstrated in Fig. 6.

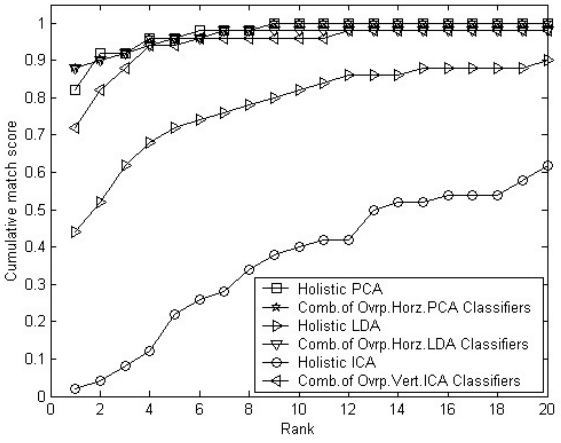

Fig. 6 Performance of the holistic PCA, LDA and ICA approaches and the best PCA-, LDA- and ICA-based combination of classifiers

The best partitioning results are obtained by the overlapped horizontal partitioning for PCA and LDA, and by overlapped vertical partitioning for ICA approach. That is, overlapped partitioning for all the approaches improves the performance of the corresponding holistic approach. On the one hand, it can be stated that overlapped vertical partitioning on ICA achieves better recognition performance compared to the performance of the holistic ICA and LDA approaches. On the other hand, the highest recognition performance is obtained by overlapped horizontal partitioning on PCA and LDA which achieves the best performance compared to the performance of all the holistic approaches and the performance of overlapped vertical partitioning on ICA. In another point of view, it can be stated that overlapped partitioning on LDA achieves better recognition performance compared to the holistic LDA and even to the holistic PCA performance.

5 Conclusions

The effect of overlapped partitioning on the recognition performance of PCA-, 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 PCA, LDA and ICA approaches are improved by overlapped and non-overlapped horizontal and vertical partitioning of images. The horizontal and vertical overlapped partitioning results are comparably better in ICA than the non-overlapped partitioning results and the best recognition results are obtained with overlapped horizontal partitioning in LDA while PCA recognition performance is not affected by overlapped partitioning.

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