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Effective channels in classification and functional connectivity pattern of prefrontal cortex by functional near infrared spectroscopy signals

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ABSTRACT

In this paper, we apply support vector machine (SVM) based classification of functional near-infrared spectroscopy (fNIRS) which is non-invasive monitoring of human brain function by measuring the changes in the concentration of oxyhemoglobin and deoxyhemoglobin. Data collected from 11 healthy volunteers and 16 schizophrenia subjects. Signals were first preprocessed and decomposed by using discrete wavelet transform DWT to eliminate systemic physiological interference. A preliminary analysis based on Genetic Algorithm (GA) favored eight channels of the reconstructed fNIRS signals for further analysis. Energy in these 8 reconstructed signals was computed and used for classification of signals. SVM based classifier was employed to diagnosis schizophrenia. The results show the promising classification accuracy of nearly 84% in detection of schizophrenia from healthy subjects. The major finding of this study is that selected channels were able to identify differences in functional connectivity patterns of prefrontal cortex (PFC) elicited by Stroop task.

1. Introduction

fNIRS has been an attracting non-invasive measure of cerebral hemodynamic changes associated with functional brain activity [1–3]. Similar to functional magnetic resonance imaging (fMRI), fNIRS can be used to record changes in cerebral blood oxygenation during specific tasks. This technique has been applied to the study of several brain diseases [4]. In comparison with fMRI, this is a smaller, portable and cheaper method. For these reasons, fNIRS techniques are ideally suited for the development of portable and potentially bedside monitoring systems.

In this work the focus is on usage of advanced signal processing techniques to improve the clinical sensitivity and specificity of the fNIRS system. SVMs have recently been used in a range of problems including pattern recognition [5]. SVM classifies data with different class labels by determining a set of support vectors that are members of the set of training inputs that outline a hyperplane in the feature space. SVM provides a generic mechanism that fits the hyperplane surface to the training data using a kernel function. When using SVM, two problems are confronted; how to choose the optimal input feature subset for SVM, and how to set the best kernel parameters. These two problems are crucial, because the feature subset choice influences the appropriate kernel parameters and vice versa [6]. By feature selection, we can save significant computation time and build models that generalize a better way for unseen data points. The choice of feature, proper parameters setting can improve the SVM classification accuracy. Feature selection is used to reduce the number of fields presented to the process.

Genetic algorithms (GAs) are relatively insensitive to noise; they seem to be an excellent choice for the basis of a more robust feature selection strategy for improving the performance of classification [7]. G.A with binary chromosomes is used for channels selection to reduce the dimension of feature space.

Schizophrenia is a complex and widespread disorder giving rise to a great burden of suffering and impairment to both patients and their families' [8]. Increasing attention to schizophrenic patients is being observed. In addition to classification, the investigation of functional connectivity may contribute to a better understanding of the mental illness helping to understand underlying mechanisms of the disease. The brain is a dynamic system in which the correlation between the regions and reshape's is continuous. Many

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experimental studies suggest that cognitive states are associated with specific patterns of functional connectivity [9]. The partial correlation matrix may be viewed as a representation of functional connectivity of the brain system [10,11].

In this paper, we present a method for classifying fNIRS data using wavelet transform, G.A and SVM. The results show that frequency band between 0.003 and 0.110 Hz is important for classification, also the pattern of functional connectivity is correspondent with selected channels proposed by the G.A algorithm.

2. Materials and methods

2.1. Subjects and protocol

The data were collected previously in a study conducted at Pamukkale University, Denizli, Turkey [12]. A subgroup of that data were used in this study coming from 11 healthy volunteers (ages 30.2 ± 10.4 years,) from college students and staff and 16 schizophrenia subjects (32.6 ± 8.3 years) and similar gender distribution (male/female ratio is approximately 2/3). Controls and schizophrenia were evaluated during a color–word matching STROOP task, which is known to activate particularly the frontal lobe. Three types of stimuli namely incongruent stimuli, neutral stimuli and congruent stimuli are applied. During Stroop task two rows of letters appeared on the screen and subjects were instructed to decide whether the color of the top row letters corresponded to the name written on the bottom row. Response was given by pressing the right button of a mouse with index finger (YES-response) and left button of a mouse with middle finger (NO-response) of the right hand. During the neutral trials, the letters in the top row were “XXXX” printed in red, green, blue or yellow, and the bottom row consisted of Turkish names of color words of “RED”, “GREEN”, “BLUE” and “YELLOW” printed in white. For congruent trials, the top row consisted of Turkish names of color words of “RED”, “GREEN”, and “BLUE” and “YELLOW” printed in congruent color. For the incongruent condition, the color word was printed in different color to produce interference between coloring the word and naming it [12]. See Fig. 1 [13]. The trials were presented in a semi blocked manner. Each block includes six trials. Inter stimulus interval within the block was 4.5 s and the blocks were placed 20 s apart in time. The trial type was homogeneous within a block (but the arrangements of false and correct trials were altering.) There were five blocks of each type. Tests were performed in a silent, lightly dimmed room. Words were shown on an LCD screen that was located 0.5 m away from subjects. Ethics Review Board of Bogazici University approved the task protocol [14].

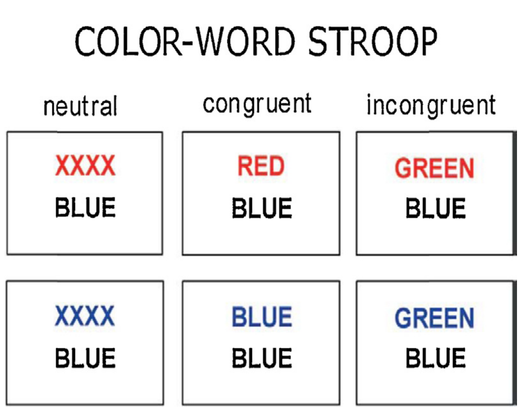

Fig. 1. Stroop task [13].

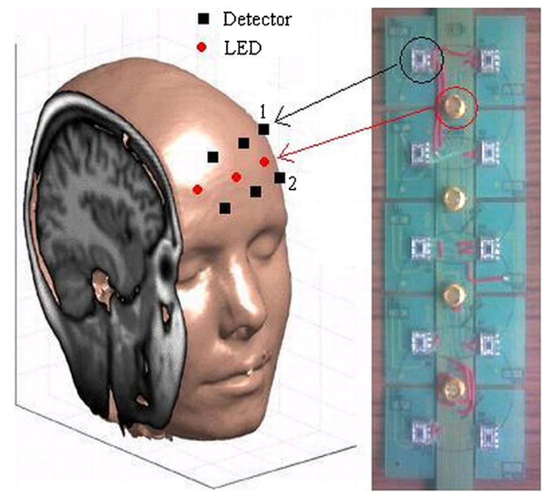

Fig. 2. Details of probe [16].

2.2. Data acquisition

The fNIRS data was collected by the NIROXCOPE 301 system developed at the Neuro-Optical Imaging Laboratory with a 16 channels continuous wave dual wavelength fNIRS system [12,14,15]. The device is capable of transmitting near infrared light at two wavelengths (730 and 850 nm), which are known to be able to penetrate through the scalp and probe the cerebral cortex. Changes in light absorption, as measured by fNIRS at each of the two wavelengths, can be used to calculate relative changes of oxyhemoglobin (HbO_2) and deoxyhemoglobin (Hb) dependent measures versus time by using the modified Beer–Lambert Law. Employing four LEDs and ten detectors, the device can sample 16 different channels in the brain simultaneously. See Fig. 2 for the details of the probe. LEDs and detectors were placed in a flexible printed circuit board that was specially designed to fit the curvature of the forehead [16]. Jobsis first reported that near infrared light could diffuse through the intact scalp and skull and can be used for tracing hemoglobin concentration changes within the brain [15,16]. Cope proposed a modified Beer Lambert Law to quantify changes in chromophore concentration [1].

2.3. Data pre-processing

Neuronal activity related signals in fNIRS data are shown to occupy the frequency range of 0.003–0.110 Hz [17,18]. Since the sampling rate of our data is 1.7 Hz the available frequency range is 0 to 850 mHz, we chose a decomposition tree for the discrete wavelet transform (DWT) with 3 levels. According to the frequency band of interest (0.003–0.110 Hz), A3 was selected. See Fig. 3.

The wavelet energy can be used to extract only the useful information from the signal about the process under study. Wavelet Energy gives the information about energy associated with the frequency bands [19].

2.4. Channel selection using genetic algorithm

In this step, G.A with binary chromosomes is used for channel selection to reduce the dimensions of feature space. The G.A is an optimization procedure that operates in binary search spaces (the search space consists of binary strings). A point in the search space is represented by a finite sequence of 0''s and 1s, called a chromosome. The algorithm manipulates a finite set of chromosomes, the population, immanent resembling the mechanism of natural evolution [20].