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Design and Development of Brain Signal Detection Using EEG Technology

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***Abstract* —** This work presents the design and development of brain computer interface detection as an alternative communication channels to be used in Robotics. It encompasses the implementations of an ElectroEncephaloGraph (EEG), as well as the developments of all computational methods and necessary techniques to identify mental activity. The developed brain computer interface (BCI) is applied to activate the movements of a 120lb mobile robot, associated four different mental activities to robot command. The interface is based on EEG signal analyses, which extracts features that can be classified as specific mental activities. First, a signal processing is performed from the EEG data, filtering noise, using a spatial filter's to increase the scalp signal resolution, and extracting relevant features. Then a different classifier models are proposed, evaluated and compared. At last two implementations of the developed classifiers are proposed to improve the rate of successful command to the mobile robots. In one of the implementations, 91% average hit rates is obtained, with only 1.25% wrong commands after 400 attempts to the control mobile robots.

Index Terms: Brain Computer Interface, Electro Encephalo Gram, Electro Myo Gram, Level Analyzer Techniques, Robotic Wheelchair.

I. INTRODUCTION

The patterns of interactions between these neurons are represented as thoughts and emotional state. These entire electrical waves will be sensed by the brain waves sensor and it wills converts the data into packets and transmits through Bluetooth medium. Level Analyzer Unit (LAU) will receive the brain wave raw data and it will extract and process the signal using Matlab platforms. Then the control commands will be transmitted to the robotic module to process. With this entire systems, [1].

The regulations is usually obtained from IC voltage regulator unit, which takes a DC voltages and provided a somewhat lower DC voltages, Which remains the same even if the inputs DC voltage varies, or the output Load connected to the DC voltage change.

Finally, in additions to the motor related rhythms, Anderson and Millán analyzed continuous variations of EEG rhythm, but not only over the sensor motor cortex and in specific frequency bands. The reason is that a number of neurons cognitive studies have found that different mental activities (such as imaginations of movement, arithmetic operations, or language activates local cortical areas at different extent. The insights gathered from these studies guide the placement of electrode to get more relevant signals for the different task to be recognized.

A BCI application includes control of the elements in a computer environment such as cursor positioning or visiting of virtual apartments spelling software and command of an external device such as a robots or prosthesis. Recent applications in robotics are the control of a wheelchairs and the control of the Khepera mobile robots.

In this work, a not invasive BCI based on EEG analysis system is proposed to control a mobile robot. Control is provided through their four specific mental activities: imaginary movements of feet, tongue, left arm, and right arms. These activities correlated with 4 robot movements, respectively: stop, move forward, turn left and turn right. The interface classifies the user's mental activity, sending the corresponding commands to activate the mobile robot. Note that the user does not need to be able to perform such feet, tongue or arm movement; just imagining them is enough to activate the robots.

This paper is organized in a seven sections. Section 2 described the implementations of the electroencephalograph used in this work. Section 3 presents how signals have been preprocessed, followed by Section 4, where classifier models are proposed. Section 5 showed experiment to evaluates the classifiers, while Section 6 shown the applications to the mobile robot. Finally this Section 7 discusses the conclusions of this works.

II. GRAPHICAL USER INTERFACE (GUI):

A graphical user interface (GUI) is a graphical display in one or more windows containing controls, called components that enable a user to perform interactive tasks. The user's of the GUI does not have to create a script or type commands at the command line to accomplish the tasks. Unlike coding programs to accomplish tasks, the user of a GUI need not understand the detail of how the tasks are performed.

MATLAB's Graphical User Interface Development Environment (GUIDE) provides a rich set of tools for incorporating the graphical user interfaces (GUIs) in M-functions. Using GUIDE, the processes of laying out a GUI (i.e., its buttons, popup menus, etc.) and programming the operation of the GUI are divided by conveniently into two easily managed and relatively independent tasks.

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III. PREPROCESSING

Preprocessing is more performed as PC notebooks in a basically four steps: noise filtering, spatial filtering, feature extractions and subject artifact detections.

A. Electrical noise

Most sources of external noises can be avoided by appropriately controlling the environments in which the measurement takes places.

But not all interference can be eliminated in this ways. Even if the electronic components are enclosed in a metal box and properly grounded, EEG signals are not totally free from powers line and other noise. Thus, a low pass Butterworth eighth order digital filters with cutoff frequency of 35Hz was designed to eliminate any residual noise, keeping only the EEG frequencies of interest.

B. Spatial Filtering

Conventional monopole electroencephalographic (EEG) recording have a poor spatial resolutions. The scalp potential distributions can be viewed as a 'blurred' copy of the original cortical potential distribution. However, local estimations can be obtained, by Horthy's methods, computing the difference between the potential at each electrode site and the average potentials of its nearest neighbors [21]

$$4 \cdot \frac{Vn - (VA + VB + VC)/3}{d^2}$$

Where Vn is the potential recorders at the nodal electrode, VA, VB, VC are the potentials recorded at the surrounding electrode, and d is the distance between the nodal and the surrounding electrode.

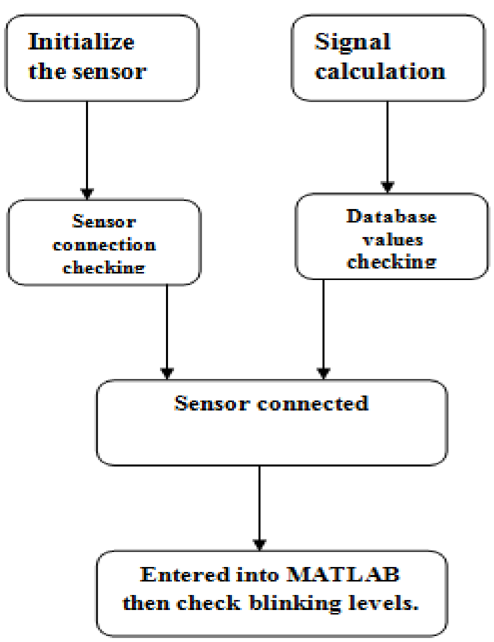

Fig 1: BCI Software architecture

The signal processing can be done in a data processing module with the help of MATLAB tool. The captured signals are preprocessed by think gear and sents to the PC.

IV. DATA PROCESSING MODULE

The artifacts and noise produced in the systems can be removed by performing FFT analysis. The Attention13 and blinking signal levels are differentiates by using the level analyzer techniques. The output signals are transmitted to the wheelchairs.

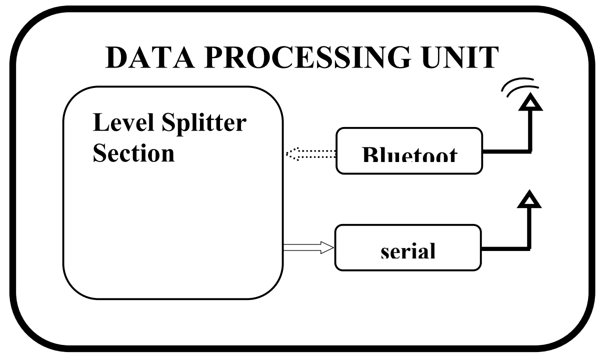

Fig 2: Data processing unit

A. Robotic Wheelchair Module

Robot wheelchair consist of an ARM 7 Microprocessors to control the movements of the wheelchair by capturing the command received. The prototypes model of the wheelchair with above specification is designed by evaluating the working models.

B. ARM Processor

ARM 7 (LPC2148) processor based on 32 bit operation, with RISC (Reduced Instruction Set Computer) Principle. It is based on Von Neumann Architecture, which shares the data and instructions both in the same bus. The ARM 7 processors having 16 data registers and two processor status registers. It uses Pipeline Mechanisms to execute the instructions. The main features of ARM 7 are low powers and high performance. In this hardware's setup, an ARM processor is used for receiving the signal from RF module and processes it. After processing the signals, if it sends to the control to the DC motors circuit in order to direct the movements of the wheelchair accordingly (forward, left, right and backward).

V. RESULTS AND DISCUSSIONS

ARM 7 Processor act as controlling core and Zigbee communications act as a transmissions medium for data transfer. The Personal computer is working as a signal-processing center by using MATLAB computing environment. Neurosky technologies is used, to capturing the neuron signals pattern from the user, where the single channels dry and biosensor located at the FP1 frontal lobe with minimal hair areas. It delivers the raw EEG signals with some noise and artifact's values.

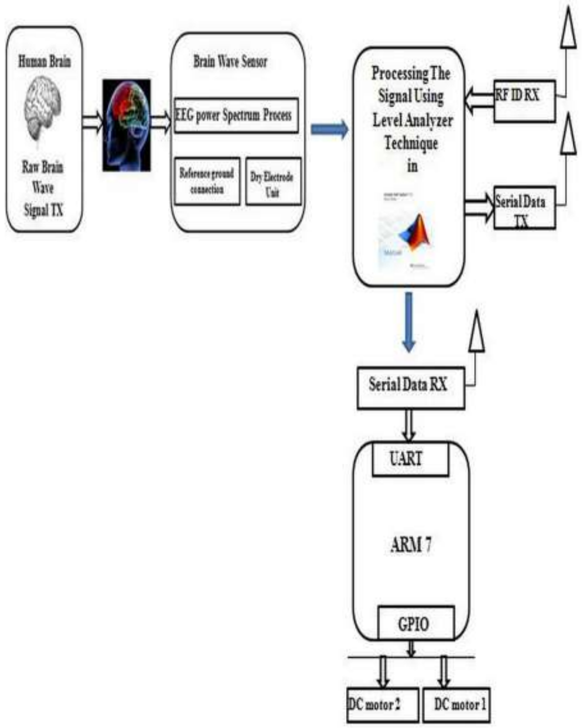

Fig.3 The overview of the system.

To communicate the peoples with independent of wires and provided enhanced portability's, free motions, wearable with low power consumptions. Figure 8 shows the experimental setups.

VI. APPLICATION TO A MOBILE ROBOT

To validate the proposed methodologies, the developed BCI is applied to a 2- wheeled 120lb mobile robot. Laboratory from the PUC - Rio University. It was already programmed to follow radio frequency (RF) commands; therefore no further development was necessary. In additions, such system is analogous to an electrical wheelchair, one of the possible applications of the BCI: it is drives by only two active wheel using differential drives, and it has enough traction to carry an adult.

The BCI commands are translate to four different movements: turn 30 degrees to the right (RM) turn 30 degrees to the left (LM), move forward 500mm (UM), and stop (DM). Note that any values other than 30 degrees and 500mm could been used.

The communications with the robot is made through a PCTx modules [27], which receives values from an USB connection and translates it into commands to a Futaba 75MHz RF transmitter that activate the robot.

The PC portion of the application is implements under the MATLAB environment, including data acquisition from the EEG A/D converters, preprocessing, processing, and sending the commands to the PCTx module. The PC used in the experiment is a 2.2GHz.

Note that the five seconds pause between recordings is important for the user to relax and get ready for the next steps. Also, discarding the first second of each recording is important for efficient calibrations, to guarantee no auditory artifact is present due to the short beep that signal the start of each count. This process is repeated in until 700 trials are recorded (400 are used for training), taking about 20 minutes for 1-second trials and 5-second pauses.

In the second steps of the calibration, the obtained dataset is used to train the classifiers. The training of 4 neural networks takes less than 30 second in the used notebooks.

After the training, the system is ready to continuously identify mental activities to control the mobile robots. Each trial takes less than 30ms to be compute, which is insignificant if compared to the 1s duration of each trial. Most of these 30ms are spend on input and output interfacing, not on the methodology calculation.

Both threshold and statistical implementation is evaluated by asking the user to performs 100 time each mental activity, while looking at the mobile robots. Then, the number of successful, unclear (when no mental task is chosen within the limit number of trials) and wrong command are stored.

VII. CONCLUSION

A synchronous operant conditioning BCI was developed in operating with four mental activities for the activation of mobile robots. The BCI uses intuitive mental activities such as imaginary movement of the left arm to turn the robot left, without the need for imagining arithmetic operation or spinning solids. It was evaluated from 2.000 test trials without the mobile robots and 400 attempts with the robot. It was found that the features related to signal power in Alpha and Beta band represents suitably the behavior of the EEG signals in the frequency time domains during imaginary motor function. The proposed methods not only resulted in a high rate of successful commands about 90% for threshold and statistical implementations but also greatly decreased the number of wrong commands as low as 1.35% for the statistical implementation due to their concept of an 'unclear' command, when no action is taken each mobile robot commands was identified in average after 5 trials, which could translate into 3 seconds or less depending on the chosen trial period. Further tests showed time intervals as low as 5 seconds between mobile robot commands with similar hit rates. Another advantages of both methodologies is that the system calibration for a given user takes only about 15 minutes.

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