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Original Article

EEG Based Brain Computer Interface for Controlling a Robot Arm Movement Through Thought

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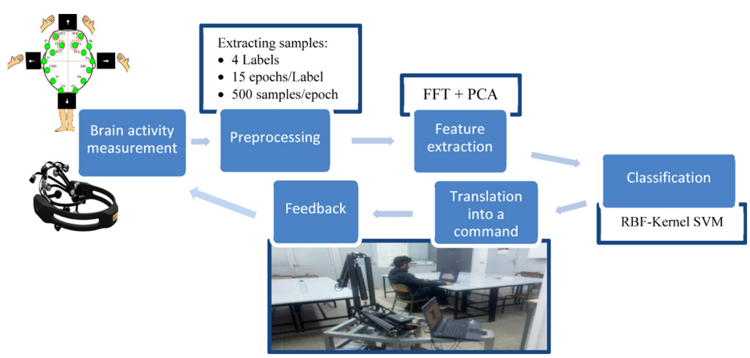
Highlights

- The use of Brain Computer Interface to help a handicapped user to find an object.
- Use of electroencephalogram based on four mental tasks to control the robot arm.
- The system enabled the control of the robot achieving an averaged accuracy of 85.45%.

Graphical abstract



Abstract

Background: The Brain Computer Interfaces (BCI) are devices allowing direct communication between the brain of a user and a machine. This technology can be used by disabled people in order to improve their independence and maximize their capabilities such as finding an object in the environment. Such devices can be realized by the non-invasive measurement of information from the cortex by electroencephalography (EEG).
Methods: Our work proposes a novel BCI system that consists of controlling a robot arm based on the user's thought. Four subjects (1 female and 3 males) aged between 20 and 29 years have participated to our experiment. They have been instructed to imagine the execution of movements of the right hand, the left hand, both right and left hands or the movement of the feet depending on the protocol established.

EMOTIV EPOC headset was used to record neuronal electrical activities from the subject's scalp, these activities were then sent to the computer for analysis. Feature extraction was performed using the Principal Component Analysis (PCA) method combined with the Fast Fourier transform (FFT) spectrum within the frequency band responsible for sensorimotor rhythms (8 Hz–22 Hz).

These features were then fed into a Support Vector Machine (SVM) classifier based on a Radial Base Function (RBF) whose outputs were translated into commands to control the robot arm.
Results: The proposed BCI enabled the control of the robot arm in the four directions: right, left, up and down, achieving an averaged accuracy of 85.45% across all the subjects.
Conclusion: The results obtained would encourage, with further developments, the use of the proposed BCI to perform more complex tasks such as execution of successive movements or stopping the execution once a searched object is detected. This would provide a useful assistance means for people with motor impairment.

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Keywords: Brain–machine interface; Electroencephalography; Emotiv Epoc headset; Fast Fourier transform; Principal component analysis; Support vector machine

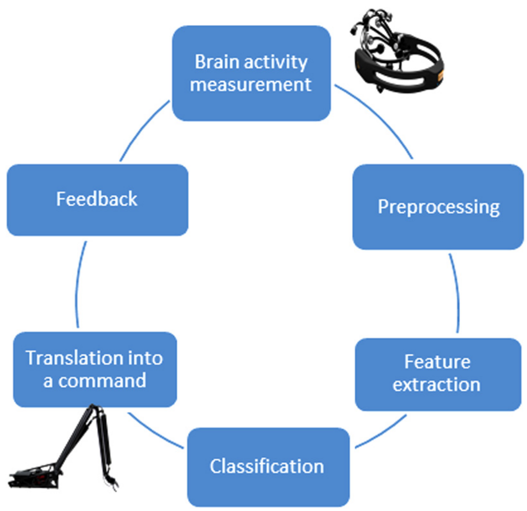

Fig. 1. Brain computer interface system.

1. Introduction

Our brain controls the various functions of the body. Each area of the brain is responsible for a specific function, such as arm and leg movements, vision, hearing and intelligence. The spinal cord is an organ that has a lot of functionality in our nervous system among them the transmission of control messages to the muscles, damage to this organ causes in paralysis. Therefore, patients who are suffering from this severe problem such as motor disabilities cannot handle the simplest daily routines and they need a great deal of support to improve their ability to carry out and move on with normal life. As a result, this problem has an impact on a person's quality of life and adds a high cost for the residential care packages since an assistance is always needed to serve patient.

As a solution the Brain Computer Interfaces are devices allowing direct communication between the brain of a user and a machine, these systems can be used in patient assistance or rehabilitation and require a closed-loop process, most of time composed of six steps (Fig. 1): brain activity measurement, preprocessing, feature extraction, classification, translation into a command and feedback.

Numerous works which Brain Computer Interfaces have been used in controlling robotic platforms can be found in the literature.

Moreover since 1960, researchers [1] introduced the term cyborg and the idea to control an electronic system using brain activity. In 1973 researchers [2] tested the first real experiment on humans. The latter had an electronic control system via brain activity measured by EEG.

The past few years various ways in controlling robotic platforms for people suffering from a diverse range of impairments were investigated. Guger and his colleagues had already shown that it is possible for patients suffering from 'locked-in syndrome', spinal cord injury or damaged regions of the brain responsible for the body movement to control a hand prosthesis by thought without the use of invasive techniques [3,4], another systems were proposed and applied for people with disability in order to control a wheelchair or robot arms [5,6].

BCIs appeared in the computer gaming domain, they have been applied in the virtual simulations, such as games or virtual tours. Pfurtscheller, Leeb and his collaborators [7,8] developed an application in which the subject can move in a virtual street by imagining the movement of the feet to move forward and movement of the right hand to stop. Then researchers start developing various novel applications with relatively low cost non-invasive EEG equipment and software development kits (SDKs). Furthermore, gaming technology has been assisted by virtual and augmented reality systems, making hybrid BCI systems for enhancing the user experience, study and improvement of brain-computer interaction [9].

In fact, what was once science fiction became a reality with the Brain Computer Interface. This approach became possible through the use of technology and mathematical method describing certain physical processes occurring in the brain and corresponding to specific mental tasks. Wavelet-based feature extraction algorithms were introduced in [10]. Power Spectral Density (PSD) [11], Band Powers (BP) [12], Adaptive Auto Regressive (AAR) [13], were also used for feature extraction. A great variety of classification methods was also used to design BCI systems. Linear Discriminant Analysis [14], Support Vector Machine (SVM) [15], and Hidden Markov Model [16] are some examples of widely used classifiers in this field. Classification of mental tasks has been introduced in several works ([17–19]), however, just a few applications in real time have been reported in the literature. Recently, Hortal designed a BCI for controlling an industrial robot arm through mental tasks [20] in which the system performed SVM classification of four mental states to control in real time the movements of the robot with an accuracy achieving 70%. The mental activities consisted of motor tasks involving two imagined movements of both hands separately and two concentration tasks which consisted of a mental recitation of the alphabet backward and a mental count down from 20 to 0. This work had been tested with two volunteers only.

The current work focuses on a non-invasive and spontaneous BCI based on the use of EEG biosignals elicited through mental tasks to control the movements of a robot arm with the goal to help handicapped people find a specific object in the environment. The BCI consists of two steps. Firstly, an Off-line BCI with four mental motor tasks is used to train a volunteer and brain activities recorded are analyzed and processed for feature extraction. Secondly, a real time BCI based on RBF Kernel

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