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Facial beauty analysis based on geometric feature: Toward attractiveness assessment application

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ABSTRACT

Facial beauty analysis has been an emerging subject of multimedia and biometrics. This paper aims at exploring the essence of facial beauty from the viewpoint of geometric characteristic toward an interactive attractiveness assessment (IAA) application. As a result, a geometric facial beauty analysis method is proposed from the perspective of machine learning. Due to the troublesome and subjective beauty labeling, the accurately labeled data scarcity is caused, and result in very few labeled data. Additionally, facial beauty is related to several typical features such as texture, color, etc., which, however, can be easily deformed by *make-up*. For addressing these issues, a semi-supervised *facial beauty analysis* framework that is characterized by feeding geometric feature into the intelligent attractiveness assessment system is proposed. For experimental study, we have established a geometric facial beauty (GFB) dataset including Asian male and female faces. Moreover, an existing multi-modal beauty (M^2B) database including western and eastern female faces is also tested. Experiments demonstrate the effectiveness of the proposed method. Some new perspectives on the essence of beauty and the topic of facial aesthetic are revealed. The impact of this work lies in that it will attract more researchers in related areas for beauty exploration by using intelligent algorithms. Also, the significance lies in that it should well promote the diversity of expert and intelligent systems in addressing such challenging facial aesthetic perception and rating issue.

1. Introduction

Facial beauty is an everlasting topic of human society. Beauty perception has been studied for years, but scientists have not yet reached consensus on which factors are dominant in the perception and evaluation of facial attractiveness. In ancient times, researchers had discovered several rules for human beauty. For example, ancient Chinese and Greek scholars have proposed a set of general rules for beauty assessment by measuring the vertical and horizontal distances between organs on the faces and their ratios between these distances. They believe that the attractive human faces may follow the beauty and harmony rules in nature (e.g. golden ratio).

In modern times, facial beauty has been thoroughly studied and can be divided into several different approaches. One approach is to follow the rules of ancient scholars with more methodologies. A typical example is the Marquardt beauty analysis (http://www.beautyanalysis.com) in which a golden decagon matrix is constructed based on the traditional golden ratio. Marquardt beauty analysis is used as the geometric "source code" in producing a standard human face mask for facial beauty where the positions of each facial organs are well defined. The mask is also viewed as a perfect mask. The matching degree between a human face and the mask can be defined as the facial beauty score.

Evidences showed that many attractive faces, regardless of races, cultures and times, could match the mask fairly well. Similar work was also described in Jefferson (2004). Another approach in facial beauty studies was introduced by psychology and social scientists, who study the human's perception on facial beauty. In their research, several facial images were first collected and used to generate several simulated images. The raw and simulated images would be shown to several raters for a psychology experiment, and then the raters' perceptions about all images were collected and analyzed. Several interesting phenomena have been discovered in these experiments. For example, the average face of the whole set of faces is always considered to be more attractive than most of all individual faces (Langlois & Roggman, 1990), but may not be the most attractive face since the average face of a set of

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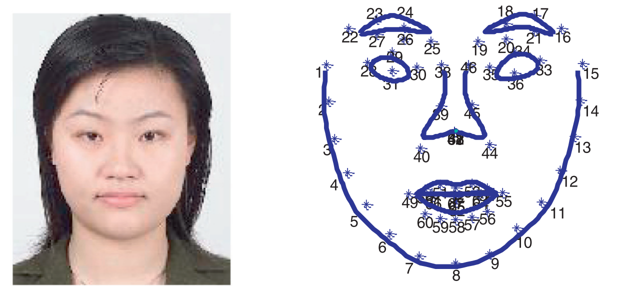
attractive faces is recognized to be more attractive than the average face of the whole set (Perrett, May, & Yoshikawa, 1994). Beyond the average face hypothesis, human perception on symmetrical faces (Perrett, Burt, Penton-Voak, Lee, Rowland, & Edwards, 1999; Rhodes, Proffitt, Grady, & Sumich, 1998; Swaddle & Cuthill, 1995) and other facial features (Johnston & Franklin, 1993; Penton-Voak et al., 2001; Slater, Rosenblatt, Penton-Voak, & Perrett, 2001) have also been studied.

With the rapid development of pattern analysis and machine learning techniques, computer aided approaches for beauty analysis are emerging in recent years which have brought several virtues. *First*, it gives us much more opportunity to construct large data sets with thousands of facial images (Davis & Lazebnik, 2008; Zhang, Zhao, & Chen, 2011; Gray et al., 2010) and discover new patterns relevant to beauty perception. *Second*, automatic pattern analysis techniques make it easier to discover implicit rules and knowledge in beauty. For example, feature selection techniques make us understand what kinds of features contribute more for attractive faces (Altwaijry & Belongie, 2013; Chang and Chou, 2009), and the mapping from facial features to beauty scores can explain how beauty perception varies with the change of facial appearance (Davis & Lazebnik, 2008). *Third*, automatic machines have been invented to predict the beauty score of a face (Kagian, Dror, Leyvand, Cohen-Or, & Ruppin, 2007) and beautify a facial image (Leyvand, Cohen-Or, Dror, & Lischinski, 2008), which is valuable for application in plastic surgery as well as other applications such as computer assisted beauty search of partners (Whitehill & Movellan, 2008), animation, advertising, computer games, video conferencing (Gunes, 2011), etc. Pattern analysis and machine learning based techniques, such as neural networks, support vector machines, K-nearest neighbor, linear regression, Ada-boost algorithms, and principal component analysis, have been proven to be promised supervised and unsupervised approaches for beauty analysis and application (Aarabi, Hughes, Mohajer, & Emami, 2001; Bottino & Laurentini, 2010; Eisenthal & Dror, 2006; Gray, Yu, Xu, & Gong, 2010; Mu, 2013; Sutić, Rešković, Huić, & Jukić, 2010).

Motivated by pattern analysis based approaches, this paper aims to make specialized investigation on the nature of facial beauty based on the geometric feature instead of facial texture and skin based features that may change with human aging and make up. For beauty perception of facial images, beauty analysis is handled as a regularized regression problem. The beauty model is defined as a beauty score function that maps a facial image into a score representing how attractive the face is. To fully explore the contribution of geometric feature in facial beauty, we focus on the geometric features (i.e. facial shape) such that the beauty score function can be modeled easily. This choice is made with consideration that the geometric features are essential and invariable, and closely related with facial beauty, while other features like texture, skin and hair color are easy to be changed by general makeup. Since the geometric features cannot represent the whole information of a face and the raters' decision on the attractiveness of a face may also be disturbed by those easily changed facial features (e.g. skin), thus constructing a computational beauty model directly on the geometric features is not suitable. To solve the problem, we define the geometric beauty score as the supremum of the all faces' beauty scores under the given geometric feature and other possible features. To learn the proposed geometric beauty score function, a Hessian energy based semi-supervised manifold weighted regression is presented in this paper. Additionally, a database of Chinese faces for facial beauty analysis has been established.

The contributions of this paper can be summarized as follows:

- This paper proposes a novel definition of facial beauty score function for studying facial attractiveness based on geometric feature, which reveals the fundamental cues of facial beauty, and avoids the impact of texture, skin, etc.
- A Hessian semi-supervised geometric beauty framework with random projection is proposed for modeling facial beauty score function, such that the attractiveness of a large number of real-world unlabeled faces can be automatically analyzed by the proposed method, which is labor free.
- The proposed work is less laborious due to that the labeling process of facial beauty score is unnecessary in training phase. For modeling, the attractive faces are of movie stars from Internet and the unattractive faces are generated by an existing deformation algorithm, while the real-world faces keeps unlabeled.
- Extensive experiments on two facial beauty databases are implemented for revealing the essence of beauty under the guide of geometric characteristics.



(a) raw face image (b) geometric face

Fig. 1. One example of geometric landmark representation.

The paper is organized as follows. In Section 2, the related works closely associated with this paper are presented. The proposed definition of facial beauty score function, the geometric beauty analysis framework, and the final algorithm for the proposed framework are described in Section 3. The established facial beauty dataset and the experiments including facial beauty modeling, testing and raters' verification are presented in Section 4. The experiment on an existing multi-modal facial beauty database is further studied for better evidence in Section 5. A discussion on the topic of facial beauty in terms of pros and cons is presented in Section 6. Finally, Section 7 concludes this paper.

2. Related work

2.1. Facial geometric representation

Geometric features are the most vital information of human beauty, which involve the distance between organs, the shape of face and organs, and so on. The complete geometric information of a face can be represented by a 3-D surface model. However, due to the complexity and difficulty to construct a 3-D face model, 2-D landmark features are used to characterize the geometric information of faces. Given a face image, the 2-D landmark features can be extracted by detecting the face region using Ada-boost or neural network based methods (Rowley & Baluja, 1998; Viola, 2004) first and then applying the ASM model (Cootes, 1995) to extract the n landmark points of the face in the detected region.

The coordinates $\{(x_1, y_1), (x_2, y_2), \cdots, (x_{68}, y_{68})\}$ of these landmark points can be used as the geometric feature of the face. For visualization, we present an example of a facial image and the geometric landmark coordinates in Fig. 1(a) and (b) which shows 68 landmark points as Zhang et al. (2011), respectively. However, the geometric feature simply uses the landmark coordinates which is defined in a coordinate system on the original image, thus the