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Robust face recognition after plastic surgery using region-based approaches

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ABSTRACT

This paper advances the use of region-based strategies for addressing the problem of face recognition after plastic surgery. The proposed methods implement the region-based approach in several ways. FARO (FAce Recognition against Occlusions and Expression Variations) divides the face into relevant regions (left eye, right eye, nose and mouth) and then codes them independently using Partitioned Iterated Function System (PIFS) processing. FACE (Face Analysis for Commercial Entities) applies a localized version of image correlation index. Finally, the Split Face Architecture (SFA), adaptive and integrative in nature, can leverage any known recognition method, from PCA to most recent ones (including FARO and FACE), provided that it is possible to divide the face into regions. Experimental results, compared with those available from recent experiments reported in literature, show that our methods yield much better performance than state-of-the art algorithms, both holistic and region based.

1. Introduction

The widening use of digital beautification (e.g., for images used in gossip magazines or advertisement) and of plastic surgery (which concretely changes the appearance of a person) can be considered as new emerging factors hindering face recognition. During recognition in uncontrolled settings, changes in pose, illumination and expression (PIE) can be addressed using specific strategies [53,5], or even "corrected" by requiring the user to repeat the enrolment/testing procedure. Face plastic surgery, however, makes the changes permanent. Moreover, the decreased costs of advanced surgical technologies makes such practices more and more affordable and thus widespread. Such surgeries are used for cosmetic purposes, to improve the facial appearance, or to correct and/or reconstruct the face from disfiguration due to illness or injury.

Automatic evaluation of the perceived beauty of an object, in general, and of a face, in particular, together with the means to enhance it, have long been of much interest to artists and researchers in various fields. As an example, automatic ranking of human face beauty is the basis of the research by Eisenthal et al. [18], which explores the notion of facial attractiveness through the application of machine learning techniques. The work is based on the accepted and often experimentally demonstrated assumption that there are objective regularities to be analyzed and learned. Using the original images, the authors try to learn and analyze the mapping from two-dimensional facial images to their attractiveness scores, assigned by human raters, in order to produce human-like evaluation of facial appeal. In order to increase such appeal, human face beautification has used cosmetics for a long time, with plastic surgery playing an increasing role recently. At the same time, current digital techniques allow "virtual" beautification of face images. Characteristic of such an approach, the work by Leyvand et al. [30] expands the results by Eisenthal by attempting a data-driven enhancement of facial attractiveness. These techniques may be used by professional photographers to enhance portraits, or even by surgeons to plan for plastic surgery. Such modifications can affect the ability of an automatic biometric system to tag faces in a collection of digital images even if they often entail only localized changes. In general, the number, regions, and span of the changes underwent would affect the subject recognisability after plastic surgery to different extents. As extensive surgical procedures can significantly hinder biometric recognition, especially in the case of mass screening using automatic face recognition they can also be misused to conceal

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personal identity. To mention some common examples, "light" cases of dermabrasion that affect the skin texture may negatively affect texture-based methods. Light lifting of forehead, eye contours or cheeks skin, however, hardly produces significant changes in appearance and is unlikely to seriously affect recognition. Some local plastic surgery procedures can adversely affect automatic recognition similar to pose or expression variations in uncontrolled settings, and can further induce "reverse" ageing, which makes people look younger. Singh et al. [42,44] tested the effects of plastic surgery on face recognition using an ad-hoc database, and compared the results obtained by competitive algorithms. All the techniques tested provided very poor recognition performance, and the authors concluded [44] that face recognition is not yet mature enough to extensively handle in a robust fashion the effects of plastic surgery.

In this paper we start from the conclusions in [44], and therefore we will use their results for comparative evaluation.

We briefly review some background on the methods representative of state of the art face recognition approaches and how they are affected by local changes induced by plastic surgery. One approach is global in nature. It considers holistic appearance features that capture the overall face appearance. Among the most popular global methods, we mention Principal Component Analysis (PCA) and Fisher Discriminant Analysis (FDA). Since the introduction of PCA for face recognition [26,47], such holistic approaches have been extensively investigated in this field. PCA finds the principal components of the original face image space and provides an optimal transformation for face representation. This consists in projecting the original face image onto a lower dimensional feature space by retaining only coefficients associated with the largest eigenvalues. However, the transformation found by the PCA is optimal for representing face patterns, but not for recognizing them [17]. Accurate face classification further requires discriminative features, which is the main motivation for using Fisher Discriminant Analysis (FDA), often referred as Linear Discriminant Analysis (LDA), in face recognition [19]. In fact, the latter generally outperforms PCA by both minimizing the within-class variance and maximizing the between-class variance of a given set of face images by means of a linear transformation [8,33]. FDA, similar to PCA, is still very sensitive to local changes. Local distortions such as illumination changes or occlusions heavily influence the features, leading to a significant drop in accuracy, since each pixel within the image influences almost all the dimensions of the subspace projection.

While PCA and FDA are appearance-based but global algorithms [1], a related example of appearance-based but local algorithm is Local Feature Analysis (LFA) [38]. LFA builds an object representation in terms of local features, exploiting PCA to extract a hierarchical orthonormal basis for the linear subspace spanned by the input ensemble. This is obtained by the diagonalization of the correlation matrix and ordering the eigenvalues according to their magnitude. Yet another local appearance approach, Circular Local Binary Pattern (CLBP), a variation of LBP, has also been proposed for face recognition [3] and is leveraged in texture-based algorithms often used in commercial applications. A further example of texture-based feature is proposed in [43] and exploits a neural network architecture to extract the phase features of the face texture using 2D log polar Gabor transform (GNN). Speeded Up Robust Features (SURF) [6] is yet another descriptor-based local approach. The 64-dimensional SURF descriptor is conceptually similar to the SIFT descriptor, and also focuses on the spatial distribution of gradient information within the interest point neighborhood.

In recent years, wide popularity has been gained by sparse representations, even for face recognition [51]. The usefulness of such representations, however, has been more and more questioned (see for example [40]). In particular, such methods require several examples for each object to be identified, and suffer from image misalignment. This might be a serious problem in cases when only one face image is available in the enrolment gallery (e.g., photos for id cards and passports). To partially solve these problems, in [2] a region based-approach is exploited to better adapt sparse representation to face recognition, using face images external to the gallery to solve the multiple sample problem.

The nature of the face recognition problem after plastic surgery seems to suggest a local approach. As a matter of fact, localized comparison of various features is often exploited in literature for face recognition. As recent examples elastic local reconstruction is used [52], online learning from local features is proposed as a strategy for video-based recognition [35], and local features are used for 3D recognition [27]. The approach espoused in this paper is therefore a region-based approach, where we process each relevant face region as a separate biometric source. To deal with this strategy in a most effective way we first performed an empirical analysis of the contributions made by different face regions to the face recognition process. Next we measured the effect of different surgical operations on each face component (eyes, nose, mouth). After these preliminary steps, we tested two methods, namely FARO (FAce Recognition against Occlusions and Expression Variations) [11], which is a fractal technique based on Partitioned Iterated Function System (PIFS) [20], and FACE (Face Analysis for Commercial Entities) [12], which exploits a similarity measure computed through a localized version of the correlation index. Both methods use a localized region-based like approach. The first one performs recognition by appropriately considering the division of face into regions traditionally considered significant for human physiognomy (eyes, nose and mouth). The second method does not exploit the regions "semantics" but rather performs similarity computation by merely dividing the image into blocks of equal size. FARO and FACE are compared with PCA, FDA, and LBP. A third approach proposed, related to the protocol for combining results from different face regions, regardless of the method used to process them, is the Split Face Architecture (SFA). It is adaptive (regarding thresholds) and integrative (regarding components). Using SFA, we expand our evaluation on the effects of plastic surgery to process each face region as a separate biometrics [10]. The experiments involving images before and after plastic surgery were all performed using the same database described and used by Singh et al. [44]. In summary, five different algorithms were evaluated: PCA, FDA, LBP, FARO, and FACE, either applied globally or integrating separate results from face regions through the SFA protocol. It is worth underlining that we used an advanced version of LPB, Multiscale, Rotation Invariant LBP, with Uniform Patterns [32,54]. Variations due to plastic surgery may be further confounded by uncontrolled settings such, as illumination and pose. The use of methods that are robust with respect to the latter confounding factors allows to assess better the net effect of plastic surgery in face recognition. The comparison with additional methods is indirectly derived from results reported in literature [2,9,42,44].

1.1. Contributions of the present work

In the experiments previously reported [10], SFA was tested using FARO on AR-Faces. In the experiments presented in [14] we measured the performance of PCA, LDA, FARO and FACE on the database presented in [44] to study the performance of a face recognition system after plastic surgery. The selected recognizers were applied globally to the whole face, though considering the inherent local approach underlying FARO and FACE. The present work provides a twofold contribution. First, we demonstrate that the increased performance obtained in face recognition does not