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EEG-based mild depressive detection using feature selection methods and classifiers

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ABSTRACT

Background and objective: Depression has become a major health burden worldwide, and effectively detection of such disorder is a great challenge which requires latest technological tool, such as Electroencephalography (EEG). This EEG-based research seeks to find prominent frequency band and brain regions that are most related to mild depression, as well as an optimal combination of classification algorithms and feature selection methods which can be used in future mild depression detection.

Methods: An experiment based on facial expression viewing task (Emo_block and Neu_block) was conducted, and EEG data of 37 university students were collected using a 128 channel HydroCel Geodesic Sensor Net (HCGSN). For discriminating mild depressive patients and normal controls, BayesNet (BN), Support Vector Machine (SVM), Logistic Regression (LR), k-nearest neighbor (KNN) and RandomForest (RF) classifiers were used. And BestFirst (BF), GreedyStepwise (GSW), GeneticSearch (GS), LinearForwordSelection (LFS) and RankSearch (RS) based on Correlation Features Selection (CFS) were applied for linear and non-linear EEG features selection. Independent Samples T-test with Bonferroni correction was used to find the significantly discriminant electrodes and features.

Results: Data mining results indicate that optimal performance is achieved using a combination of feature selection method GSW based on CFS and classifier KNN for beta frequency band. Accuracies achieved 92.00% and 98.00%, and AUC achieved 0.957 and 0.997, for Emo_block and Neu_block beta band data respectively. T-test results validate the effectiveness of selected features by search method GSW. Simplified EEG system with only FP1, FP2, F3, O2, T3 electrodes was also explored with linear features, which yielded accuracies of 91.70% and 96.00%, AUC of 0.952 and 0.972, for Emo_block and Neu_block respectively.

Conclusions: Classification results obtained by GSW + KNN are encouraging and better than previously published results. In the spatial distribution of features, we find that left parietotemporal lobe in beta EEG frequency band has greater effect on mild depression detection. And fewer EEG channels (FP1, FP2, F3, O2 and T3) combined with linear features may be good candidates for usage in portable systems for mild depression detection.

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1. Introduction

Depression is a common mental disorder that already affects more than 350 million people worldwide [1]. Furthermore, it is estimated by the World Health Organization that depression will become the second leading cause of illness by the year 2020 [2]. In particular, college students suffer from various factors which could lead to depression, poor academic performance, lower socioeconomic status, and stressful tasks such as examinations [3–5]. Ibrahim et al. [5] suggested that the depression rate among university students ranged from 10% to 85%, and found the prevalence of moderate depression in university students from Egypt was as high as 37% [6]. Othieno et al. [3] and Oppong Asante and Andoh-Arthur [7] found similar results in students from universities in Kenyan and Ghana, with prevalences of 35.7% and 31.1% respectively. While research papers were addressing the issue of high occurrence of depression among college students, there were few that provided the solutions. As we all know, current diagnostic techniques of depression have the obvious disadvantages [8], which are associated with patient denial, poor sensitivity, subjective biases and inaccuracy. Hence, one of the most difficult challenges would be to find an easy, accurate and practical method of detection depression. With a deepening sense of urgency, we are exploring such method with EEG.

Electroencephalography (EEG) is an objective and reliable method for the evaluation of brain function which is often used in auxiliary diagnosis of illnesses such as depression [9], seizure and schizophrenia [10]. The advantages of EEG are sensitivity, relatively low-cost and convenience of recording. Henriques and Davidson [11] recorded baseline resting (closed eyes) electroencephalogram activity from 5 clinically depressed and 13 control participants. Analysis of the EEG indicated that depressed subjects had less left-sided activation than normal control subjects. Fingelkurts et al. [12] recorded resting EEG data from 12 severely depressive patients and 10 normal subjects to study the composition of EEG brain oscillations. This study found that severe depression affects brain activity across nearly the whole cortex and embodies in considerable restructuring brain oscillations in a wide range of frequency: 0.5–30 Hz. Furthermore, in recent years, there are many studies using various classification techniques and feature selection methods based on EEG signals to discriminate depressed patients and normal controls. For example, Erguzel et al. [13] used a genetic algorithm (GA) for feature selection and back-propagation neural network (BPNN) for classification which was tested on 147 severely depressed patients with an accuracy of 89.12%. Hosseinifard et al. [14] showed that a combination of a GA for feature selection and a support vector machine (SVM) for classification could achieve an overall accuracy of 88.6%. Hosseinifard et al. [15] used power ratings of four EEG bands and four nonlinear features for classifying 45 depressed patients and 45 normal subjects and applied k-nearest neighbor (KNN), linear discrimination analysis (LDA) and Logistic regression (LR) for classification. This approach achieved the highest classification accuracy of 90% given by a nonlinear feature selection and LR classifier. Spyrou et al. [16] used Random Forest (RF), Random Tree, Multilayer Perceptron (MPL Network) and SVM to identify 34 participants suffering from both cognitive impairment and geriatric depression (mean age 69.81) and 32 control subjects (mean age 70.33) using synchronization and oscillatory features. Results indicated that RF gained the highest accuracy (95.5%). However, these methods mainly aim at detecting depression, there are few studies that provide effective detection means for mild depression, so as to help mild depression take precautions and avoid mild depression evolving into major depression. In this paper we want to find out the more suitable and effective method for mild depression detection.

In addition, several previous studies have demonstrated that depression can affect the ability to recognize different facial emotions [17]. The results suggest that depressed patients pay more attention to facial images expressing negative emotions than neutral emotions, when the images were presented at the same time [18,19]. And relevant researchers [20,21] have indicated that the use of emotional faces expressions rather than words could obtain more consistent results in studies of attention biases in depression. We therefore adopted a similar paradigm to discriminate between mild depressive patients and normal controls. The sensory data from the patients were extracted from 17 EEG features including eight linear features and nine non-linear features from 16 electrodes, and five classifiers were then applied. The challenge is then to find an optimal combination of features and classifiers that can be effective in portable applications with limited channels and processing time.

Firstly we used five classifiers including BayesNet (BN), SVM, LR, KNN, and RF for classifying 10 mildly depressed patients and 10 healthy participants. To eliminate the redundant and less discriminant features, and hence maximize classification performance, we adopted five feature search methods including BestFirst (BF), GreedyStepwise (GSW), GeneticSearch (GS), LinearForwordSelection (LFS) and RankSearch (RS) based on Correlation Features Selection (CFS), for linear and nonlinear EEG features selection. We then compared their performance to find the best selection method and classifier combination to identify the mildly depressive patients. A second element of our work is that we evaluated the feature distribution across the two brain hemispheres to identify which brain regions and frequency bands show significant differences between mildly depressed and normal subjects. Then we tried to find the fewer electrodes and features to detect mild depressive patients effectively to apply in real time system and portable devices.

2. Methods

2.1. *Subjects*

Aimed at the high occurrence of depression in current campus, we did the questionnaire survey for more than 200 undergraduates to record socio-demographic information in Lanzhou University (Lanzhou, Gansu province of China). By questionnaire screening only 37 right-handed volunteers participated in the study. All participants had no prior history of psychopathology and had normal or corrected-to-normal vision. Before the start of the experiment participants were asked to complete the Beck Depression Inventory test-II (BDI-II) [22], BDI