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The analysis of facial beauty: an emerging area of research in pattern analysis

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Abstract. Much research presented recently supports the idea that the human perception of attractiveness is data-driven and largely irrespective of the perceiver. This suggests using pattern analysis techniques for beauty analysis. Several scientific papers on this subject are appearing in image processing, computer vision and pattern analysis contexts, or use techniques of these areas. In this paper, we will survey the recent studies on automatic analysis of facial beauty, and discuss research lines and practical applications.

Keywords: Face image analysis, facial landmarks, attractiveness.

1 Introduction

Analyzing 2D or 3D images of humans is a main area of research in pattern analysis and computer vision. The human face is by far the part of the body which conveys more information to human beings, and thus potentially to computer systems [2]. Such information span identity, intentions, emotional and health states, attractiveness, age, gender, ethnicity, attention, etc. At present, the most studied application of face image analysis is identity recognition [1], which is essentially an engineering deformable object recognition problem. Other face image analysis applications are multidisciplinary and related to human sciences and medicine. They are essentially 1) analyzing human expressions, and 2) analyzing face attractiveness.

The first is by far the most studied problem, particularly to capture human expression for animating the faces of virtual characters. A much more challenging problem is interpreting facial expressions, that is mapping expressions onto emotional states [2], [3]. The results presented are not yet convincing, since tracing backward the path from expressions (effects) to the emotions (causes), requires a shared and coherent model of the human emotions and of their effects on facial features, which psychophysiology has not yet supplied [3]. The second multidisciplinary problem, that is the analysis of human beauty and its measure, has been widely debated for centuries in human science, and, more recently, in plastic surgery and orthodontics. In the last decades, several thousands of papers on this subject have been published in these areas. The human science researchers involved in these studies are: social and developmental psychologists, cognitive psychologists and neuroscientists and evolutionary psychologists and biologists. Applying pattern analysis and computer vision techniques for analyzing beauty is a relatively new research field. The purpose of this paper is to survey rationale, techniques, results, applications and open problems in this emerging area.

2 Beauty in human sciences and medicine

Social importance of attractiveness. What is beauty? Philosopher, scientists and artists debated the problem for centuries. A controversial long lasting question is whether beauty is objective or subjective, or if “Beauty is in the eye of the beholder”, according to a sentence of the writer Margaret Wolfe Hungerford (1878). Important personages, as David Hume (1741), have supported this thesis or, as Immanuel Kant (1790), the opposite. Coming to our times, a number of recent behavioural, social and psychological studies, as well as everyday common experience, show that face and body harmony is extremely important in general social life. Looking unpleasant or different seriously affects self-esteem and can result in social isolation, depression and serious psychological disorders [35]. Thus, is not surprising that, according to a recent estimate, in the US more money is spent annually on beauty related items or services than on both education and social services [5].

Classic Beauty canons. Since ancient times, the supporters of beauty as an objective and measurable property attempted to state ideal proportions, or beauty canons, for the human body and its parts. The Greek sculptor Polykleitos was the first to define aesthetics in mathematical terms in his “*Kanon*” treatise. Marcus Vitruvius, a Roman architect, introduced the idea of facial trisection, or facial thirds, largely used in medicine and anthropometry (Fig. 1).

Fig. 1. Facial trisection, as originally described by Vitruvius

Renaissance artists, as Leonardo da Vinci, Leon Battista Alberti, Albrecht Duerer and Piero della Francesca, reformulated and documented the classic canons. Descriptions of the classic canons can be found in [6]. These canons have been used for centuries in art by sculptors, painters, and are a rough working guide for plastic surgeons. From the classic concept of ideal proportions also stems the debate about the relevance of the golden ratio in beautiful faces. The golden ratio is an irrational number, approximately 1.618, obtained by dividing a segment into two parts, a and b, such that $a/b = (a+b)/a$. Since ancient times, the golden ratio has been used explicitly, or claimed later to have been used, by a score of sculptors, painters, architects and even composers. Today, some papers in plastic surgery and orthodontics contexts support the idea of an universal standard of beauty based on the golden ratio [31], [32]. However, several experimental studies found a little correlation between the asserted ideal proportions and the beauty scores received by human raters [33], [34].

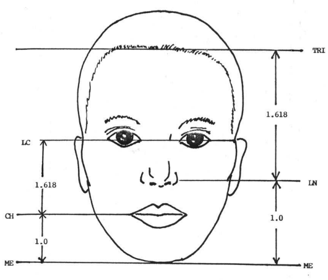

Fig. 2. The divine proportions of the face and the golden ratio

The objective nature of facial beauty. In this subsection we present the empirical results supporting the idea that facial beauty has an objective nature: *brain activity patterns*; *cross-cultural consistency of beauty ratings; infant's preference for attractive faces.*

Brain activity patterns. Psychophysiology and neuropsychology have detected the brain areas where the assessment of facial beauty is processed. Activity patterns related to explicit attractiveness judgement of 2D face images have been measured with MRI and NIRS techniques and correlated with the beauty score of the faces. Brain patterns showed greater response to highly attractive and unattractive faces [23], [47]. These results could lead to practical "ground truth" beauty assessing techniques.

Cross-cultural consistency of attractiveness ratings. Many experimental researches based on various groups of human raters have been performed. For instance, consistency of attractiveness ratings (correlation greater than 0.9) was reported in [9] for groups of Asian, Hispanic, Black and White Americans, male and female, both as subject and judges. In [10] it was reported that English, Asian, and Oriental female raters showed very close agreement in assessing the attractiveness of a selection of Greek man. Other experiments used synthetic faces [8].

Several studies compared the ratings of different professional groups, as for instance clinicians specialized in orthodontics and normal hospital clerks [11]. Attractiveness self-ratings and third-party ratings have also been compared too [41]. Moreover, most papers aimed at automatically rating beauty of previously rated images by human observers, validated the human "ground truth" ratings by checking their consistency, for instance correlating the scores of different groups.

The conclusion is that a substantial beauty rating congruence exists over ethnicity, social class, age, and sex. Rating congruence is particularly strong for very unattractive and very beautiful faces [8], which appears in agreement with the analysis of brain activity patterns.

Infant preference for attractive faces. Babies as young as three/six months were found to be able to distinguish between faces previously rated as attractive or unattractive by adult raters. This conclusion was obtained observing the time spent by the babies in looking at each face. Since very young babies should not be affected by cultural standards about beauty, these studies seem to indicate that appreciating beauty is an innate human capability [28], [39].

Concluding, even if the problem of which are the objective elements of beauty is still much debated, we can conclude that there is strong evidence that these objective elements exist, are relatively stable in time and space, and they could be measured.

3 Applications of machine beauty analysis

Clearly, a fundamental application area of machine beauty analysis is supporting human sciences research. However, automatically ranking, or suggesting ways for improving attractiveness, could result in many applications in other scientific, professional and end user areas. Beauty ranking programs could be used for preparing professional carnet, screening applicants for jobs where attractiveness is a basic requirement, in social network contexts. Potentially very popular end user or professional applications could be constructed for supporting and suggesting make-up styles. A related application, automatic photo retouch, will be discussed in the following [14].
Another important application area is plastic surgery. Some computer tools have been proposed for supporting surgery planning. These tools present images of the possible effects of the surgery based on 2D images [29], or 3D scans [30], morphed with manual interfaces. How to manipulate faces, as well as the evaluation of the results, is currently left to the surgeon's judgement. Beauty scoring programs, able to evaluate the various possible surgery outcomes, or also to suggest how to enhance attractiveness would be of great help.

4 Computer-based beauty analysis

In this section, we survey the papers recently appeared on the automatic analysis of beauty, and of its elements. Observe that the general approaches for most face image processing applications, including beauty analysis, are similar, and can be roughly divided into holistic, as PCA, LDA, and feature based. Holistic techniques perform an automatic extraction of significant data based on a number of face samples. The precise meaning of the data obtained, complex combination of the original 2D or 3D data, is often difficult to state. In the feature based approach the features significant for a given problem are selected *a priori*. Their meaning is clear, but elements relevant to the particular problem could have been overlooked.

Shape and texture. The relative relevance to attractiveness of face shape and colour texture has been experimentally investigated. In [24], different skin textures obtained from photographs of 170 women were applied to a common 3D face model and rendered with the same illumination. Experiments showed a high correlation between the beauty scores of the original face images and of the 3D model textured with them. Several other results support the importance of skin colour texture for attractiveness [27], [25], especially in intersex evaluation, a thesis also supported by Darwin [26].

Fig. 3. Effects of symmetry: original face, left and right symmetries

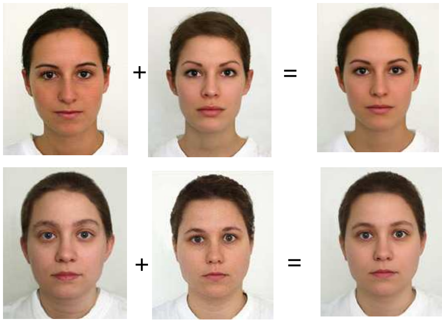

Fig. 4. Averaging faces improves (female) attractiveness.

Symmetry and averageness. Several researches dealt with the role of symmetry and averageness in attractiveness. A pioneer in these studies was Sir Francis Galton, which in 1879 created photographs where the images of different faces were superimposed [40]. Today researchers use image processing techniques for finding the sagittal (symmetry) plane, locating facial landmarks, measuring asymmetry, and creating artificial symmetrical, morphed and average faces.

The effects of asymmetry on attractiveness perception have been investigated in several experiments [8], [12], [13]. Male and female images have been rated, and the ratings related with the asymmetry of the original faces and with the ratings of the faces made symmetric with left and right symmetries. The results are rather controversial. Low degrees of asymmetries do not seem to affect attractiveness. Some research even found a negative correlation between symmetry and attractiveness [13].

The effect of averageness on attractiveness perception is a related problem. According to evolutionary biology, evolutionary pressure operates against the extremes of the population, and average facial prototypes should be preferred by conspecifics [36]. Composite or average 2D face images, created by normalizing eyes and mouth position and averaging their pixel values, have been rated and their ranks compared with those of the original faces [12], [7]. Even in this case the results are controversial. For female faces, the ratings of composite faces were better than those of the original faces (see Fig. 4). However, composites are more symmetrical and rather free of facial blemishes. For male faces, composites were found less attractive than normal faces [7], possibly since attractive male faces show strong features perceived as dominance indicators and resistance to parasites [37]. According to [8], average faces are attractive, but very attractive faces are not average, as shown by the preference given to warped faces obtained by increasing the distance of facial landmarks from the average landmark position. A 3D analysis of the influence on attractiveness of averageness both of 3D shape and 2D texture is described in [19]. The 3D database included 100 young adult males and females. The 3D shapes and the 2D textures were separately averaged, and artificial face images were created in two different ways, first by morphing individual texture maps onto the average 3D head, and then the average texture onto the individual heads, using corresponding feature points. The original, texture-normalized and shape-normalized images were rated by a 36 people panel on a 5 level scale. The results show that attractiveness scores are larger for texture normalized and even more for shape-normalized images.

Enhancing beauty. An automatic system for enhancing facial attractiveness of frontal colour photographs has been presented in [14]. It is aimed at professional retouching, and requires a database of faces rated beautiful. Each face is triangulated, starting from 84 landmarks, and 234 lengths, normalized by the square root of the face area, make a representative vector. The vector of the face to beautify is compared using various techniques with the vectors of the beautiful faces. Finally, the triangulation of the original face is warped toward those of the beautiful faces more similar to the original.

A system for planning rhinoplastic surgery has been presented in [38]. In the case of rhinoplasty, the profile is the most relevant feature, and the system is based on a data-base of profiles of faces rated beautiful or at least regular. In general there is not a unique prototype of a beautiful facial feature (nose in this case), but different shapes could be more or less attractive, depending on the general harmony and integration with the rest of the face [30]. The system looks in the database for the most similar profile, excluding the nose. Then, it applies the nose profile of the selected face to the profile to improve, providing an effective suggestion for the plastic surgeon.

Assessing beauty. Several papers are aimed at automatically measuring face attractiveness. Most of these papers use the feature approach. The general idea is to look, in some particular face space, for the nearest samples of a training set of rated faces and construct a vote depending in some way on their scores.

A preliminary automatic facial beauty scoring system was described in [15]. A few face landmarks are manually determined on frontal monochromatic images, and a vector of eight ratios between landmarks distances is used to describe a face. A panel of 12 judges scored 40 training images on a four point scale. For scoring a new image, its characteristic vector is first computed. Then, the scores of the 10 nearest faces in the face space are averaged.

A similar approach is reported in [16] and [17]. Also in these cases 2D frontal images are used. 215 female images were rated on a 10 level scale from 48 human referees [16]. Standard deviation of scores for each training, showed rather compact distributions around the average vote. Smaller variances were found for very high (beautiful) and very low (unpleasant) scores. Automatically detected landmarks were used for constructing a representative vector of 13 distances ratios. Several classifiers were experimented, obtaining, on the average, score rather close to those of human referees. Investigations on the classification results in relation with age, ethnicity, gender of the referees, and with some classical beauty canons are presented in [18].

In [20], 91 color frontal images of young Caucasian female were rated on a 7 point scale by 27 raters. To validate ranks, raters were divided several times at random into 2 groups, and the ratings compared, finding 0.92 as mean correlation. For each face image, 84 feature points were automatically extracted, and a feature vector was constructed containing 3486 normalized distances between them and 3486 slopes of the distance segments. These data were reduced to 90 using PCA, and integrated with a measure of asymmetry and samples of skin colour and smoothness in selected face areas, resulting in a 98 dimension representative vector. Several rating experiments were performed with real and artificial face images, comparing human and automatic ratings, and analyzing also the relevance of the various features used. A 0.82 Pearson correlation with human ratings was found, more significant than that found in [21], owing to the larger feature vector.

A regression analysis has been used in [22] to determine the relevance to beauty of three attractiveness predictors: neoclassic canons, feature symmetry and golden ratio. The database included 420 frontal expressionless gray scale Caucasian faces selected in the FERET database, and 32 pictures of movie actors. The raters were 36, and the scores were given on a ten levels scale. Several measures were extracted from the position of 29 landmarks. The results show that several of the rules specified by these beauty predictors have actually little relation with the beauty score.

In [46], the significance to attractiveness of 17 geometric facial measures was investigated using Artificial Neural Networks. The features were classified for their relative contribution to attractiveness. Some feature dimension, as lower lip thickness, were found to be positively associated with attractiveness, other, as nose area, negatively. It has

been found that the more significant are mouth width, nose width and distance between pupils, the less significant eye sizes.
Landmarks based and holistic approaches have been compared in [21]. Two data sets, each with 92 frontal images of young Caucasian American and Israeli females, were rated by 28 raters on a seven level scale, and consistency of ratings was verified. 37 normalized facial feature distances and data related to hair colour, facial symmetry and smoothness were inserted in the feature vector. PCA was used for decorrelating the geometric data. The holistic approach applied PCA on images normalized using centers of eyes and mouth. The eigenfaces most correlated with the human attractiveness ratings were selected. An interesting result is that such eigenfaces did not correspond to the highest eigenvalues, and contain clearer details of facial features like nose, eyes and lips rather than general description of hairs and face contours. For assessing attractiveness, both K-nearest neighbours and support vector machines were used, and correlation between machine and human scores was given as a function of the dimension of the feature vector. Several results are interesting. Feature based beauty prediction performed better than holistic: a top Pearson correlation of almost 0.6 versus 0.45 is reported. Probably, this is due to, the normalization of eyes and mouth position, which changes some landmark distances' ratios that are related to the general harmony of the face. A better prediction was simply obtained combining linearly the two predictions.
An automated scoring system for learning the personal preferences of individual users from example images has been presented in [42]. 70.000 web collected 2D images were used. The images were labelled for 3D pose (yaw, pitch, and roll) and for 2D positions of 6 landmarks [43]. 1000 male and 1000 female almost frontal images were selected. 8 raters were asked to state their preferences toward images of the opposite sex on a 4 points scale. For training a SVM regressor, eigenfaces, Gabor filters, edge orientation histograms, and geometric feature were used. The best average Pearson correlation with human scores (0.28) was obtained with Gabor filters, whose correlation with individual preferences was higher (up to 0.45). Some experiment was also reported for relating smile, detected through Facial Action Coding System (FACS) [4], and attractiveness.
Another large Web face database was used in [44]. From the website *hotornot.com* over 30.000 attractiveness rated images were downloaded, and the best 4000 images, almost evenly divided between the two genders, were selected and rectified with an affine transformation. Gaussian RBF kernel and a ridge regression were experimented for various textural features. The female dataset showed better prediction, and cheeks and mouth proved to be more effective predictors than eyes. A particular kernel regression technique was experimented in [45] on the same face images set.

5 Open problems and areas of research

Although some interesting results are emerging, much further work is possible. In particular, the main question, which are the objective elements of facial beauty, is far from being answered. Several elements of beauty have been investigated, but not yet combined in an overall framework.
Most results have been obtained analyzing 2D images, often monochromatic, medium quality and frontal. There is little doubt that in this way much valuable information relevant to attractiveness is lost. Important applications, as supporting plastic surgery, are essentially 3D and require 3D face scans. A problem for further 3D beauty research, as well as for 3D identity recognition, is that only a few 3D face data bases exist, containing a relatively small number of face scans. In addition, selecting beautiful faces in these data bases strongly reduces the number of samples useful for attractiveness studies. Then, for carrying on further studies on attractiveness, 3D data-bases containing also beautiful faces should be constructed.
Another open problem concerns the density of sampling of the face and beautiful face spaces. In fact, several approaches for measuring attractiveness, or suggesting ways for improving attractiveness are based on finding the nearest face samples in some face space. To be effective this approach requires a dense sampling of the face space,

or of the space of the beautiful faces only. This raises the question: how many samples are required for an adequate sampling of the face space, from the point of view of attractiveness, or of the sub-manifold of the beautiful faces?
Most papers on analyzing and assessing beauty are based on facial landmarks for constructing some representative geometric feature vector. This technique appears convenient for capturing the general harmony of face, but small details and facial texture, important elements of beauty, are essentially lost. Holistic techniques appear more suited to capture the texture. Small shape details of particularly important areas, such as mouth and eyes, are not efficiently captured neither by 2D or 3D landmarks nor by holistic techniques. A local detailed analysis could substantially improve the capture of relevant features. Then, mixed techniques could be effective.
Up to now, the matter of attractiveness research has been expressionless images. However, expressions are relevant to attractiveness: it is a common everyday experience that smiling can light a plain nondescript face. Up to now, no research has been reported aimed at extending attractiveness analysis to facial expressions.
Finally, other areas of research could concern: body attractiveness (actually limited to simple body shape indices), feasible shape or texture changes able to enhance attractiveness, and the study of *dynamic beauty*, or "grace", or "elegance", of movements.

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