Original Article

An accurate emotion recognition system using ECG and GSR signals and matching pursuit method

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Abstract

Background: The purpose of the current study was to examine the effectiveness of Matching Pursuit (MP) algorithm in emotion recognition.

Methods: Electrocardiogram (ECG) and galvanic skin responses (GSR) of 11 healthy students were collected while subjects were listening to emotional music clips. Applying three dictionaries, including two wavelet packet dictionaries (Coiflet, and Daubechies) and discrete cosine transform, MP coefficients were extracted from ECG and GSR signals. Next, some statistical indices were calculated from the MP coefficients. Then, three dimensionality reduction methods, including Principal Component Analysis (PCA), Linear Discriminant Analysis, and Kernel PCA were applied. The dimensionality reduced features were fed into the Probabilistic Neural Network in subject-dependent and subject-independent modes. Emotion classes were described by a two-dimensional emotion space, including four quadrants of valence and arousal plane, valence based, and arousal based emotional states.

Results: Using PCA, the highest recognition rate of 100% was achieved for sigma = 0.01 in all classification schemes. In addition, the classification performance of ECG features was evidently better than that of GSR features. Similar results were obtained for subject-dependent emotion classification mode.

Conclusions: An accurate emotion recognition system was proposed using MP algorithm and wavelet dictionaries.

Generally, monitoring and evaluation of Autonomic Nerve System (ANS) has been performed by physiological measures, including electrocardiogram (ECG), Galvanic Skin Response (GSR), Blood Pressure (BP), and respiration rates. Among them, there is a special attention on the ECG and GSR to evaluate different pathological and psychophysiological conditions. The ECG is one of the most informative signals for evaluating the electrical activity of the heart and the GSR can provide enlightening evidences for the assessment of the sweet glands function as an ANS indicator [1]. These measures offer simple, effective, low cost, noninvasive, and continuous recordings. However, to identify desired patterns associated with the distinctive mental and physiological states, automatic interpretation is crucial.

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At a glance commentary

Scientific background on the subject

The main goal of this study was to examine the performance of an automatic emotion recognition system based on Matching Pursuit (MP) algorithm using galvanic skin response (GSR) and electrocardiogram (ECG) time series.

What this study adds to the field

An accurate emotion recognition system was proposed using MP algorithm with the maximum recognition rate of 100%. In addition, the classification performance of ECG features was better than that of GSR measures.

Several studies have been conducted to find the relationships between emotion and ANS function. To address this topic, Kreibig carried out a review of 134 articles studying emotional ANS responding in healthy individuals, as well as the choice of physiological measures in evaluating ANS reactivity [2]. Significant ANS response specificity was concluded in emotion, especially for some distinct affective states. Earlier, Levenson also examined the ANS as an indicator for detecting the occurrence of emotion [3]. In some scientific research, distinct sympathetic and parasympathetic divisions of the ANS functions has been considered. For example, the sympathetic activation and vagal deactivation has been demonstrated for anxiety [4]. However, a greatly diverged autonomic signature has been reported during the occurrence of emotions [2].

Automated biosignal classification has been an interesting issue in many fields of medical research, including health and disease monitoring. Emotion recognition is one of the important areas. Several emotion recognition applications have been demonstrated for human life, including computer games and entertainments, humanoid robotics, intellectual disabilities, and patient/doctor interaction in some diseases, such as schizophrenia and autism [5–8]. The importance of emotion recognition has resulted in the advent of “affective computing”. Many attempts have been made to develop automatic devices which can manage the problem of human emotion recognition and interpretation. Several methodologies have been suggested to improve the recognition rates. These methodologies comprise the application of time domain, spectral components, wavelet transform, and nonlinear analysis.

Dynamic structures of physiological signals and quickly fluctuation in their patterns recommend their decomposition over large classes of waveforms. For this purpose, Fourier Transform (FT) and wavelet analysis have been introduced, which are not always satisfactory. FT results in a poor exemplification of functions that are well localized in time. In addition, in both aforementioned techniques, the signal transition from their expansion coefficients cannot be easily detected and identified, because the information may be diluted over the entire analysis. Wacker and Witte claimed that among time-frequency methods, Matching Pursuit (MP) algorithm is a desirable one, as it provides a promising time-frequency resolution for all frequencies and reduces cross terms concurrently [9]. In addition, MP is the first processing procedure which adapts the window length to the local features of the examined time series [10,11]. Applying this method, periodic and transient structures of the signal are defined parametrically by time span, time occurrence, frequency, amplitude, and phase.

The time-frequency resolution of MP is high, and this technique has been successfully used in many areas of biomedical research. Durka and Blińska studied transients in sleep Electroencephalogram (EEG) by means of MP algorithm [11]. It has shown that sleep spindles can be localized with high precision. In addition, their time span and intensities were recognized. The authors claimed that applying MP technique, different structures in data can be identified and the spatiotemporal characteristics can be monitored. Bardonova et al. used MP to detect the frequency changes in heart signals [12]. The heart cycles were decomposed, and a relative frequency histogram of the data was calculated. They showed that frequency changes in the QRS complex of ECG signals can be analyzed during the experiment using MP technique. Sommermeyer et al. proposed an algorithm based on MP to examine photoplethysmographic signals of patients with sleep disorders [13]. The system offered information about the central or obstructive sleep apnea. The promising specificity (90%) and sensitivity (95%) were revealed. To classify ECG features, Pantelopoulos and Bourbakis examined the effectiveness of the projections of ECG samples on wavelet packet dictionaries extracted from MP algorithm [14]. Hongxin et al. employed MP with Gabor dictionary to compress EEG and ECG signals [15]. Genetic algorithm was also implemented to reduce computational complexity. By applying the proposed algorithm, a higher compression ratio and lower reconstruction errors have been achieved compared to the traditional methods. It has confirmed that the MP technique is a suitable tool for studying the nonstationary physiological signals.

In the current study, the performance of MP on GSR and ECG time series was assessed. Special emphasis was put on the emotional responses elicited by music.

Considering the music as a method intended to stimulate certain emotions, very few investigations on emotion recognition have been done using intelligent algorithms and classifiers. Kim and Andre proposed an emotion recognition system based on four physiological signals, including electromyogram (EMG), ECG, respiration changes (RSP), and skin conductivity (SC) [16]. Entropy, time-frequency indices, spectral measures, and geometric analysis were calculated to find the most relevant features. They performed subject-dependent and subject-independent classification. For two above mentioned cases, the maximum classification rates of 95% and 70% were achieved, respectively. Duan et al. assessed the performance of k nearest neighbor (KNN), support vector machine (SVM), and least squares in emotion recognition using EEG signal [17]. After smoothing EEG power spectrum features, their dimension was reduced by means of minimal redundancy maximal relevance (MRMR) and principal component analysis (PCA). The proposed framework resulted
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