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Recognition of facial expressions using Gabor wavelets and learning vector quantization

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Abstract

Facial expression recognition has potential applications in different aspects of day-to-day life not yet realized due to absence of effective expression recognition techniques. This paper discusses the application of Gabor filter based feature extraction in combination with learning vector quantization (LVQ) for recognition of seven different facial expressions from still pictures of the human face. The results presented here are better in several aspects from earlier work in facial expression recognition. Firstly, it is observed that LVQ based feature classification technique proposed in this study performs better in recognizing fear expressions than multilayer perceptron (MLP) based classification technique used in earlier work. Secondly, this study indicates that the Japanese Female Facial Expression (JAFFE) database contains expressers that expressed expressions incorrectly and these incorrect images adversely affect the development of a reliable facial expression recognition system. By excluding the two expressers from the data set, an improvement in recognition rate from 87.51% to 90.22% has been achieved. The present study, therefore, proves the feasibility of computer vision based facial expression recognition for practical applications like surveillance and human computer interaction.

Keywords: Facial expression recognition; Gabor wavelets; Learning vector quantization; JAFFE; Principal component analysis

1. Introduction

Facial expressions provide an important behavioral measure for the study of emotions, cognitive processes and social interaction (Bartlett et al., 1999; Yuki et al., 2005) and thus automatic facial expression recognition systems can provide a less intrusive method to apprehend the emotion activity of a person of interest. With the availability of low cost imaging and computational devices, automatic facial recognition systems now have a potential to be useful in several day-to-day application environments like operator fatigue detection in industries, user mood detection in human computer interaction (HCI) and possibly in identifying suspicious persons in airports, railway stations and other places with higher threat of terrorism attacks.

Facial expression recognition is also a necessary step towards a computer facilitated human interaction system (Lyons et al., 1998) as facial expressions play a significant role in conveying human emotions. Any natural HCI system thus should take advantage of the human facial expressions.

There exists a debate in psychology and behavioral science literature regarding whether facial expressions are universal or not and also regarding whether facial expressions are "eruptions" (meaning facial expressions occur involuntarily) or "declarations" (meaning that they are voluntary) (Friudlund, 2006). Extreme positions taken by early theorists have gradually given way to recent interactionist perspectives integrating evidence for both universality and cultural specificity (Elfenbein and Ambady, 2003). Research has shown that facial expressions are correctly recognized by people universally at a rate greater than that allowed by chance alone and hence in this respect, facial expressions are universal. At the same time, research also shows that cultural exposure increases the

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chances of correct recognition of facial expressions indicating cultural dependence (Yuki et al., 2005; Elfenbein and Ambady, 2003, 2002).

Until recently, there were only two options for correct recognition of facial expressions: human observer based coding system (Elfenbein and Ambady, 2003) and electromyography (EMG) based systems (Cohn et al., 2002). Human observer based methods are time consuming to learn and use, and they are difficult to standardize, especially across laboratories and over time. The other approach, facial EMG, requires placement of sensors on the face, which may inhibit certain facial actions and which rules out its use for naturalistic observation. An emerging alternative is automated facial image analysis using computer vision (Cohn and Kanade, 2006). The research in computer vision based recognition of facial expressions has progressed for long irrespective of the psychological debate. The primary inspiration of such research efforts has been the human ability to recognize facial expressions by just looking at still or video images with a high rate of correct recognition. The potential benefits of computer recognition of facial expressions in security applications and HCI have been the motivations in most of the cases.

There are two different approaches commonly used in computer vision based facial expression recognition so far: recognition using 2D still images and recognition using image sequences. Approaches using image sequence often apply optical flow analysis to the image sequence and use pattern recognition tools to recognize optical flow patterns associated with particular facial expression (Cohn and Kanade, 2006; Amr Goneid and Rana el Kaliouby, 2002; Xiaoming Liu et al., 2002; Lien et al., 1999). This approach requires acquisition of multiple frames of images to recognize expressions and thus has limitations in real-time performance and robustness. Facial expression recognition using still images often use feature based methods (Lyons et al., 1998; Zhang et al., 1998; Chellappa et al., 1995; Marian Stewart Bartlett et al., 2003) for recognition and thus have fairly fast performance but the challenge in this approach is to develop a feature extraction method that works well regardless of variations in human subjects and environmental conditions.

Gabor filter banks are reasonable models of visual processing in primary visual cortex and are one of the most successful approaches for processing images of the human face (Fasel et al., 2002). Lyons et al. (1998) proposed a Gabor wavelet based facial expression coding system and show that their representation method has a high degree of correlation with the human semantic ratings. In Zhang et al. (1998), Gabor filter banks based facial expression coding for feature extraction and multilayer perceptron (MLP) based feature classification is reported to have performed better than geometric feature based facial expression recognition. In this paper, the feature extraction method proposed in Lyons et al. (1998) is adopted. Principal component analysis (PCA) is used for reducing the length of the feature vector.

Neural networks have been widely used for classification and recognition tasks. The use of neural networks in face recognition has addressed several problems: gender classification (Zehang Sun et al., 2002), face recognition (Lawrence et al., 1996) and classification of facial expressions (De Stefano et al., 1995). There are different architectures of neural networks each having their own strengths and drawbacks. Good performance of a given architecture in a particular problem does not ensure similar results in a different problem. In this paper, benefits of using a learning vector quantization (LVQ) are explored for recognition of facial expression rather than MLP as in Zhang et al. (1998). By using the same Japanese Female Facial Expression (JAFFE) database for training and testing, the performance of MLP reported in an earlier work (Zhang et al., 1998) is compared with that of LVQ for facial expression recognition.

The rest of the paper is organized as follows: image acquisition and preprocessing is discussed in Section 2 of this paper; Section 3 describes feature extraction and the PCA is discussed in Section 4. Section 5 describes the JAFFE database and Section 6 introduces classification approach adopted in this work. Section 7 presents the results and observations of this study and finally, the conclusion is presented in Section 8.

2. Image acquisition and preprocessing

A practical facial expression recognition system is shown in Fig. 1 below. The recognition process begins by first acquiring the image using an image acquisition device like a camera. The image acquired then needs to be preprocessed such that environmental and other variations in different images are minimized. Usually, the image preprocessing step comprises of operations like image scaling, image brightness and contrast adjustment and other image enhancement operations. In this study, an

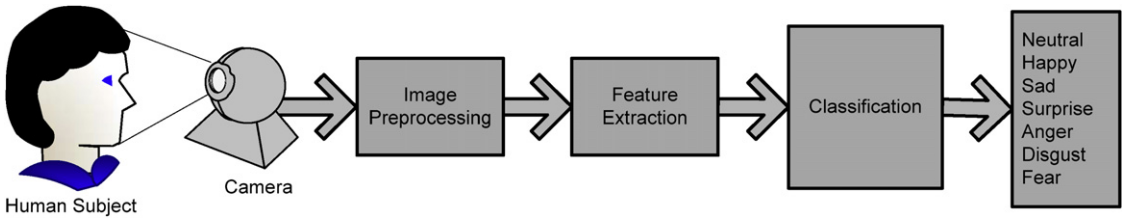

Fig. 1. Facial expression recognition system overview.