Human-Machine Interfaces Based on EMG and EEG Applied to Robotic Systems

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Abstract. Two different electro-biological signal based Human-Machine Interfaces (HMIs) were developed: EMG and EEG based. Such interfaces present like main characteristics relatively simple acquisition and processing systems, which need of few hardware and software resources, so that they are computational and financial low cost solutions. Both interfaces have been applied to robotic systems and their performance have been shown up in such applications. The EMG based HMI was tested in a mobile robot, while the EEG based HMI was tested as much in a mobile robot as a robotic manipulator.

1 Introduction

Electro-biological signals have recently become the focus of several research institutes, stimulated, mainly, by recent findings in the areas of cardio, muscular and neurosciences, by the availability of more efficient and low cost computational resources, and by the increasing knowledge and comprehension about motor dysfunctions [2][5].

Electrical signals of different parts of the human-body can be used as command signals for controlling systems. However, it is necessary that the user can intentionally generate such signals. Also it is necessary that the interface adopted (Human-Machine Interface - HMI) can ”understand” and process such signals, setting the command that better fits the wish of the user. Then, a HMI can be used to improve the movement capacity of people with motor dysfunctions, using, for example, a robotic wheelchair to carry them.

Among the many kinds of electro-biological signals which can be used in HMIs, those more commonly employed in such devices are: Electro-MyoGraphical (EMG), Electro-OculoGraphical (EOG) and Electro-EncephaloGraphical (EEG) signals.

EMG signals have a standard behavior, what is a great characteristic to take into account as a starting point of a HMI project. However, there are inherent problems in using it. Taking into account that the assistive technology proposed here is also directed to people with neuromotor disabilities, some muscle spasms, for example, can occur on these people, which represent a very serious problem (unless the HMI has a robust way

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to reject these disturbances) when using a system controlled by EMG signals. Severe neuromotor injuries can also cause loss of muscle mobility, being impossible to use any kind of EMG based control.

Thus, other communication channels (electro-biological signals) are explored in this work, in order to develop systems that give better life conditions to those people. Brain signals can be a solution to these problems. Good temporal resolution, portability and low cost are some advantages related to EEG signals when compared to other ways to acquire brain signals [6].

There exist several methods to use EEG signals as a communication channel. The goal of this work is based on the ERS/ERD (Event Related Synchronization / Desynchronization) complex, because such one is easier to be identified using relatively simple processing signal techniques. These patterns represent band power changes on the brain rhythms in a specific frequency band. The ERD is related to a band power decrease while ERS represents a band power increase. These patterns used here are those present in the alpha band of the occipital region (region related to visual information processing). The ERD is related to concentration or existence of visual stimulus while a condition of a relaxed visual area with few, or absence, of visual stimulus, characterizes an ERS. Using a simple and low cost HMI [2] based on ERD/ERS, it was possible to control devices such as a mobile robot [2] and also a robotic manipulator [1].

This work presents the development sequence of HMIs in which is taken into account the previous considerations, so that the difficult degree in relation to both signal acquisition and processing is gradually increased, according to it is shown in Section 2. This way, in the first stage of implementation of the HMI, an eye blink signal (EMG) based system was done, like is shown in Section 2.1. Such system was used to control a mobile robot, which was able to navigate in a semi-structured environment. Next, a module capable to acquire and process EEG signals was developed (Section 2.2). Currently it is been explored the ERS/ERD complex of the signals acquired by electrodes placed on the subject's occipital region (O_1 and O_2 electrodes, according 10-20 standard), which are related to visual activity. Such modules have been used to control a mobile robot and a robotic manipulator. The results are shown in Section 3. In Section 4 the final considerations are done in addition to future plans for development of the electro-biological signals based HMI.

2 Acquisition Systems

Two different electro-biological signals based Human-Machine Interfaces (HMIs) were developed: EMG and EEG. The first one allows a person to command devices through eye blinks [4]. The other one allows brain commands as well as to control devices [1]. In this section a succinct presentation of such systems is done.

2.1 EMG

Fig. 1 shows the structure of the EMG based on HMI developed. Such HMI is composed of a signal acquisition and processing system. No complex practical preparation is required to use the system. The subject is supposed to use a commercial cap (for convenience) with the correct electrodes position according to 10-20 International System. The respective head positions to be used should be clean and it is not necessary to shave the hair, but applying a gel to improve head/electrode contact. The reference is connected to the ear. The acquisition is done by electrodes which send the user's electro-biological signals to be amplified and filtered on the signal conditioning and power supply board. Afterwards, these signals are sent to other board which does A/D conversion. Finally, such signals are transmitted to a desktop computer, where their processing is done, generating or not a specific command for controlling a mobile robot. A subject closes the control loop, providing the necessary biological feedback.

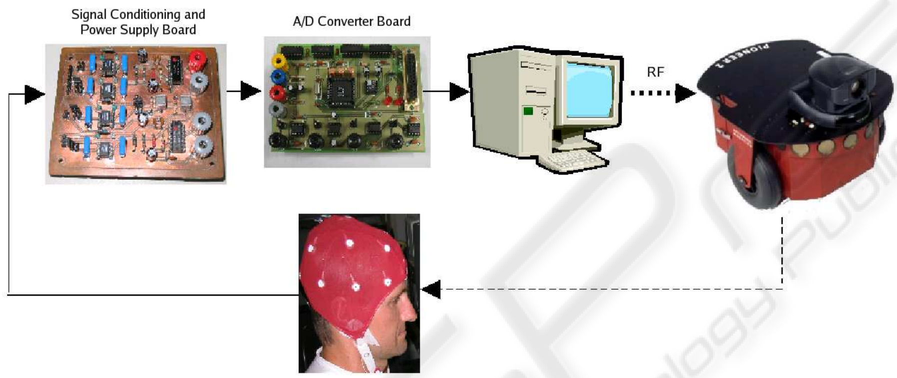

Fig. 1. The structure of the proposed system.

The board's power source is designed to reduce the interference of the electric appliances frequency and other external electronic equipments, such as switching supplying, on the acquisition system. The A/D converter board has four analog channels allowing expansion through cascade connections, increasing the number of channels being processed. The interface for the user/machine communication is programmed in the desktop computer, as well as the signal processing software, that sends the control commands to the mobile robot. These commands are transmitted to the robot through an Ethernet Radio.

The experiments here reported were carried out with a Pioneer 2DX wheeled mobile robot. This robot has a microcontroller for the low level instructions and an embedded PC (Intel Pentium MMX 266 MHz, 128 MB RAM).

For generating a command, the user should be able to blink his/her eyes. To help him/her in this task an electronic board with automatic scanning (desktop microcomputer) was implemented. It represents the area from a robot's navigation environment divided in cells, according to Fig. 2. This way, when the wished cell is swept, the user blinks a determined eye and the EMG signal is captured and processed by the acquisition and processing systems.

Since the EMG signals due to eye blinks have a well-defined standard behavior Fig. 3, the necessary processing system is relatively simple. It works as follow: Firstly,

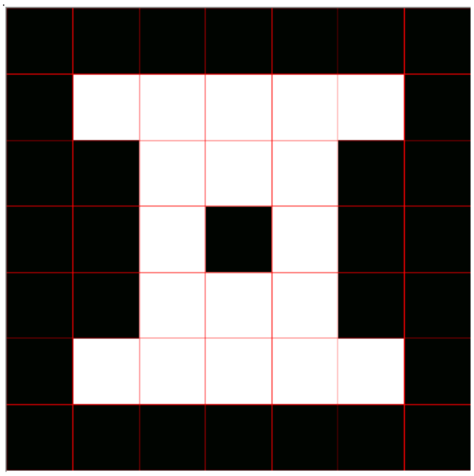

Fig. 2. System's electronic board.

a threshold is experimentally established for each user, based on the changes observed in a signal interval that contains a set of eye blinks (training stage). During the system run, whenever the signal generated by an eye blink of the user goes above the threshold established, a counter starts counting the number of samples received ever since. When the signal falls below the threshold, the number of samples counted is compared with a predefined one: if it is greater than the pre-defined number, the HMI detects an eye blink. Otherwise, the HMI detects that there was not an eye blink. After that, the counter is reset and a new cycle starts.

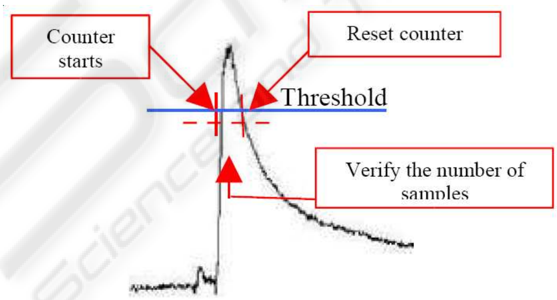

Fig. 3. Eye blink detection.

2.2 EEG

The hardware developed to work with EEG data was used to operate a mobile robot [2] and also an industrial manipulator [1]. The last one, includes a teleoperation via TCP/IP.

The hardware is composed basically of a signal conditioning board (filter/amplification function) followed by an acquisition board, responsible for A/D conversion. Signal processing and the generation of control actions in order to operate the robots are done by an application running on a PC. This application also implements the user/machine software interface.

Electrodes placed on O_1 and O_2 positions (according to 10-20 system) of the operator's head acquire EEG signals that are filtered (band pass: 0.5 Hz to 40 Hz) and amplified.

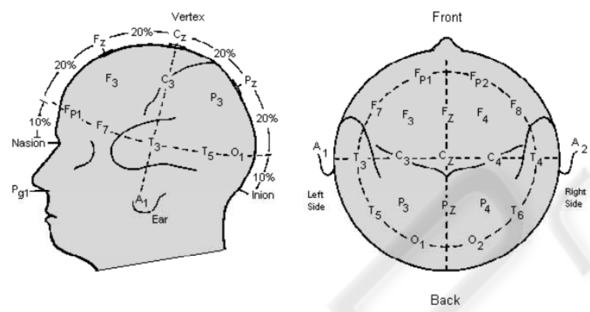

Fig. 4. 10-20 International System for electrodes placement.

Once conditioned, the signal is digitalized and pre-processed to remove artifacts. Afterwards, a power analysis of the signal allows the identification of a low (ERD) or high (ERS) energy in alpha band (8-13 Hz) as illustrated in Fig. 5. Using this information the machine makes decisions.

In the first case (operating a mobile robot), the alpha band power analysis is used to change states of a Finite State Machine (FSM) and to generate commands (front, right, left, back) to the robot.

In the case of operating an industrial manipulator (BOSCH SR800) via TCP/IP, it is presented to the operator the manipulator's workspace divided in cells. The application scans all cells and the user's alpha band power analysis is used to select one of them. This is accomplished by determining an ERD or ERS pattern. When the user has the eyes open the signal's power is low (ERD), but when the eyes are closed an ERS can be identified by the increasing of the band power over a established threshold, and thus, the cell is selected. When it is done, the coordinates of this cell are sent via TCP/IP to a remote computer which controls the manipulator, moving its end effector toward the desired position. At the same time, the data incoming from encoders are sent back to the user's PC (the local one) in order to update the screen with the current positions of the manipulator. The whole system is illustrated in Fig. 6.

In both cases a calibration process is necessary before starting the experiments. This procedure consists of acquiring about 10 seconds EEG data to analyse ERD level. Based on this information, the threshold used to detect an ERS is set to 5 up to 10 times the

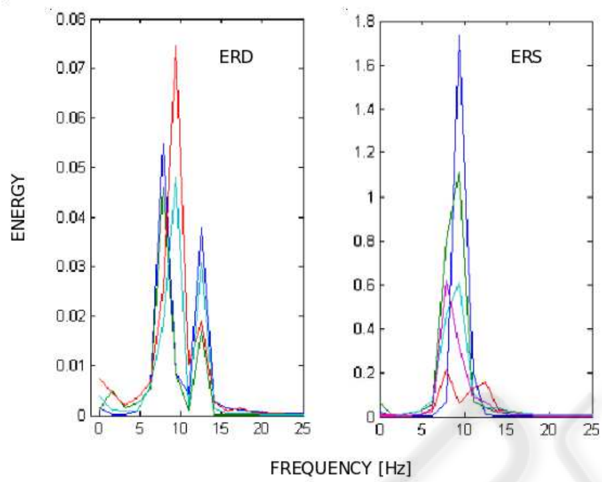

Fig. 5. ERD and ERS energy levels [3].

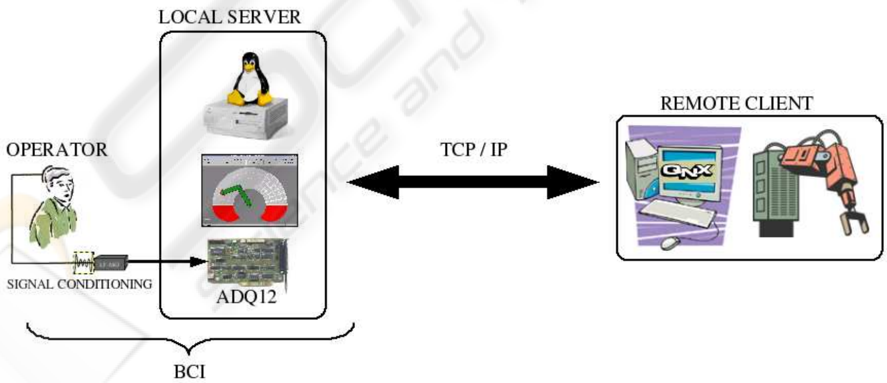

Fig. 6. EEG based system.

ERD's level. This is very important because these levels change constantly in time and from person to person.

3 Results

Both HMIs presented in Section 2 have been used to command robotic devices by subject previously trained to operate them. The EMG based HMI was used to command a mobile robot, while the EEG based HMI was used to command both a mobile robot and a robotic manipulator. In this section results from each test done are shown.

3.1 EMG

Firstly, eight subjects were asked to accomplish ten eye blinks with each eye, in order to test the eye blink identification algorithm. The results of these experiments are shown in Table 1. The subjects could also choose to wear the electrode cap or individual surface electrodes. Only results of subjects which were able to perform blinks with both eyes are considered, according Table 1.

Table 1. Success results using right and left eye.

Volunteer	Right Eye	Left Eye
1	8	9
2	10	10
3	10	8
4	10	10
5	10	9
6	10	10
7	10	10

So, an average rightness of 95.71% about the results reached by subjects with ability to blink both eyes allowed to conclude that the system could be used to command devices.

One among the subjects that presented a good performance in the experiment with eye blinks system was asked to determine a destination point on the electronic board described in Section 2. After such subject to select a destination point through eye blinks (see Section 2), the control software started to guide the robot to such point, following the path determined by a path planning algorithm [4], which is based on the Dijkstra's Algorithm, that determines a secure path, that is, more distant of walls and obstacles.

Fig. 7 shows the map of a navigating environment and the path generated by the system to go from an initial position to a destination position selected by the user. That path is transmitted to the mobile robot, which knows its navigating environment. Fig. 8 shows the result of the navigation executed by the robot during the experiments.

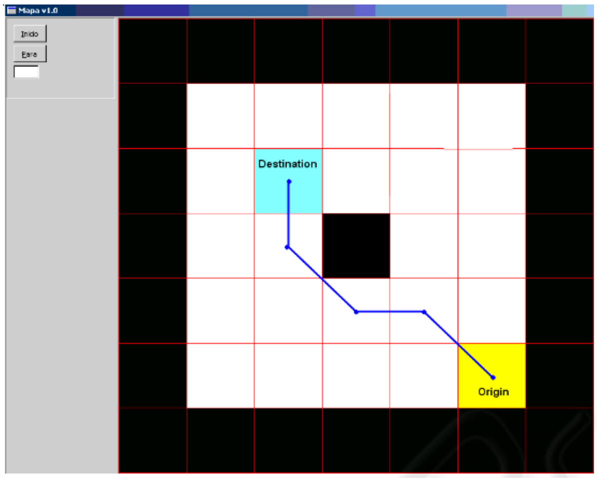

Fig. 7. Path generated by the system.

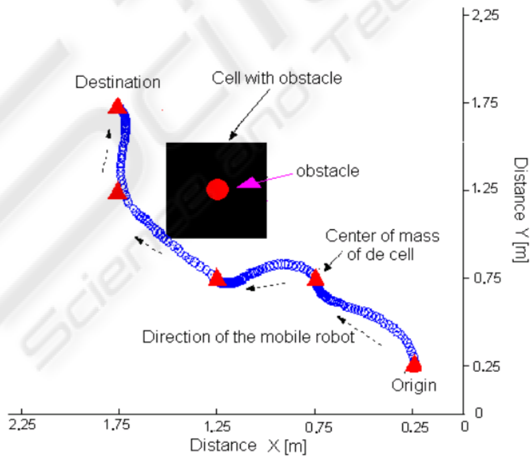

Fig. 8. Result of the experiment with unpredicted obstacle distant of the robot's navigation path.

3.2 EEG

This HMI was proved by a group of 25 people (age between 20 and 50 years old) without neuromotor disabilities. The results are presented in Fig. 9. As can be seen, most of people learned how to use the HMI in less than 15 minutes with only one experiment.

Additionally the operation of complex systems such as an industrial manipulator and a mobile robot with a considerable low cost HMI is shown, also providing efficient results.

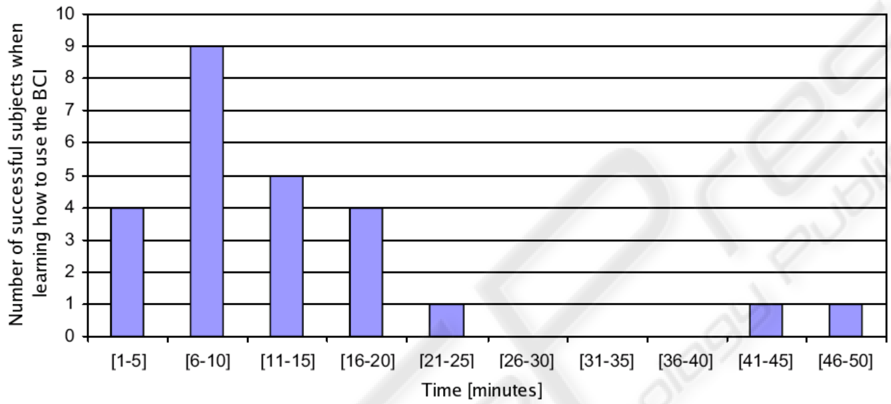

Fig. 9. Number of successful subjects when learning how to use the HMI versus training time required (in minutes).

4 Conclusions

A review of two different HMIs developed is done in this work: EMG and EEG based. Both interfaces show oneself to be simple implementation and low cost solutions.

The EMG signal was initially chosen as electro-biological signal due to be a behaved signal of easy acquisition and processing compared to other electro-biological signals as, for example, EEG. The results demonstrate the HMI is easy to operate by users which can blink their eyes according their wishes. This HMI was tested in a mobile robot, so that a user could point to a destination position, through an eye blink, to be reached by the robot. In all tests, the mobile reached to the destination pointed by the user.

The EEG based HMI can be seen like an evolution of the EMG based HMI due to the increasing of the difficult degree presents as much in the acquisition system as in the processing system. It has been used the called ERS/ERD complex, which can be relatively easy identifying it, what allowed, in any case, a simple and low cost solution, as previously commented. This HMI was tested as much in a mobile robot as in a robotic manipulator. In both cases, the command was executed by the robotic devices.

Such works are initial parts of a system to help people with neuromotor diseases, including those with severe dysfunctions. The next steps are: to convert a commercial wheelchair in an autonomous mobile vehicle; to implement the HMI onboard such autonomous wheelchair to assist people with motor diseases; to explore more characteristics of EEG signals, making the Brain Computer Interface (BCI) more robust and faster, allowing a secure use by people with severe motor dysfunctions.

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