# BRAIN CONTROLLED AND ENVIRONMENTAL AUTO-ADJUSTMENT SMART HOME NETWORK

S.PRADEEP[1], V.PADMAJOTHI[2]
[1]PG Scholar, Embedded System Technology, SRM University, Chennai
[2]Assistant Professor, Embedded System Technology, SRM University, Chennai
pradeep.2dec1991@gmail.com, padmajothi.v@ktr.srmuniv.ac.in

***Abstract*—The environmental control systems are designed to improve human quality of life. The work deals with the smart home network controlled directly using the human physiological state. Based on the technique of brain computer interface (BCI), the BCI technique can be integrated with universal plug and play (UPnP) home networking for smart house applications. The model mainly consists of a wireless physiological signal acquisition module, an embedded signal processing module and a host system. The physiological signal acquisition module and embedded signal processing module were designed for long-term electroencephalogram (EEG) monitoring and backend analysis, respectively. The low power consumption and small sized modules are suitable for smart house applications in daily life. This BCI system uses a single EEG channel to monitor active state also makes the system to be used in real time. The setup can be operated in a home network, and the controlling of the devices can be automatically controlled by the change of the user's active state. This model provides a novel system prototype for home network control, and can be extended and integrated with the UPnP home networking for other applications.**

***Keywords*—Brain computer interface (BCI), electroencephalogram, universal plug and play (UPnP), EEG values, bluetooth.**

## I.INTRODUCTION

A rapid growth of research on smart houses is proposed and developed to provide various kinds of environmental control systems. Some environmental control systems in a smart house employed radio frequency identification (RFID), external sensor modules, and voice recognition as the controlled signals. RFID tag or external sensors are usually installed in different areas in advance for automatic detection of users' motions. By combining with universal plug and play (UPnP) home networks, the users could send out service requests from their personal digital assistant, mobile phones, a wearable appliance, or external sensors to home server either with voice, graphic user interface, or motion. Moreover, with the development of brain computer interface (BCI), it is an extremely new option to apply the physiological signals as the stimulus of environmental control system in a smart house. But in the existing brain computer interface-based environmental control systems the user's active mental command is required to control external devices. Hence, these systems lack the capability to control devices automatically and adaptively according to the user's current cognitive state. Also, most of current BCI-based environmental control systems are very inconvenient because bulky and expensive electroencephalogram (EEG) machines and personal computers are both required for physiological signals acquisition and backend analysis, which will limit the flexibility, portability, and practicability of these systems.

Therefore, the proposed model is a cost effective, simply extendable and easy-to-use brain computer interface-based smart auto-adjustment control system to control electric home appliances based on the change of user's cognitive state (drowsiness or alertness). In this model a wireless physiological signal acquisition module and an embedded signal processing module were also proposed. Different from other BCI systems, which are usually bulky and have to transmit an EEG signal to a backend personal computer to process the EEG signal, this wireless physiological signal acquisition module and embedded signal processing module contain the advantages of small volume and low power consumption, and are more suitable for practical application. The UPnP home networking can easily be integrated with electric home appliances for other applications.

The wearable middleware framework consists of various components. The bridge system architecture proposed in this section works as one of the components. It is mainly composed of Device Discovery Module, UPnP Virtual Agent and Profile Manager. The bridge is a typical example of an interworking device. Device Discovery Module and Virtual UPnP Agent work together to bridge the Bluetooth device to the UPnP environment, and in the meanwhile an UPnP description file is created by interworking with the Profile Manager.

The lower-layer interface of the bridge refers to the API (Application Program Interface) of the SAL (System Adaptation Layer). It is used to provide transparency to the subordinate OS and enhance scalability with other media. The underlying OS can be replaced without changing the internal implementation of the bridge components. Likewise, the bridge component can be extended to support another protocol rather than Bluetooth by revising the lower-layer interface.

The higher-layer interface refers to the API that can be used when the application accesses the bridge. The application can use all the functions of the bridge simply through the higher layer interface API without having to access the inner modules of the bridge. The higher-layer interface allows any application to use the bridging function easily. The Device Discovery Module plays the role of detecting a Bluetooth device in run time and extracting information from it. The information of the Bluetooth device generally consists of the Bluetooth GAP (Generic Access Profile) and SDP information. The extracted information is transmitted to the Profile Manager component, where the UPnP description-type profile is created. The list on detected Bluetooth devices is also maintained and each device is identified as a currently activated UPnP device.

The Virtual UPnP Agent registers the detected Bluetooth devices in the UPnP network with the XML-type device profile, which is created as a virtual UPnP device by the Profile Manager component. The Virtual UPnP Agent is the core module that bridges the Bluetooth devices to the UPnP network. The Bluetooth device registered as a virtual UPnP device now can be detected through the UPnP Control Point. Likewise, the bridged device list can be accessed to get detailed information on the currently bridged Bluetooth device using the higher-layer interface API. The Profile Manager generally controls three types of profiles—user, device, and service. The device profile comes in the form of an UPnP description file. The Profile Manager handles creating, modifying, and deleting the device profile, whereas the other two components support the bridging function itself by interworking with the Profile Manager.

## II. BCI BASED CONTROL SYSTEM

The Electroencephalogram (EEG) pulses that are sensed by the brain computer interface have to be processed by the physiological signal acquisition module. The processed signal is transmitted via Bluetooth to an embedded processing module. A simple control protocol is to be created such that the home network is controlled based on the processed signal inputs.A smart home network is to be designed based on the cognitive nature of an individual that is sensed using a Brain Computer Interface. The block diagram of the model is represented as shown in Fig.1.

The system architecture of the proposed model mainly consists of four parts: 1) wireless physiological signal acquisition module; 2) embedded signal processing module and3) host system. Here, the wireless physiological signal acquisition module is designed to acquire and transmit an EEG signal to the embedded signal processing module wirelessly via Bluetooth. Bluetooth provides a short range wireless and secure communication between devices to eliminate the need for messy cables.

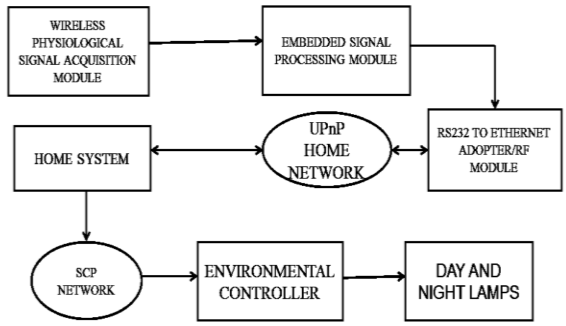


Fig.1. System architecture of proposed BCI based smart living environmental auto-adjustment control system.

By using the encryption function in the security procedures of Bluetooth, it will translate the transmitted data into secret code to avoid the contents being eavesdropped. The embedded signal processing module is designed to estimate the user’s cognitive state from his or her EEG, and provides the estimated cognitive state to the host system. The host system is designed for data storage/display, and is also served as an UPnP control point to manage the request from UPnP control device as well as the SCP/PLC environmental controller, which is used to control electric home appliances, such as day and night lamps, air conditioners, and others.

### *A.Wireless Physiological Signal Acquisition Module*

The block diagram of the proposed wireless physiological acquisition module is shown in Fig.2. It mainly consists of a front end amplifier unit, a microprocessor unit, and a wireless transmission unit. Here, the front end amplifier unit contains a preamplifier, a band-pass filter, and a 12-bit analog to digital converter (ADC). The gain of the front-end amplifier unit is set to 5040 times with a passing frequency band of 0.1– 100 Hz. EEG data digitized by ADC with the sampling rate of 512 Hz will be stored into the memory of the microprocessor unit, and then be processed to pass through a moving average filter in the microprocessor unit to remove power-line interference before being sent to the wireless transmission unit.

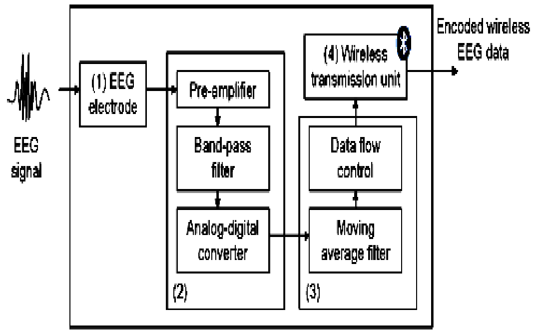


Fig.2. Block diagram of wireless physiological signal acquisition module

The wireless transmission unit consists of a printed circuit board antenna and a Bluetooth module, which is fully compliant with the Bluetooth v2.0+ EDR specification. This module operates at 31mA with 3.7 V DC power supply, and can continuously operate over 33 h with a commercial 1100 mAh Li-ion battery. The volume of the proposed wireless physiological signal acquisition module is about 4 cm × 2.5 cm × 0.6 cm, which is small enough to be embedded into a headband as a wearable device.

*B. Embedded Signal Processing Module*

The proposed embedded signal processing module that contains a powerful computation capability and can support various peripheral interfaces is developed to perform the real time cognitive state detection algorithm, and is also evaluated as the UPnP control device to send out the estimated cognitive state and EEG signal to host system to drive environmental controller via UPnP home networking. Here, the Arduino embedded processor is used in the embedded signal processing unit. The operating clock frequency of central processing unit can run at up to 16 MHz. It contains two 16-bit multiply-and-accumulate to execute 1200 lines addition and multiplication functions and also has four independent direct memory access mechanisms to effectively reduce the processing time of core. A memory-mapped thin film transistor liquid crystal display, which shares the same memory bus with synchronous dynamic random access memory, is used in this module. Here, serial peripheral interface Flash is used to replace the parallel NOR flash to reduce the module size. Furthermore, this module also contains power management circuits.

The embedded processor communicates with wireless transmission unit via universal asynchronous receiver/transmitter interface. This module can be operated with a 5 V DC power supply, and it can continuously operate for more than 45 h operations. The volume of the embedded signal processing module is about 2.4 inches × 2.1 inches × 0.5 inch. The cognitive state detection algorithm was implemented as a multithreaded application on operation system. The received EEG data will be real-time processed, analysed and displayed by the embedded signal processing module. When the change of cognitive state of the user is detected, the corresponding command will be transmitted either by radio frequency (RF) module or by Ethernet (a RS232-to-Ethernet adopter module is required) through UPnP protocol to the host system.

*C. Host System and Environmental Controller*

The host system is an UPnP/SCP bridge and is also served as the home gateway to internet network. With UPnP/SCP techniques, the system is realized to simply plug-and play IP/non-IP consumer equipment in home networking without any complicated settings. In the host system computer, Windows XP was used as the operation system, and the host system program, developed on Microsoft Visual C#, was designed to provide following functions: data storage and display, UPnP control point to receive and reply the request from UPnP control device and SCP host to transmit control commands to environmental controller for operations. A SCP-based environmental controller with four channel AC/DC power line control outputs is used to control home equipment in this paper. All settings and control commands are accomplished with writing/reading three continuous registers. Two or more kinds of commands can be sent from the host system to environmental controller to control the endpoints according to user’s cognitive state. In this paper, the SCP based environmental controller is used to control the day and night lamps in the showroom. The adjustable DC outputs of environmental controller can be also employed if adjustable illumination of lights is required.

## III.RESULTS

The EEG electrodes are connected to the Arduino Uno board. The electrodes are used to measure the alpha, beta and gamma values of EEG pulse signal. These electrodes are placed around the forehead of a person. The EEG values are sensed and sent through a motor driver unit. The values are passed to the Arduino Uno board.

The transmitter side and the receiver side setup are shown in EEG shown in Fig.3 (a) and Fig.3 (b). The Arduino software version 1.0.3 is used program the Arduino Uno board. The board has to be selected in the software. The board is uploaded with the program to read the EEG values.

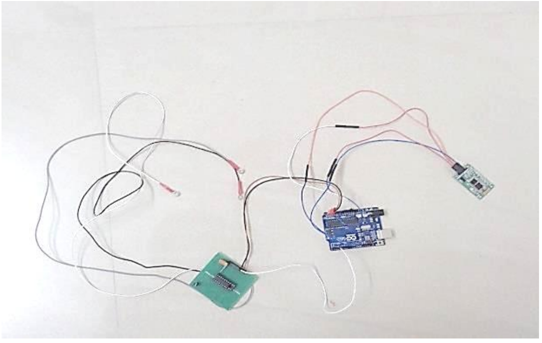

Fig.3 (a) Transmitter unit of BCI

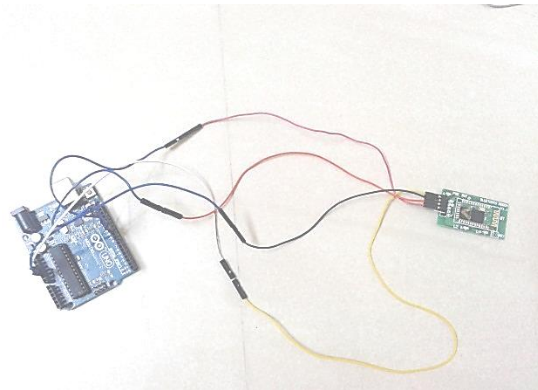

Fig.3 (b) Receiver unit of BCI

The alpha, beta and gamma values are displayed as shown in Fig.4.These three values have a specific range in them.

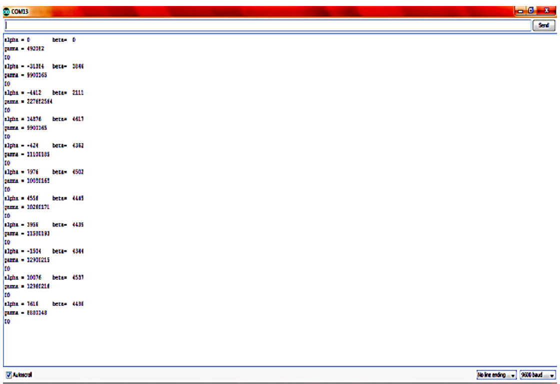

Fig.4 Alpha, Beta and Gamma values at the receiver

The three values at various instants can be tabulated as shown in the Table I.These values are then transmitted through the Bluetooth module HC05 to another receiving unit.

The threshold range can be set for the values to control the electrical devices. When the received value is within the threshold range then the corresponding electrical device can switched on.

TABLE I EEG values at various instants

| ALPHA | BETA | GAMMA |
|---|---|---|
| 8412 | 3417 | 30916577 |
| 15164 | 4116 | 30780513 |
| 5824 | 4272 | 30360506 |
| 11524 | 4263 | 30900515 |
| 6364 | 4173 | 30300505 |
| 11764 | 4572 | 30960516 |

## IV. CONCLUSION

The proposed model is to control a home network using the BCI. The EEG values measured using sensing electrodes are used in controlling the devices. The measured values are transmitted from the Arduino Uno board via the Bluetooth module to a receiver Bluetooth module .The alpha, beta and gamma values are analysed for various instants. These values are used to control electrical devices connected in the smart home network.

The transmitted values are received using a Bluetooth module and sent to another Arduino Uno controller unit. The values are checked based on the threshold value that has been set up. The values change at the transmitter side based on the cognitive state of the individual. The electrical devices connected to the controller unit can be switched ON or OFF based the EEG values.The setup can be operated in a home network, and the controlling of the devices can be automatically controlled by the change of the user's active state.

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