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Electroencephalogram (EEG) Sensor for Teleoperation of Domotics Applications via Virtual Environments

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Abstract

This article describes the development of a virtual environment used to simulate a domotic environment controlled by the acquisition of electroencephalographic signals, captured by the Emotive Epoc sensor. The base modules of this sensor are used for the identification of control actions oriented to the control of the actuation signals in the environment, validating the functionality of the tool through five test users, obtaining 87% accuracy in the execution of actions remote command of virtual environment.

Keywords: virtual environment, domotics, EEG signals, brain computer interface

INTRODUCTION

The accelerated technological advance is at hand with innovative applications that aim to improve the quality of life of people. The development of new teleoperation and control interfaces, oriented to various tasks is part of this progress. Within this field the brain computer interfaces (BCI) [1] have delved many applications ranging from biometric brain recognition [2] to control robotic agents [3].

The basis of the BCI are electroencephalography (EEG) signals, which are acquired through specialized sensors [4] that are necessarily invasive, i.e. require to be located in the user, but acquire user-friendly features, as wireless connectivity [5]. By acquiring these signals, sleep factors [6] [7] or stress [8] can be analyzed.

So that one of the practical applications for BCI-based systems development focuses on virtual environments, these environments allow the design of spaces that guide the training of systems for adjustment and calibration of BCI [9]. One of the most used sensors for this type of development and capture of EEG signals is the Emotiv EPOC [10], used in this work.

Next, the implementation of a virtual domotic environment is presented, which allows to verify the status of user commands in the environment, by capturing their EEG signals used as control signals. The control signals are then sent to an embedded reference system ST32F407-VG Discovery, which is responsible for reading the control signals and handling the respective actuators outside the PC, as remote validation of the virtual environment.

The article is divided into three sections the first presents the virtual environment, the second the results obtained and the final section the conclusions reached.

VIRTUAL ENVIRONMENT FOR DOMOTICS APPLICATIONS

The proposed system is based on an interaction with the user that carries the BCI system, in this case the commercial Emotiv EPOC sensor, with which the EGG signals are captured. The Emotiv EPOC signal is acquired by the PC, wirelessly, interpreted by proprietary software of the sensor developer, which allows to register mental associations based on the modules: Affective, Cognitive and Expressive, bases for the interpretation of sensor signals. The central control software was developed in the "Processing" programming environment, which corresponds to a programming in JAVA. The developed environment includes the reading of the Emotiv EPOC sensors through the Open Sound Control (OSC) protocol, which is normally used to communicate musical instruments, computers and other multimedia devices. In addition, it has the house plans, and simple functions of the same, a serial communication (RS 232) that is associated with an external embedded system (ST32F407VG), which allows to interact with some actuators that emulate the functions of intelligent housing proposed. The wiring diagram of the proposed system can be seen in Figure 1.

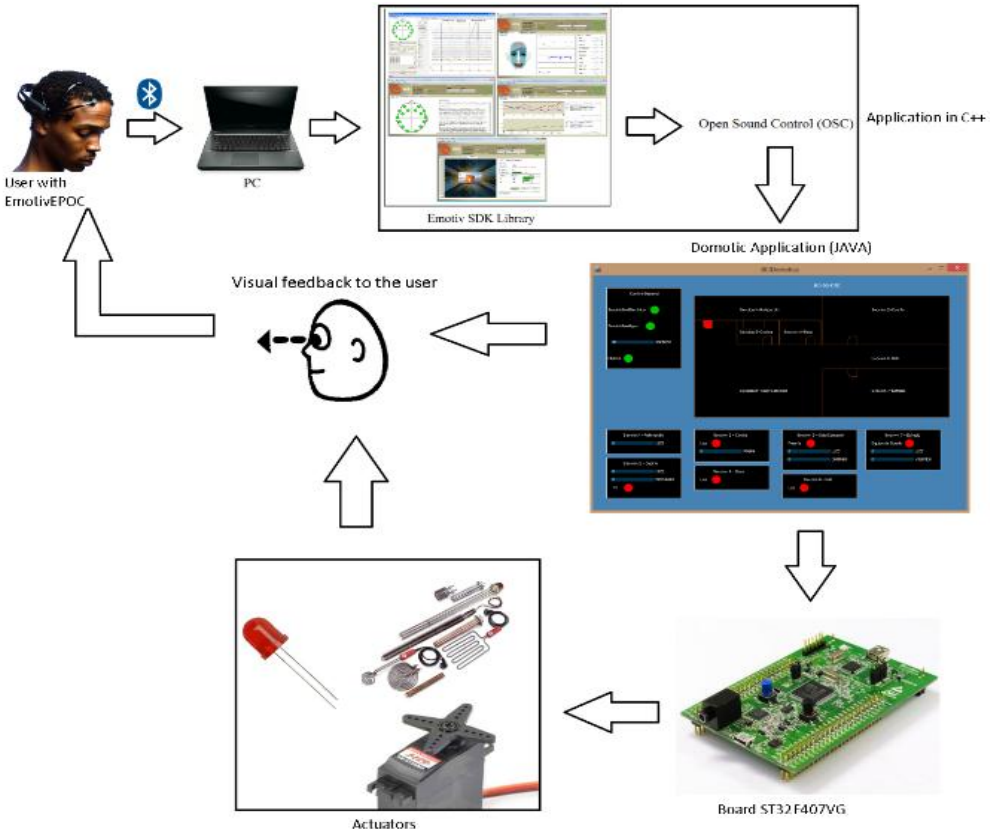

Figure 1. Diagram of connections of the domotic environment controlled by BCI

From the capture of the EEG data from the sensor, the analysis and the sending of the different signals are performed by the OSC protocol. It is used a client PC, which houses the software made in JAVA, which allows to interpret the data sent by the OSC protocol and fulfills the functions of the domotic environment.

Such data are sorted in the 3 modules of the sensor: affective, expressive and cognitive. The affective and expressive modules do not require any training but can be improved by training the user. On the other hand, the cognitive module requires training by the user, who exercises his neuronal signals to be recognized by an artificial neural network that learns to distinguish between these signals, which would correspond to a determined action.

The software developed in Java recognizes different signals (18 in total) from the Emotiv EPOC and takes them as boolean or floating type values. They take about 10 signs of the expressive module, corresponding to blink, left wink, right wink, see left, see right, smile, jaw tight, smirk left, smirk right and laugh, 4 signs of the affective module corresponding to meditation, frustration, emotion and boredom and 4 signs of the cognitive module, push, pull, left and right. Such signals are the source of control of the domotic environment.

The virtual domotic environment is developed in Processing (JAVA), includes: an interface with the state of the housing sensors and the status of each of the devices controlled. Such data are displayed in order to facilitate visualization of the user's interaction with the environment. The implemented interface is shown in Figure 2.

Figure 2. Virtual Domotic Environment

General control and section control are proposed. The general control includes the control of the electrical supply, the water supply, the temperature of the house and an alarm. Sectional controls are provided in each room and can control from the light intensity of a room, the on / off of a TV, the opening of blinds or curtains, the lighting of a bulb, the temperature of the stove, the opening/closing of a door, to the on/off sound equipment and the volume of it. This structure can be seen in Figures 4, 5 and 6

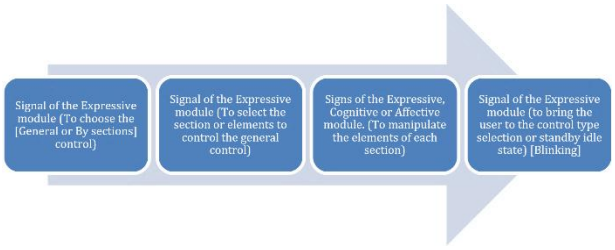

Figure 3. User Information Flow to Domotic Environment

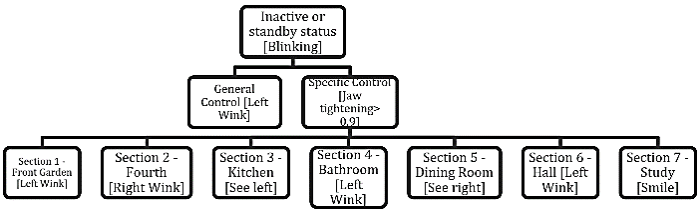

Figure 4. General structure and control signals

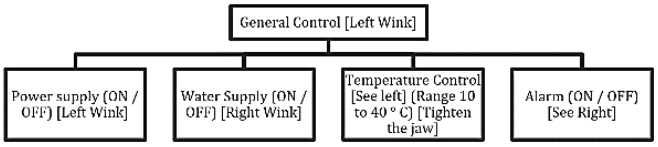

Figure 5. General Control Elements and Signals

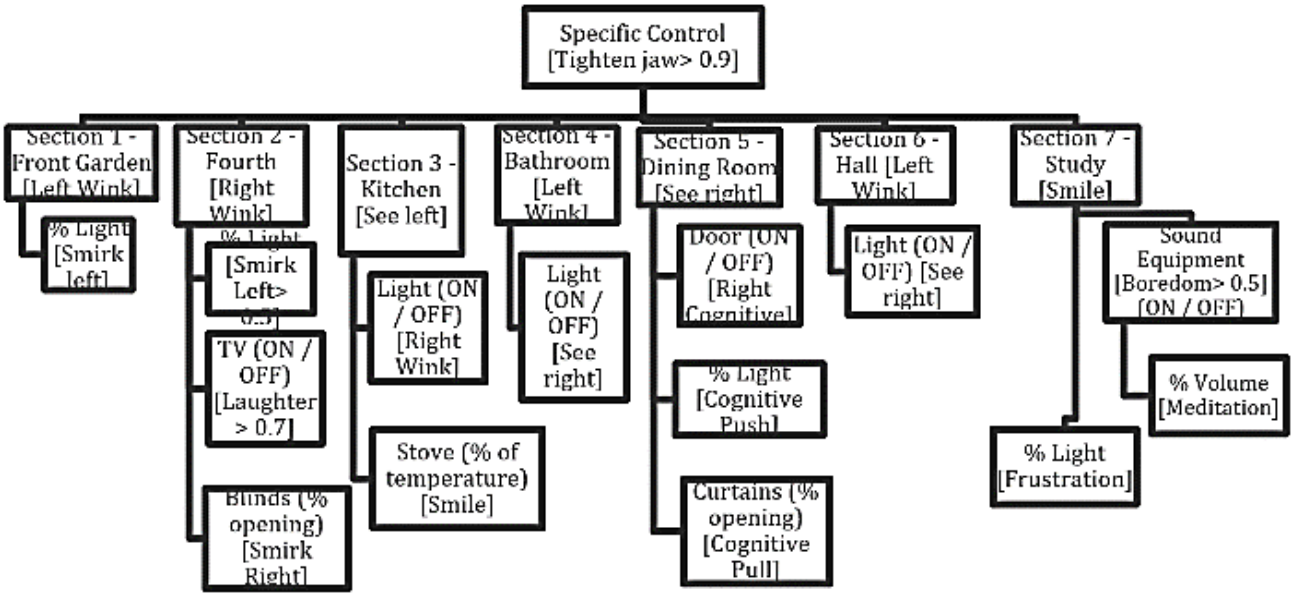

Figure 6. Control Elements by Sections and Handling Signals

RESULTS

The virtual environment was evaluated with 5 users, who had a percentage of success in the affective module between 70 and 85%, in the expressive module between 80 and 95%, and in the cognitive module between 5 and 15%, in relation to the discrimination of the signals described for each module. Subsequently, the same users underwent a training of 1.5 hours, which consists in performing thoughts associated with a specific movement (cognitive module), in order to train an artificial neural network (for each user), which after some preparation manages to interpret these signals. Tests are performed again and the performance of the modules affective

and expressive, remains the same range, while the cognitive module improves its percentage of successes (65 to 95%). These results are tabulated in Table 1.

Table 1. Percentage of successes per module

Module	% of initial success	% of successes after training
Affective	70-85%	70-85%
Expressive	80-95%	80-95%
Cognitive	5-15%	65-95%

It is evident the ease and versatility of EEG sensor training, Emotiv as a BCI device applicable to domotic control systems, because its affective, cognitive and expressive modules allow a wide range of signals for teleoperation. This allows to extract a sequence of domotic control to be executed by each test user, this sequence corresponds to: activation power supply - on light hall - on light study - off light study - on light bath - water supply - off light bath - off light hall - on room light. As a base route for the virtual environment, the results obtained by user are tabulated in table 2.

Table 2. User Validation

User	**Percentage of accuracy (%)**	**Execution time (minutes)**
#1	92	2,25
#2	85	2,53
#3	88,6	3,20
#4	90,1	2,43
#5	79,6	3,15

Variations in the execution response of the domotic control sequence are given by the ease of the user in the adaptation with the system, repetitions of control signals are presented to fix their state, so that the execution time increases. These repetitions are the basis of decreasing accuracy in the execution of the domotic control sequence, except the user 3 that takes more time to recognize the performance signal that should be executed but its application ends up being successful, that is why it takes more time with a good level of success.

CONCLUSIONS

Because the affective and expressive modules do not require much training, they are adequate to develop a system indifferent to the user, between these two the simplest is the expressive, because of the ease of the user in performing such gestures.

The developed application responded in a desired way, but the algorithms of control are not very simple for the users, reason why in the future could be improved, either simplifying the algorithms or implementing techniques like the P300 or the evoked potential.

Finally, it can be seen that the domotic applications through BCI interfaces are very appealing not only to the disabled public, but also to the public in general, since they allow to greatly improve the quality of life and to simplify many of the habitual actions of today.

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