COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 116 (2014) 169–176

journal homepage: www.intl.elsevierhealth.com/journals/cmpb

Control of a 2 DoF robot using a Brain–Machine Interface

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ARTICLE INFO

Article history:
Received 23 July 2013
Received in revised form
10 February 2014
Accepted 25 February 2014

Keywords:
Brain–Machine Interface
Support Vector Machine
Planar robot
Hierarchical control
Directional control

ABSTRACT

In this paper, a non-invasive spontaneous Brain–Machine Interface (BMI) is used to control the movement of a planar robot. To that end, two mental tasks are used to manage the visual interface that controls the robot. The robot used is a PupArm, a force-controlled planar robot designed by the nBio research group at the Miguel Hernández University of Elche (Spain). Two control strategies are compared: hierarchical and directional control. The experimental test (performed by four users) consists of reaching four targets. The errors and time used during the performance of the tests are compared in both control strategies (hierarchical and directional control). The advantages and disadvantages of each method are shown after the analysis of the results. The hierarchical control allows an accurate approaching to the goals but it is slower than using the directional control which, on the contrary, is less precise. The results show both strategies are useful to control this planar robot. In the future, by adding an extra device like a gripper, this BMI could be used in assistive applications such as grasping daily objects in a realistic environment. In order to compare the behavior of the system taking into account the opinion of the users, a NASA Tasks Load Index (TLX) questionnaire is filled out after two sessions are completed.

1. Introduction

In recent years, there has been an important increase in the use of assistive technologies to help disabled people [1,2]. Through Brain–Machine Interfaces (BMI) [3], people affected by Cerebrovascular Accident (CVA) or people with other severe motor disabilities, such as tetraplegia, due to Spinal Cord Injury (SCI) can control systems such as wheelchairs [4,5] or PC [6,7]. These interfaces take advantage of the measurement of the electrical activity of the brain to achieve this control. In this field there are many options, both invasive [8] and non-invasive [9]. However, the use of non-invasive systems in humans extensively facilitates the work because of their easy placement and to avoid medical limitations and also ethical constraints that an invasive system involves.

Using non-invasive interfaces, same similar systems have been used. In [10], an industrial manipulator is controlled using evoked potentials as ERD (Event Related Potential). In this paper, a spontaneous interface is applied to manage the system using mental tasks as motor imagery. Motor imagery consists of the imagination of real motor movement performed by the user. According to Decety and Lindgren, the mental activity of an actual and an imagined motor

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http://dx.doi.org/10.1016/j.cmpb.2014.02.018

movement follows the same pattern [11]. The analysis of the activity in regions destined to motion action may allow the detection of different mental tasks such as motor imaginary. Moreover, other kinds of metal activity (concentration tasks) are studied in order to obtain a better differentiation between mental tasks. The use of these EEG signals can allow patients with mobility impairments to control systems that grant more freedom and provide an improvement in their quality of life. The BMI is capable of translating the EEG signals into control outputs that are transferred to an external device that can be operated without performing any physical movement.

In this paper, the differentiation of two mental tasks is performed to control a planar robot in the horizontal plane. Mental tasks differentiation can be based on different techniques for both the extraction of the features used for classification and the classification method itself. Typically, electrical signals acquired from the scalp of the user are processed to extract the frequency components of these signals. This processing is performed to facilitate the work to the next stage, the classification of the signals to distinguish the mental tasks performed. In this part there are multiple options such as the use of artificial neural networks or other methods like Bayesian classifiers or systems based on Support Vector Machine (SVM) [12,13].

In this work, two mental tasks will be used to control the movement of a robot in the horizontal plane. To that end, a SVM-based system is used. This kind of classifier is often used to detect motor imagery tasks [14,15]. This system allows, through two strategies (hierarchical and directional), the robot motion control in two axes. The aim of this work is to verify the accuracy of the system, evaluating the time required to perform different tasks of achieving goals. The tests have been performed by two users in two different sessions. On each session, the user has to reach four targets twice (once for each control strategy).

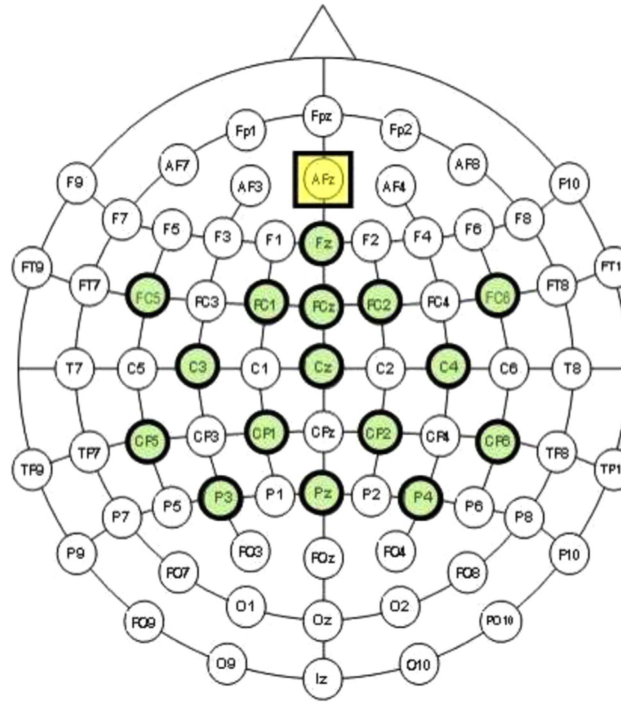

Fig. 1 – Placement of the electrodes according to the International 10-10 system.

2. Methodology

The differentiation between two mental tasks is used to control the movement of a planar robot. To that end, two control strategies are used. First of all, the appropriate tasks have to be selected in order to obtain the best results for each user. To do that, an analysis of 12 mental tasks is done and a combination of two mental tasks is selected for each user.

2.1. *Selection of mental tasks*

Depending on the used tasks, the success in the results can be very different. In order to improve results and to make easier the control of the robot, the best combination of two mental tasks is selected for each user. All of them performed 12 runs which contained 12 different mental tasks. The 12 mental tasks are divided into four groups including three tasks each one. Each group of tasks is analyzed using three different registers of the user in order to obtain enough trials for every task.

In order to select the pair of tasks used to control the planar robot, all the combination of two mental tasks are analyzed. The success rate in the classification of these tasks is calculated using a SVM-based system. By using this classifier, the results of the classification are obtained and the combination with the most accurate behavior is selected. The method used is similar to the method developed in a previous work [16].

As in the previous work mentioned before, the 12 mental tasks used are the following:

1. Imagination of right hand movements (open/close)
2. Imagination of left hand movements (open/close)
3. Mentally countdown from 20 to 0
4. Imagination of repetitive right arm movements
5. Imagination of repetitive left arm movements
6. Imagination of repetitive right leg movements
7. Imagination of repetitive left leg movements
8. Imagination of tongue movements
9. Imagination of head movements
10. Imagination of rotation of a cube
11. Mentally perform mathematical operations
12. Recite the alphabet backwards

2.2. *Register*

During the recordings, the EEG signals are registered through 16 active electrodes. These electrodes are placed using the g.GAMMAcap from the company g.tec. This cap is very useful, as it allows an easy placement of the electrodes. The 16 electrodes are placed following a uniform distribution over the scalp. According to the International 10-10 system, the position of the electrodes is the following: Fz, FC5, FC1, FCz, FC2, FC6, C3, Cz, C4, CP5, CP1, CP2, CP6, P3, Pz and P4. This distribution of the electrodes is shown in Fig. 1. These electrodes are