A Comprehensive Survey on Face Image Analysis

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INTRODUCTION

Face of a person is an important part of human body, and is often the first part perceived by other people. Face can be used to identify a person, to assess people's feeling, to transmit various kinds of information, to communicate with other persons, etc (Zhang, 2011). The information obtained from face contains and provides abundant meanings, such as the age, emotion, gender, health, psychology, profession, race, *etc* (Li & Jain, 2004). Specialists have long practiced related researches, especially from psychological and psychophysical point of view. Facial action (Zhu et al., 2009) and Facial behavior (Zhu et al., 2011) have also attracted many attention.

With the progress in electronic equipments and computational devices, many computer image techniques have been developed. The automatic investigation of face images is based on and evolved from a number of image techniques. According to the classification of image techniques (Zhang, 2009) in image engineering (IE), and the current research and application levels, techniques used to treat face images are mainly under the category of image analysis (IA). Therefore, the automatic investigation of face images is often called face image analysis, though before analysis, many image processing (IP) techniques have been served in various pre-processing stages; and after analysis, some image understanding (IU) techniques might be used to further interpret the original world.

While human beings are quite good in seeing face images and picking out suitable information for making appropriate decision, the ability of automatic analysis of face images in complex scene by computers is still limited (Zhou, Chellappa & Zhao, 2006; Weschler, 2007). In other words, face image analysis is a difficult problem for a computer but is relatively straightforward for a human being. However, with the theoretical progress and the wide applications of face image

analysis in the recent years, this field is undergoing great changes (Zhang, 2011). With the accumulation of the research results and application experiences, it is expected that automatic investigation of face images would be possible under various difficult conditions in the near future and would allow people to use it in areas such as biometrics, biomedical applications, human computer interaction, human behavior and emotion study, security and surveillance system, etc.

This article tries to provide a comprehensive review of this field, its development, its main techniques and steps, some current research focus and potential directions.

BACKGROUND

Using image analysis techniques to study face images has started some 30 years ago, one of the earliest work is dated to the 1980s (Baron, 1981). However, though automatic face recognition has been actively studied for over three decades as a means of human identification, it is only in recent the face image analysis has experienced significant growth and progress with the mature of image techniques.

The progress of research in face image analysis is reflected by the large number of papers published in these years. Take "face image analysis" as a key word and search it in the column of "Subject/Title/Abstract" in EI Compendex (http://www.ei.org) provides the results (the total number is more than 10000) shown in Figure 1. It shows the numbers of publication for each three years (accumulating the numbers over each of three years makes the curve smooth), which clearly illustrates the fast increasing in the last years. A jump from 2000-02 to 2003-05 is also obviously noticeable.

With the increase of journal and conference publications for researches and applications, many survey papers have been published, such as (Wayman, 2002;

Figure 1. Illustration of the numbers of publications with "facial image analysis"
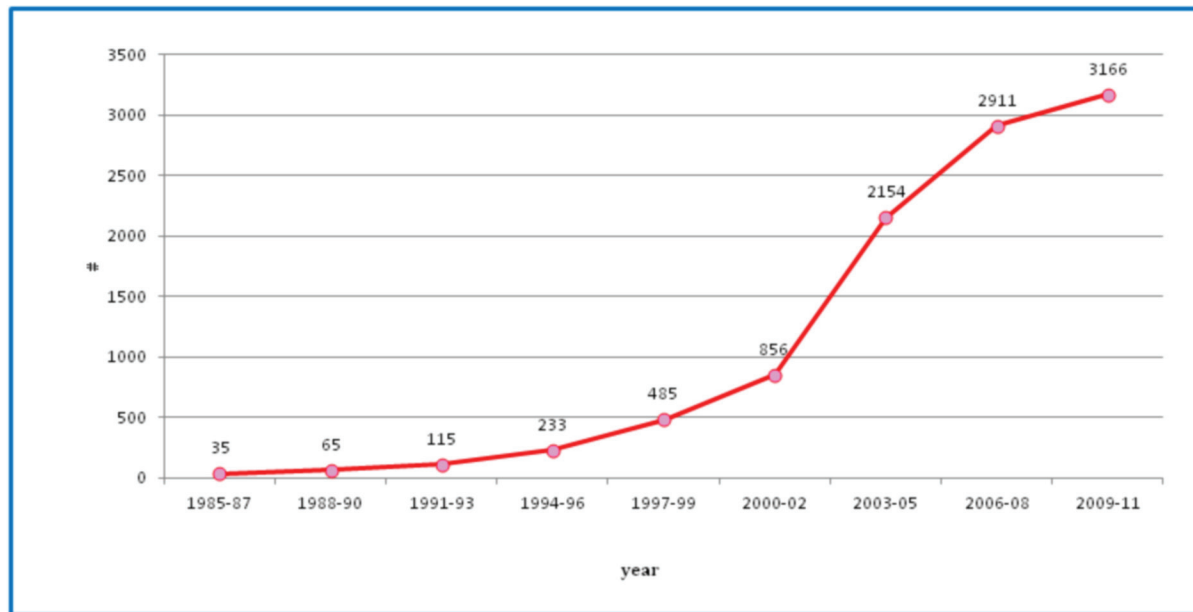
Yang, Kriegman & Ahuja, 2002; Pan et al., 2003; Zhao, Chellappa & Rosenfeld, 2003; Bowyer, Chang & Flynn, 2004; Riaz, Gilgiti & Mirza, 2004; Short, Kittler & Messer, 2004; Bronstein, Bronstein & Kimmel, 2005; Kittler et al., 2005; Kong et al., 2005; Tan & Zhang, 2006; Iancu, Corcoran & Costache, 2007; Li & Zhang, 2007; Zou, Kittler & Messer, 2007; Jia & Zhang, 2008; Kruger, Zhang & Xie, 2008; Nikolaos & Feng, 2008; Widanagamaachchi & Dharmaratne, 2008; Yan & Zhang, 2008a; Erik & Trivedi, 2009; Barr, 2012; and Rajalakshmi & Jeyakumar, 2012). In addition, a number of specialized books have also been available, such as (Bartlett, 2001; Li & Jain, 2004; Wen & Huang, 2004; Zhou, Chellappa & Zhao, 2006; Weschler, 2007; and Zhang 2011).

TECHNIQUE OVERVIEW

Face image analysis is a complex procedure and should be completed in a number of steps; each of them has specific functions and performs particular tasks. To carry out these tasks and to fulfill these functions, many techniques have been developed. After listing the procedure and modules of face image analysis, two currently important groups of techniques are introduced, their principles are summarized and their evaluations are discussed below.

The Modules of Face Image Analysis

The procedure of face image analysis (from input images to output results) consists of several main steps. They can be grouped into four modules, as shown in Figure 2.

The functions of these four modules are described shortly as follows:

Face Location

Analyzing faces needs to locate face region from image first, this can include face detection in still image and/or face tracking in video. To determine the position and the extension of faces, often image segmentation techniques are required. This task can be much complicated with the variation of the position and posture of human body in 3-D space, as well as the deviation from the normal lighting conditions.

Feature Extraction

Once the faces from images are captured, to represent and describe the face characteristics, some suitable features should be selected and extracted from these images (Yan & Zhang, 2010). These features should represent and/or reflect the particularity of face images. Commonly used features include geometric features,

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