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Detrended Fluctuation Analysis Based on the Affective ECG

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Abstract

Electrocardiography (ECG) is one of the most important physiological signals, which has been proven to contain reliable affective information. Four kinds of objective affects including happiness, sadness, angry and fear, are induced by affective fragments from movies, and ECG signals are recorded by Biopac MP 150 synchronously. In an independent experiment the affective videos are played twice, and in the second presentation the press file of affective re-evaluation is obtained, which registers the subjective experience of participants and help us intercept the reliable affective ECG. The detrended fluctuation analysis is used to quantitate the temporal correlations by the scaling exponent in affective ECG. And the result showed that ECG of happiness, sadness, angry and fear had long-range correlations. Then the scaling exponent is used by the binary classifier of Fisher as an affective feature, and the result showed that the correct recognition rate of happiness, sadness, angry and fear are 89.74%, 90.1%, 70.43%, 84.44% respectively. The whole experiment displays that the nonlinear features have a fine distinction in different emotions.

Keywords: Affective ECG; Press File of Affective Re-evaluation; Detrended Fluctuation Analysis; Scaling Exponent

1 Introduction

Affect detection is the key problem of affective computing and the basic function of harmonious human-machine interactive environment. The human's emotional states are psychological and physiological changes inherently, which are manifested by behavior, facial expressions and physical signals. By analyzing of these observable signals, the human's affective state can be inferred. Currently the research of affect detection mainly focuses on the signals such as speech, facial expression, text [1] and physiological signals [2, 3]. One advantage of monitoring physiological signals rather than the face and voice is that physiology is less susceptible to social masking. This might be particularly important for certain applications such as deception detection, interventions to treat individuals with autism, and computer-mediated social interactions (e.g., computer tutors that simulate human tutors).

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ECG is one of the most important physiological signals, which has been proven to contain reliable affective information [3-6]. Recently the main methods of these studies are extracting the ECG's statistical features on time domain or frequency domain, then using these features to build affective classification mode. In the reference [3], four kinds of physiological signals are collected by BIOPAC150, which are eleectromyogram, electrocardiogram, skin conductivity and respiration changes. A large number of physiological features from various domains, including time/frequency, geometric analysis, mutiscale entropy, etc., are proposed. Based on these features, the author can find the best emotion-relevant features, the effectiveness of which is proven by classfication results. To classify four kinds of emotions, the extended Linear Discriminant Analysis (pLDA) is performed and an improved recognition accuracy of 95% and 70% for subject-dependent and subject-independent classfication is achieved. In the reference [5], author used several peripheral physiology signals, including ECG, EMG, and GSR, to realize the automative detection of affective states. And in the paper the efficacy of affect detection using a host of feature selection and classification techniques on these three physiology signals are evaluated. The results indicated that the user-dependent modeling approach based on ECG was feasible. In the reference [6], a methods based on the empirical mode decomposition is proposed to detect the emotion status. And there are many features based on the instantaneous frequency and the local oscillations within every mode are extracted. And the results show that the feasibility to setup empirical mode decomposition and to extract frequecy feature.

From the above studies, we can find that, these studies mostly have ignored the fact that cardiac system is a typical nonlinear system and ECG has many nonlinear characteristics. Only using the statistical features without nonlinear features of ECG will decrease the detection precision obviously. So in this paper a nonlinear feature will be used by Fisher classifier to detect the four kinds of target emotions, which are happiness, sadness, angry and fear. This nonlinear feature named the scaling exponent, is calculated by the algorithm of Detrended Fluctuation Analysis (DFA) and used to reveal the long-rang and power-law correlation of non-stationary time series.

2 Theory Background and Related Work

2.1 The Affective Detection Theory Based on Physiological Signals

As early as 100 years ago, psychologist, physiologist, philosopher have studied about emotion, and they generally think that emotion is a multidimensional component which includes the subjective experiences, explicit expressions and physiological activations [7]. Awakening certain parts of nervous system will provide the energy and space for the specific emotional movements. Ascending pathway will transfer the affective stimulus from the limbic system to the brain center. When the neural impulses pervade the cerebral cortex, we will experience all kinds of emotion. At the same time descending pathway regulate the awakening degree of automatic nervous system, which will control the movements of physiological signals. Consequently the physiological signals may have the distinct activity pattern in different affective state.

In many affective theories, the hypothesis of James-Lange is particularly relevant to our research. Their theory proposes that emotions are "readouts of physiological changes in the body", and the awareness of peripherally physiological changes is emotion. That means affective stimulus occurred firstly, then peripherally physiological responses appeared, such as rapid