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The cluster assessment of facial attractiveness using fuzzy neural network classifier based on 3D Moiré features

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ABSTRACT

Facial attractiveness has long been argued upon varied emphases by philosophers, artists, psychologists and biologists. A number of studies empirically investigated how facial attractiveness was influenced by 2D facial characteristics, such as symmetry, averageness and golden ratio. However, few implementations of facial beauty assessment were based on 3D facial features. The purpose of this paper is to propose a novel cluster assessment system for facial attractiveness that is characterized by the incorporation of 3D geometric Moiré features with an adjusted fuzzy neural network (FNN). We first extract 3D facial features from images acquired by a 3dMD scanner. Seven Moiré features are employed to represent a 3D facial image. The FNN classifier, taking the Moiré features as the parameters, is then trained and validated against independently conducted attractiveness ratings. A number of diverse referees were invited and offered their attractiveness ratings over a five-item Likert scale for 100 female facial images. The proposed assessment presents a high accuracy rate of 90%, and the area under curve (AUC) computed from the receiver operating characteristic (ROC) curve is 0.95. The results show that the perceptions of facial attractiveness are essentially consensus among raters, and can be mathematically modeled through supervised learning techniques. The high accuracy achieved proves that the proposed FNN classifier can serve as a general, automated and human-like judgment tool for objective classification of female facial attractiveness, and thus has potential applications to the entertainment industry, cosmetic industry, virtual media, and plastic surgery.

1. Introduction

Studies of facial attractiveness have long interested philosophers, psychologists, artists and scientists. A popular axiom concerning physical attractiveness says:"There is no standard for beauty, and it is all a personal perception." Recent scientific studies revealed, however, that attractiveness ratings showed high degree of agreement among groups of raters belonging to the same culture and even across cultures and generations [1–11]. Such findings imply there may exist facial features that contribute one's general attractiveness consistently.

Many previous studies have employed composite faces to study the effects of symmetry and averageness of the face on attractiveness [12–18]. Machine learning methods have also been utilized to investigate whether attractiveness ratings can be learned and predicted by mapping facial images to their attractiveness scales [19]. Most current work considers, however, only the 2D facial characteristics [20–23]. The purpose of this paper is thus to present a cluster assessment based on 3D Moiré features by developing a fuzzy neural network classifier (FNNC) to evaluate facial attractiveness. With a set of female 3D facial images which are independently attractiveness-rated, we extract 3D Moiré facial features, which are then employed as the input of the proposed supervised learning algorithm to construct a facial attractiveness classifier (or predictor).

The flow of constructing the proposed FNNC system for facial attractiveness is shown in Fig. 1. After acquisition of a 3D facial image, we first extract its Moiré patterns. Among features extracted from the patterns, seven quantitative representations are used for attractiveness cluster assessment. Finally, an FNN classifier is constructed and applied to determine the attractiveness class of the input image.

2. Facial attractiveness rating

One hundred (100) Taiwanese female facial images are included in the study. These images are taken from the 3dMD

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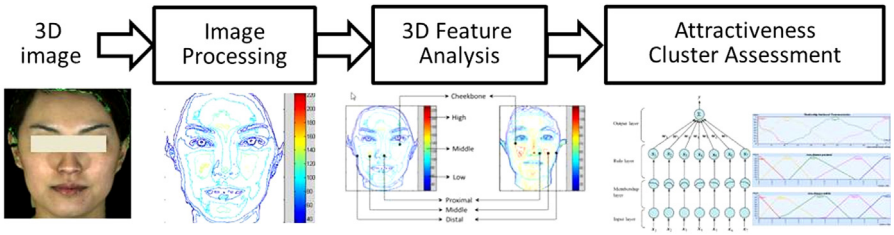

Fig. 1. Construction of the FNNC cluster assessment system for facial attractiveness.

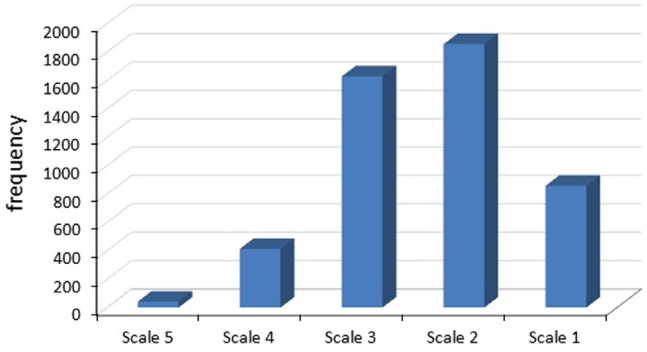

Fig. 2. The scale-frequency distribution of the facial attractiveness ratings.

Table 1
Scale to class mapping.

scale	5	4	3	2	1
class	1	2	3	4	5

cranial system which is an ultra-fast 3D cranial imaging system (an integration of anatomical 3D photography devices) that uses non-invasive imaging techniques for high-precision anatomical documentation. Its coverage includes full face with the image-capture speed at 1.5 milliseconds per image. All 100 samples, with 20–30 years old having a neutral expression are assessed for attractiveness by 48 human raters (24 males and 24 females) on a Likert scale from 1 (least attractive) to 5. All images are presented to each rater in a random order and each image is shown on a separate page with an auto-play slide show. Each rater is asked to view the image for 5 s and rate the attractiveness of each sample within a maximum of 3 s. For all 100 facial images rated by 48 people, there are 4800 possible occurrences distributed in 5 scales. Fig. 2 depicts the frequency vs. scale distribution of the ratings.

The rating of an individual facial image is computed as the mean of its overall ratings. In our results, the attractiveness ratings of all images range from 1.38 to 3.6, with a mean of 2.37 ($\mu=2.37$) and a standard deviation of 0.71 ($\sigma=0.71$).

In order to make the definition of the classes more intuitive for the proposed FNN classifier, we convert the term "scale" to "class," where "class 1" is referred as "most attractive" and the occurrences of certain class for a facial image (or pattern) are denoted as the degree of membership to that class. Table 1 shows their scale-to-class mapping. The degree of membership (of certain class) vs. image pattern is shown in Fig. 3. The image patterns are arranged in decreasing order of their mean attractiveness ratings. Different classes are represented by distinct colors and line patterns.

Reliability can be defined as that the extent to which a questionnaire, test, observation or any measurement procedure produces the same results on repeated trials. In our study, we compute reliability index to avoid the rating are subjective. Internal consistency can be estimated via the split-half reliability index, coefficient alpha index [35] or the Kuder-Richardson formula 20 (KR-20) index [36]. In general, a Cronbach's alpha level more than 0.7 is deemed as reliable, while 0.9 as excellent [35–38]. Our test reaches Cronbach's alpha coefficient of 0.981 (significantly greater than 0.9), exhibiting a high level of internal consistency.

3. 3D feature analysis

Past research attributed conventional harmonious features, such as the Golden Ratio, in faces to facial attractiveness [23–25]. These features are, however, mostly extracted from 2D facial images. As scanning techniques advance, 3D surface imaging systems, such as 3D laser and camera scanners, are widely used, especially, in clinical settings. Features extracted from images generated by these 3D modalities can reveal important characteristics that contribute facial attractiveness assessment.

3.1. 3D Moiré features detection and extraction

Moiré patterns are an object's contour lines which contain the height distribution information of the surface of a three-dimensional object [26,27]. We characterize a face by its Moiré patterns, where homogeneous regions are enclosed by contour lines to form iso-surfaces. Fig. 4 demonstrates examples of contour maps expressed in a color scale.

The contour maps in Fig. 4 suggest that the more attractive faces, i.e., with higher attractiveness rankings, exhibit more bluish (or near the blue end of the color spectrum) distribution than those with lower rankings. The blue contour lines correspond to smooth and distinctive facial features, while the reddish contours are normally resulted from defective or bumpy facial surfaces. Moiré-based colorful labels can then serve to reflect local homogeneity of the facial surface. Such observations constitute one of the underlying goals of this paper: to discover meaningful 3D features from Moiré patterns as inputs to the attractiveness cluster assessment system.

We divide the facial contour map into seven Moiré groups (Moiré sets) according to the following three characteristics (Fig. 5 shows the schematic diagram of various characteristics that result in seven Moiré groups):

- Eccentricity (maximum distance of the contour line away from the nasal tip): proximal, middle, and distal.
- Elevation (height of the contour line from the base of the coronal plane of the face): low, middle, and high.
- Cheekbone: locally enclosed contour lines immediately below eyes.

k-mean clustering ($k=5$) is then applied to partition the facial images into five classes, referred to as classes 1 through 5, ranked according to attractiveness ratings.

To determine the correspondence between the classes (thus attractiveness ratings) and the proposed Moiré groups of the contour lines, inter-class correlations are evaluated with respect