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Bispectral Analysis of EEG for Emotion Recognition

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Abstract

Emotion recognition from electroencephalogram (EEG) signals is one of the most challenging tasks. Bispectral analysis offers a way of gaining phase information by detecting phase relationships between frequency components and characterizing the non-Gaussian information contained in the EEG signals. In this paper, we explore derived features of bispectrum for quantification of emotions using a Valence-Arousal emotion model; and arrive at a feature vector through backward sequential search. Cross-validated accuracies of 64.84% for Low/High Arousal classification and 61.17% for Low/High Valence were obtained on the DEAP data set based on the proposed features; comparable to classification accuracies reported in the literature.

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Keywords: Brain Computer Interface; electroencephalogram; emotion; classification; Valence-Arousal model;

1. Introduction

Enabling human-machine interfaces to interpret emotional states paves the path towards emotionally capable machines that offer more natural interactions and better performance in the fields of rehabilitation robotics, multimedia content characterization, personalized recommender systems etc. Several approaches to emotion detection have been proposed. Characterizing emotional data from facial expressions have been explored[1]. However, such methods may be prone to deception as the associated parameters vary easily, subject to different situations. Use of physiological signals (especially electroencephalogram (EEG)) have gained a lot of interest. Time-frequency domain features such as power spectral density (PSD) and frequency power ratios have been employed with relative success[6,7]. Given the non-Guassian nature of EEG signals, it makes sense to explore higher order spectral features. In this paper, we explore derived features of bispectrum for quantification of emotions using a Valence-Arousal emotion model. Classification of emotional states viz. Low/High Arousal (calm/bored to excited/stimulated) and Low/High Valence (unhappy/sad to happy/joyful) have been considered. Classification experiments were performed over EEG signals from the DEAP dataset[2]. The choice of the Valence-Arousal model has been inspired by the circumplex model of affect[3]. Preliminary classification experiments were conducted using EEG pertaining to Fp1 and Fp2 channels. Linear Kernel Least Square Support Vector Machine (LS-SVM) and back-propogation Artificial Neural Networks (ANN) were used. Further experiments were conducted by performing backward sequential feature selection.

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2. Related Work

Modelling Emotions. Emotion is a psychological state or a process that functions in maintaining the balance of information process in the brain and the relevant goals. Every time an event is evaluated as relevant to a goal, an emotion is elicited. A model of emotion can be characterized by two main dimensions called valence and arousal. The valence is the degree of attraction or aversion that an individual feels toward a specific object or event. It ranges from negative to positive. The arousal is a physiological state of being awake or reactive to stimuli, ranging from passive to active. The valence arousal dimensional model, represented in Figure 1(a) is the accepted model.

EEG and Emotion. Emotional data can be captured by means of EEG, acquired by measuring the electrical activities at different electrode positions on the scalp. The 10-20 system of electrode placement is used. See figure 1(b). Brain wave is the composition of five main frequency bands called delta (1-3 Hz), theta (4-7 Hz), alpha (8-13 Hz), beta (14-30 Hz) and gamma (31-50 Hz). Soleymani et al.[4] employed EEG and peripheral physiological signals to classify emotions into three levels of valence and arousal. Using a support vector machine (SVM) with PSD Soleymani et al. arrived at accuracy rates of 57.0% and 52.4% for valence and arousal respectively. In another study, 66.05% and 82.46% accuracy rates for valence and arousal respectively was achieved by Huang et. al[5] using an Asymmetrical Spatial Pattern technique to extract features. Other machine learning techniques have also been applied[8,9].

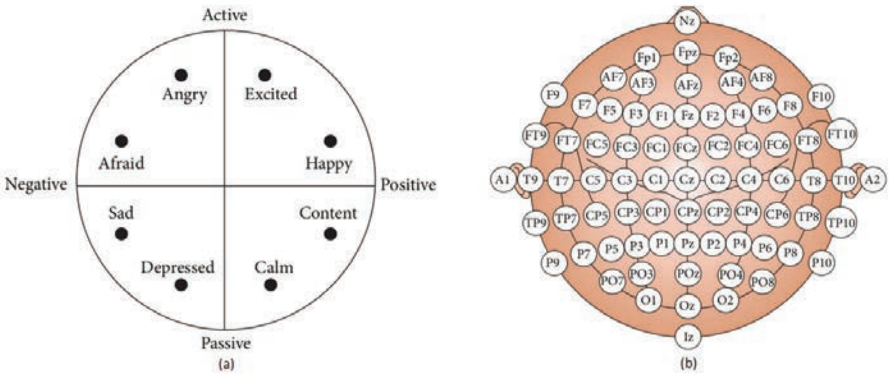

Fig. 1. (a) Valence-Arousal Model; (b) 10-20 system of electrode positions.

3. Materials

EEG Signal. Signals were acquired from the DEAP dataset[2], which is a multimodal dataset for analysis of human affective states. EEG and peripheral physiological signals of 32 subjects were recorded as each subject watched one-minute long excerpts of music videos designed to elicit peak emotional responses (For detailed discussion refer to DEAP dataset[2]). Figure 2 shows the organization of the trials vis-a-vis the section and complete experiment; the protocol followed for elicitation of emotion is marked in the trail.

Valence / Arousal. Each participant went through 40 trials of stimuli presentation (music videos). During the presentation, EEG signals were recorded at a sampling frequency of 512 Hz using 32 active AgCl electrodes, placed in accordance to the international 10-20 system. For self-assessment, the subjects selected values in the continuous scale of 1-9 to indicate their emotion states in each category. This study mapped the scales (1-9) into two levels of each valence and arousal states. The valence/arousal scale rating from 1-5 was mapped to Low valence/arousal state and the valence/arousal scale rating of 5-9 was mapped to High valence/arousal states.The choice of two level mapping (with a threshold of 5 on a scale of 1-9) is based on the analysis carried out by Koelstra et. al[2] on the DEAP dataset. According to the new scale mapping, the system provides 4 state emotion classification: High Valence, Low Valence, High Arousal and Low Arousal. The adopted mapping scheme is illustrated in Figure 3.