A Home Automation Interface for BCI application validated with SSVEP protocol

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Abstract

This work aimed at developing a BCI driven application for the control of a commercial home automation system. The application was developed using the BCI framework proposed by the SensibiLab Laboratories (Politecnico di Milano) and interfaced with a four command SSVEP based system.
A specific software module was implemented in order to provide an interaction layer with an home automation system. A MyHome® gateway was provided by BTicino spa (Erba, Italy) and a basic demonstrator was set-up in our laboratory. The standard physical communication layer of the adopted gateway is RS-232 and, in order to maximize the ease of installation, a specific RS-232 to Bluetooth module was designed. The Application layer was implemented using the OpenWebNet® language proposed by BTicino. Although the current demonstrator supports only a few light-point and some auxiliary devices, the software module supports all the options provided by the home automation system. Six healthy subjects whose ability to use the SSVEP system was already assessed were able to control the demonstrator.

1 Introduction

Home automation (or Domotics) is a field of building automation aimed at the development of specific technical solutions for private homes and dedicated to the application of technologies for the comfort and security of its residents.
Many technological field are involved in the realization of an home automation system ranging from electronics and computer science, to communication networks and the internet. From the technological research point of view, the main focus is the creation of a smart system able to efficiently control and integrate all the typical home installations, such as:

- Heating, ventilating, and air conditioning (HVAC);
- Lighting;
- Water delivery;
- Access control;
- Audio and video switching and distribution
- Intercommunication;
- Remote process monitoring and control;

thus optimizing power consumption, comfort and safety. [1].

While generally conceived as a commercial technology for comfort and luxury in high-end buildings, this technology adds alternative and flexible pathways to the typical interaction paradigm of the user with his domestic environment, thus representing an accessible and efficient solution aimed at providing disabled people with a direct environmental interaction and significantly increasing the quality of life [2].

2 Materials

The home automation interface control application is part of the BCI framework developed by the Sensibilab. The framework is composed of several hardware and software tools which were used in the development and testing of the system, even if the most part of the adopted libraries are cross platform, the current available version is for Windows® only.
A brief description of the framework architecture is here proposed using a signal-path based approach:

- The hardware acquisition unit (KimeraII) is an improvement of our previous system [3] and it consists in an eight channel battery powered EEG featuring a wireless Bluetooth communication protocol;
- An Hardware Interface Module (HIM) is the gateway between KimeraII and the controlled application. This module receives the EEG data from the device, processes it and sends the estimated classification to the AEnima module using a TCP/IP connection;
- The AEnima module is based on an Open Source graphical engine (IrrLicht) used to manage the Graphical User Interface guaranteeing flexible and versatile 2D/3D applications design tools. Communication with external control/stimulation devices and HIM timing and triggering issues are managed by a dedicated *Protocol* class.

The home automation application was developed using the commercial MyHome® system developed by BTicino (Erba, Italy). MyHome® system is based on a proprietary SCS bus technology (patented by Bticino) which guarantees the minimization of cabling requirements and a flexible modular system for easy upgrades and future system extensions. MyHome® domotics system was interfaced with a personal computer using a specific RS232 to SCS gateway: a specific communication protocol called OpenWebNet was also adopted.

2.1 MyHome Library and Configuration Software

The Home Automation Interface software is based on a communication library which was developed in order to assure a certain independence of the software from the physical connection medium and to guarantee, through modularity, ease of inclusion in any software.
The library has been built, using native C, with two different layer: the Serial layer and the OpenWebNet layer.
The Serial layer takes care of the communication between the residential gateway and the PC: it provides communication with the home automation control device using a standard RS232 port.
The OpenWebNet layer implements the basic commands of the OpenWebNet communication protocol for the control of the home automation system.
The two-layer structure of the library allows for the use of different type of connection only by adjusting the Serial Layer.

The application is able to support different installations of MyHome® system and, according to this purpose, three different configuration software were created:

- MyHome Config
- Scenarios Config
- MyHome Test

The three configuration software were designed for end-user applicability thus guaranteeing efficiency and ease of use, for this reason they have been developed with an user-friendly graphics interface which allows for the setting up in a few mouse clicks. The MyHome Test software also features a specific *Preview Mode* which allows for the testing of the entire installed system directly from the PC.

2.2 User Interface and Testing Procedure

The MyHome protocol was used in order to demonstrate the flexibility of the proposed BCI system interfacing with external components. Using the libraries illustrated in the previous chapter it was possible to create a button based menu application for the control of the home automation system. The first menu (Figure.1) allows for the selection between six submenus of commands:

- Lighting controls;
- Environments;
- Automations;
- Shutdown all;
- Exit – return to main menu;
- Scenarios.

Figure 1. Main menu of MyHome protocol

By selecting one among the different submenus, the user gain access to the corresponding GUI with the related buttons and controls: when the user select an operation in the submenu, the protocol forces the system to return to the main menu. In order to simplify and optimize user control, the cursor movement was constrained by the grid shown in Figure 2.

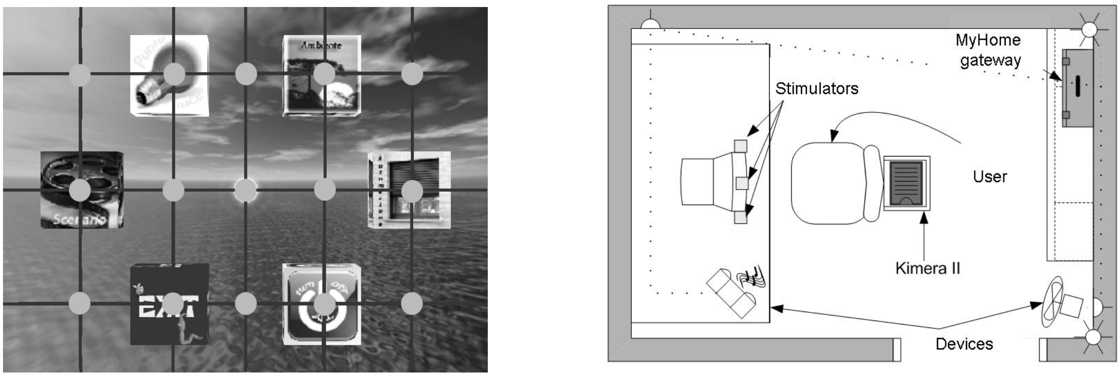

Figure 2. *On the Left:* Cursor movement grid. *On the right:* Planimetry of the acquisition room

As shown in Figure.2, a simple example of home automation system was set-up in the room where the BCI sessions took place. The user could activate two devices and two independent lights behind the user's sit. Since the SSVEP protocol is based on external optical stimulation and on the related evoked cerebral response, the activation of light-points and the consequent environmental lighting variation could have a potential effect on the SSVEP potential.
During the experimental protocol it was decided to verbally guide the user in the use of the application, thus it was also possible to verify the effect of an uncontrolled environment on system usability.

3 Results

Ten healthy subjects between 22 and 50 years old, took part to the study. The subjects were sitting on a standard office chair in front of a 19” LCD screen at a distance of about one meter.
Each subject performed a 5 steps protocol consisting in:

- A **screening phase** that lasted 190 seconds performed in order to identify the four best stimulation frequencies;
- A **calibration phase** that lasted 160 seconds for the registration of a training set for the classifier;
- A **testing phase** involving the selection of 8 different symbols that was used in order to verify the performances of the classifier;
- A **gaming protocol** which consisted of a 15 trials target reaching session;
- A **home automation** session which consisted of a free will use of the automation system.

Only the subject that were able to successfully complete the testing phase proceeded to the gaming and to the home automation protocol.
Six subjects out of ten were able to generate an SSVEP response suitable to robustly train the classifier and to complete the testing phase. All the six subjects were able to easily drive the system: in order to simplify the interaction with the graphical user interface, a researcher was near the subject and helped him/her in the navigation of the menu by verbal instructions during the session itself.
Since a key point in the SSVEP protocol is the visual stimulation, a change in the environmental lighting could compromise the functioning of the system: in order to verify the robustness of the system against this specific aspect, the first operation the user was asked to perform was to switch on the lights. All the user were able to operate the system even during increased environmental lighting conditions.

4 Discussion and Conclusion

In this work a four command based graphical user interface (UI) and a communication layer with the domotics system were developed. By interfacing the system with an SSVEP-Based Brain-Computer Interface it was possible to demonstrate the usability and the reliability of the application; the test with other BCI paradigms is mandatory; from this point of view many current BCI systems [4] may be compatible with the developed application while other may require the adaptation of the UI layer without changing the communication layer.

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