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Open-set face recognition across look-alike faces in real-world scenarios☆

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ABSTRACT

The open-set problem is among the problems that have significantly changed the performance of face recognition algorithms in real-world scenarios. Open-set operates under the supposition that not all the probes have a pair in the gallery. Most face recognition systems in real-world scenarios focus on handling pose, expression and illumination problems on face recognition. In addition to these challenges, when the number of subjects is increased for face recognition, these problems are intensified by look-alike faces for which there are two subjects with lower intra-class variations. In such challenges, the inter-class similarity is higher than the intra-class variation for these two subjects. In fact, these look-alike faces can be created as intrinsic, situation-based and also by facial plastic surgery. This work introduces three real-world open-set face recognition methods across facial plastic surgery changes and a look-alike face by 3D face reconstruction and sparse representation. Since some real-world databases for face recognition do not have multiple images per person in the gallery, with just one image per subject in the gallery, this paper proposes a novel idea to overcome this challenge by 3D modeling from gallery images and synthesizing them for generating several images. Accordingly, a 3D model is initially reconstructed from frontal face images in a real-world gallery. Then, each 3D reconstructed face in the gallery is synthesized to several possible views and a sparse dictionary is generated based on the synthesized face image for each person. Also, a likeness dictionary is defined and its optimization problem is solved by the proposed method. Finally, the face recognition is performed for open-set face recognition using three proposed representation classifications. Promising results are achieved for face recognition across plastic surgery and look-alike faces on three databases including the plastic surgery face, look-alike face and LFW databases compared to several state-of-the-art methods. Also, several real-world and open-set scenarios are performed to evaluate the proposed method on these databases in real-world scenarios.

1. Introduction

In the last two decades, real-world face recognition has been known as one of the attractive topics in computer vision research [35,36,40–48]. The open-set face recognition problem is the major challenge in face recognition [1], and operates under the supposition that not all the probes have pairs in the gallery. It requires a priori accessibility of a reject selection to respond "none of the gallery." If the probe is recognized rather than rejected, the face recognition system must then recognize the subject. Also, challenges in real-world face recognition can be roughly divided into six major categories: pose, illumination, expression, plastic surgery, aging, and look-alike faces. Among these challenges, face recognition across plastic surgery and look-alike are major ones that are one of the most important problems to be solved and have only been lately addressed by few researchers in [2–5,6–9] for face recognition across facial plastic surgery and look-alike faces, respectively. This paper will focus on the impact of look-alike faces on open-set and real-world face recognition. Generally speaking, the look-alike faces are categorized as three types including: 1) intrinsic look-alike faces, 2) situation-based look-alike faces and 3) look-alike faces through plastic surgery. In the first type (intrinsic), two face images are similar in terms of biological and as individual such as twins. Also, in the second type (situation-based), two face images become similar when they are in a similar situation such as similarity in pose, expression, makeup, and illumination. Finally, in the third and last type (plastic surgery), two face images become similar when their faces are operated under plastic surgery, such as local similarity in nose, lips and etc. after facial plastic surgery in a category of the people.

In the look-alike faces through facial plastic surgery, the operation can change the perceived appearance of texture faces. Also, in intrinsic and situation-based look-alike types, face images are similar together in terms of texture and appearance. Fig. 1 shows five pairs of look-alike faces, each of which is based on the three above types. As shown in Fig. 1, face recognition methods will possibly fail when they are faced with look-alike faces. Most of the existing face recognition

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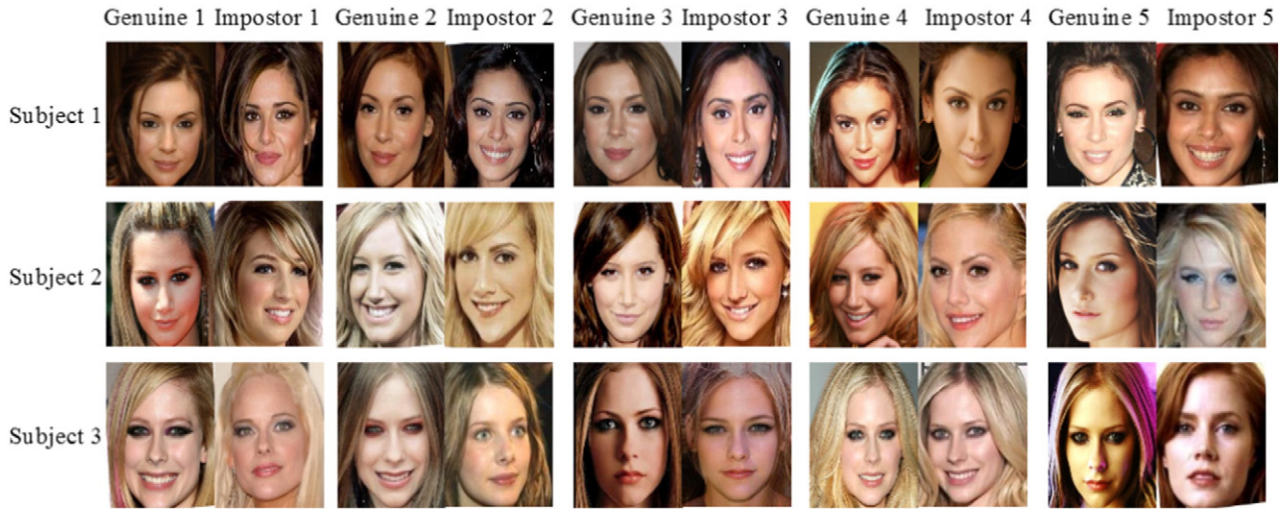

Fig. 1. Examples of look-alikes for three subjects: for each subject five genuine images and five corresponding imposter images are given. The images were taken from the look-alike face database [9].

methods are based on appearance and texture based. Nonetheless, these methods will obviously fail in the context of look-alikes because both the look-alike face subjects will have near identical subspace, feature, and possibly texture. This claim was proposed by Kosmerlj et al. in their study [10]. However, although some parts of facial depth can be changed by plastic surgery, most parts are individual (this conclusion was made in [11]) which does not change and it can discriminate the look-alike faces overall. Hence, in this paper, facial depth information is utilized to handle the impact of look-alike faces in face recognition by 3D face reconstruction from only a 2D single image.

Recently, sparse representation has had prosperous performance on face recognition and it has been successfully applied to automatic face recognition. However, most sparse representation methods for face recognition require several images for each subject in the gallery [12–15,37–39]. Since some real-world databases for face recognition do not have multiple images per person in the gallery, with just one image per subject in the gallery, this paper proposes a novel idea to overcome this challenge by 3D modeling from gallery images and synthesizing them for generating several images.

In this paper, three novel approaches are proposed for real-world and open-set face recognition by 3D face reconstruction and sparse and collaborative representations. Accordingly, a 3D model is initially reconstructed from frontal face images in a real-world gallery. To reconstruct a 3D model from each human face in real-world scenarios, a Generic Elastic Model (GEM) [11] is used. Then, each 3D reconstructed face in the gallery is synthesized to several possible views and a sparse dictionary is generated based on the synthesized face image for each person from both texture and depth synthesized images across partial pose. Then, a likeness dictionary is defined and its optimization problem is solved by the proposed method. Also, two other methods are proposed by collaborative representation, and then mixed sparse and collaborative representations for this purpose. Finally, face recognition is performed for open-set face recognition using three proposed classifications based on sparse representation classification, collaborative representation classification and both sparse and collaborative representations together.

In this paper, the main contributions are as follow:

1) The sparse representation based on the face recognition method across facial plastic surgery and look-alike faces is proposed from one single image in the gallery. To overcome the main problem in sparse representation which requires multiple samples for generating the sparse dictionary, this paper uses 3D face modeling for generating several samples for the sparse dictionary from only one single image.
2) A feature extraction is proposed to extract the feature from both facial reconstructed depth images and texture images for handling the problem of facial plastic surgery and look-alike faces in face recognition.
3) The likeness dictionary and its optimization problem are proposed to learn a new dictionary robust to look-alike face for face recognition.
4) Three open-set classification methods are proposed for real-world face recognition across plastic surgery and look-alike faces as follow: a) Open-Set Sparse Representation Classification (OSSRC), b) Open-Set Collaborative Representation Classification (OSCRC) and c) Open-Set Sparse Representation and Collaborative Representation Classification (OSSR + CRC) which is a combination of the two methods.
5) The proposed method improves the face recognition rate across plastic surgery and look-alike faces on three databases including the plastic surgery face [3], look-alike face [9] and LFW [16] databases. Also, the obtained results outperform the state-of-the-art methods. Alongside handling plastic surgery and look-alike faces, the proposed method handles pose, expression and illumination in these databases.
6) Several different real-world and open-set scenarios are performed to evaluate the proposed method on three databases including the plastic surgery face, look-alike face and LFW databases.

This paper is organized as follows: In Section 2, the related works are described. Section 3 describes the 3D face reconstruction method from a single frontal face image by GEM. In Section 4, the face recognition methods are proposed. Experimental evaluations are given in Section 5 and conclusions are presented in Section 6.

2. Related works

This paper describes two challenging tasks: 1) face recognition for look-alike faces which are categorized into three mentioned types. 2) Open-set face and real-world scenarios for face recognition. In this section, the literature related to face recognition under plastic surgery (third type of look-alike faces) is initially described. Then, the first and second types from look-alike faces are considered for analyzing the related state-of-the-art methods. Finally, the open-set and real-world scenarios are given in the literature.

2.1. Refinements of face recognition methods under plastic surgery

In this sub-section, the effect of plastic surgery on look-alike face recognition as the third type of look-alike face is investigated. Plastic