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Computer analysis of face beauty: A survey ☆

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ABSTRACT

The human face conveys to other human beings, and potentially to computer systems, information such as identity, intentions, emotional and health states, attractiveness, age, gender and ethnicity. In most cases analyzing this information involves the computer science as well as the human and medical sciences. The most studied multidisciplinary problems are analyzing emotions, estimating age and modeling aging effects. An emerging area is the analysis of human attractiveness. The purpose of this paper is to survey recent research on the computer analysis of human beauty. First we present results in human sciences and medicine pointing to a largely shared and data-driven perception of attractiveness, which is a rationale of computer beauty analysis. After discussing practical application areas, we survey current studies on the automatic analysis of facial attractiveness aimed at: (i) relating attractiveness to particular facial features; (ii) assessing attractiveness automatically; (iii) improving the attractiveness of 2D or 3D face images. Finally we discuss open problems and possible lines of research.

1. Introduction: face analysis problems

The analysis of 2D or 3D images of humans is a main research topic in pattern analysis and computer vision. Applications exist, or are forecast, in a number of areas such as identity verification, natural man–machine interfaces, surveillance, forensics, sport performance enhancement, medical diagnosis and treatments.

Special attention has been devoted to the images of hands [171,120] and faces, the tools of most human–environment interaction. In particular, the human face is by far the part of the body which conveys most information to human beings, and thus potentially to computer systems [106,118]. Such information includes identity, intentions, health and emotional states, attractiveness, age, gender, ethnicity, attention and personality traits. In several cases the analysis of this information is a multidisciplinary problem, involving areas of computer science (such as pattern analysis and computer vision), human science (such as psychology, behavioral and cognitive sciences), and medicine.

At present, the most studied and successful application of face image analysis is identity recognition or confirmation [25,174, 167,95]. For expressionless faces, the problem is essentially one of 3D object recognition, at least on short time intervals. Unrestricted identification may require the analysis of additional elements such as expressions and aging, involving much more complicated face models and a multidisciplinary approach.

Other face analysis problems are intrinsically multidisciplinary and strictly related to human sciences and medicine. The most important are estimating age and modeling face aging, capturing and understanding human expressions, and analyzing face attractiveness. Face age synthesis and estimation, surveyed in [57], has possible application in entertainment, forensics, security controls, and cosmetology. Computer analysis of human expressions is a much studied problem. A currently well-established application is *capturing* human expression in order to animate the faces of virtual characters for entertainment or to reduce video-transmission bandwidth. A much more challenging problem is *interpreting* facial expressions, i.e. mapping expressions onto emotional states [44]. One difficulty is that there is no full agreement in psychophysiology about a model of the human emotions and of their effects on facial features [126,51]. The computer analysis research in this area has been surveyed in [173,118,126,51]. Today, research is mostly focused on *affective computing,* i.e. investigating new affect-sensitive paradigms of man–machine interaction.

The computer analysis of face attractiveness is an emerging research area. What produces the human perception of beauty is a long standing problem in human sciences and, more recently, in medical areas such as plastic surgery and orthodontics. In the last few decades, several thousand papers and books on this subject have been published. A survey of the recent research on attractiveness in human sciences can be found in [87]. The researchers involved in these studies are *social and developmental psychologists*

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(in relation with the effects of attractiveness on human interaction), *cognitive psychologists and neuroscientists* (which investigate the mechanisms we use in assessing attractiveness) and *evolutionary psychologists and biologists* (which study the connection between the morphological characteristics connected with facial attractiveness and other human qualities such as health, fitness and, based on Darwin's theories of natural and sexual selection [34,35], reproductive value; these works are surveyed in [61,97]). The human perception of attractiveness is also related to face identification. Experiments have shown that the recognition rate is better for attractive and ugly faces, and lower for attractively average faces [174].

Studying beauty with pattern analysis and computer vision techniques is a relatively new research field. The purpose of this paper, which extends the preliminary material presented in [16], is to survey the rationale, techniques, results, applications, open problems and new possible lines of research in this emerging area. To the best of our knowledge, these topics have only been surveyed briefly before in [64].

The content of the paper is as follows. In Section 2, we summarize some results about facial attractiveness presented in human sciences and medical areas. Particularly relevant are the results showing that the perception of human beauty appears *largely shared by people different in culture, ethnicity and age, and thus supposedly data-driven*. These findings are a rationale of computer techniques attempting to emulate the human perception on the basis of objective facial features. In Section 3, we present the applications of automatic beauty analysis. In Section 4, we briefly survey some issues relative to the representation of faces and the extraction of facial features. In Section 5, we survey the recent research on computer beauty analysis, and in particular: (i) relating attractiveness and facial features; (ii) automatically assessing face beauty; (iii) improving attractiveness of 2D face images or 3D face scans. Finally, in Section 6, we discuss new areas of research and the open problems.

2. Beauty in human sciences and medicine

2.1. Research on attractiveness: a short history

What is beauty? Philosopher, scientists and artists have debated the problem for centuries. A controversial long lasting question is, according to an often quoted sentence of the writer Margaret Wolfe Hungerford (1878), if "Beauty is in the eye of the beholder", i.e. if beauty is purely subjective or not. Important personages, such as Immanuel Kant (1790), have supported the former thesis or, as David Hume (1741), the latter.

In any case, from ancient Greek culture to our times, no one denied the strong influence of beauty on human life. A number of recent studies, as well as everyday common experience, show that face and body harmony is extremely important in general social life [23,4,45]. In a society that is virtually obsessed by beauty, looking unpleasant or different can deeply affect self-esteem and result in social isolation, depression and serious psychological disorders [23,131,20,125,99]. Attractive people are also likely to be regarded as better than unattractive people in a broad social sense. For instance, experimental research shows that better-looking candidates are more likely to be hired than equally qualified but less attractive people [102,75,29]. Thus, it is not surprising that more money is spent annually in the US on beauty related items or services than on both education and social services [4].

2.1.1. Beauty canons

Since ancient times, the supporters of the objective and *measurable* nature of beauty have attempted to state *ideal proportions*, or *beauty canons*, for the human body and its parts. The Greek sculptor Polycleitus was the first to define aesthetics in mathematical terms in his "*Kanon*" treatise. He also pointed out the importance of symmetry in the human shape. In order to define an aesthetically pleasing face, Marcus Vitruvius, a Roman architect, introduced the concept, still largely used in medicine and anthropometry, of facial trisection, or facial thirds, in which a face can be divided by horizontal lines passing through the hairline, the glabella, the subnasale and the menton (Fig. 1, left).

Renaissance artists, such as Leonardo da Vinci, Leon Battista Alberti, Albrecht Duerer and Piero della Francesca, reformulated and documented the classic canons. (Fig. 1, right). The classic and neoclassic canons [13,163,49,9] have been used for centuries by sculptors, painters, and are a rough working guide for plastic surgeons. The same idea is at the base of some of today's beauty assessing techniques, which are merely based on geometric features computed from the position of 2D/3D facial landmarks.

2.1.2. The golden ratio

A long lasting idea, also stemming from the classic concept of ideal proportions, is the relevance of the *golden ratio* to facial beauty. The golden ratio is an irrational number, approximately 1.618, related to geometric entities, such as pentagons, and to mathematical entities, such as the Fibonacci sequence [98,42]. From ancient times, it has been used explicitly, or claimed later to have been used, by a score of sculptors, painters, architects and composers, ranging from Fidia to Le Corbousier, Dalì, Mondrian and Bela Bartok, to construct aesthetically attractive shapes and even sounds [98]. Nowadays, the idea of a universal standard of beauty based on the golden ratio (Fig. 2) still has several supporters [76,93,134,144]. Marquardt derived a facial mask summarizing the ideal proportions, an idea that received some support in the plastic surgery community [76,12,84]. However, several experimental studies found little correlation between the asserted ideal proportions and the beauty scores given by human raters [82,71,10, 147,104]. For instance, it was found that patients who were considered to be more attractive after orthognathic surgery were equally likely to move away from or towards the golden proportions [10] and a wide range of cephalometric values was found in a 3D research on professional models [113].

2.1.3. Face morphometry

Morphometric studies have been carried out in anthropology and medicine to find typical measures of facial or body features for different age, sex and ethnicity groups. In the 18th and 19th centuries most measurements were relative to bones and skull. Recently, due to the pressure of plastic surgery, the focus of these studies has moved toward the analysis of elements relevant to attractiveness, and consequently toward soft tissue morphometry. The attention has also shifted toward the soft tissue proportions in dentofacial orthopedics [138,129].

Face soft-tissue morphometry has been investigated in particular by Farkas et al. [47,50], who proposed hundreds of possible facial measures and proportion indices, whose average values have been experimentally determined for several populations and compared with some of the classic canons of beauty [13,163,50,37]. Several morphometric studies have been aimed at investigating the shape of beautiful faces [146,145,113,48]. For instance, in [146], the comparison of the 3D scans of geometric features extracted from 71 normal young Italian women and a group of 24 beautiful women in the last stages of a beauty competition pointed to some differences between normal and beautiful faces, such as a larger facial upper third and a smaller lower third for beautiful women. A few studies analyzed as well the contribution to attractiveness of facial details, such as young adults' 3D lip