Brain-controlled Portable Programmable Embedded System

Project Proposal

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Introduction

1.1 Statement of Purpose

The technology of detecting and analyzing electroencephalographic (EEG) signals already exists in labs. For instance, when we stare at a light source which blinks at a specific frequency, our brain will generate a signal at the same frequency along the scalp. The EEG technology is able to detect, amplify and recognize this particular neural signal, which gives us a new way to interact with machines: directly from brain. However, the equipment used for EEG signal detection and analysis is not portable and currently there are no devices integrated with a software system on the EEG technology. Both drawbacks prevent this new technology from prevailing in market. In this project, we aim to create a product which is specially designed for EEG technology in order to provide better user control experience in general. It has the wireless communication component to enable portability and an embedded system which takes EEG signal as input.

1.2 Objectives

1.2.1 Goals

- The device contains a LCD screen which blinks at different frequencies in different regions so as to visually stimulate the generation of EEG signals along the scalp, which can be captured by the analyzing equipment.
- The device wirelessly obtains analyzed signals.
- The device then classifies and computes the signals and updates the displays based on the software system integrated in the controller.

1.2.2 Functions

- LCD screen provides interactive displays and stimulates the generation of EEG signals in the user's brain.
- Wireless communication between EEG equipment and the device
- Software system analyzes signals from EEG equipment and updates display accordingly.

1.2.3 Benefits and Features

- Wireless signal transmission provides significant portability
- Interactive displays improve user experience
- Brain-control based inputting method realizes unique and simplified user interactions
- Large LCD screen provides effective signal stimulation without mutual interference
- Revolutionary control technology

2.0 Design

2.1 Block Diagram

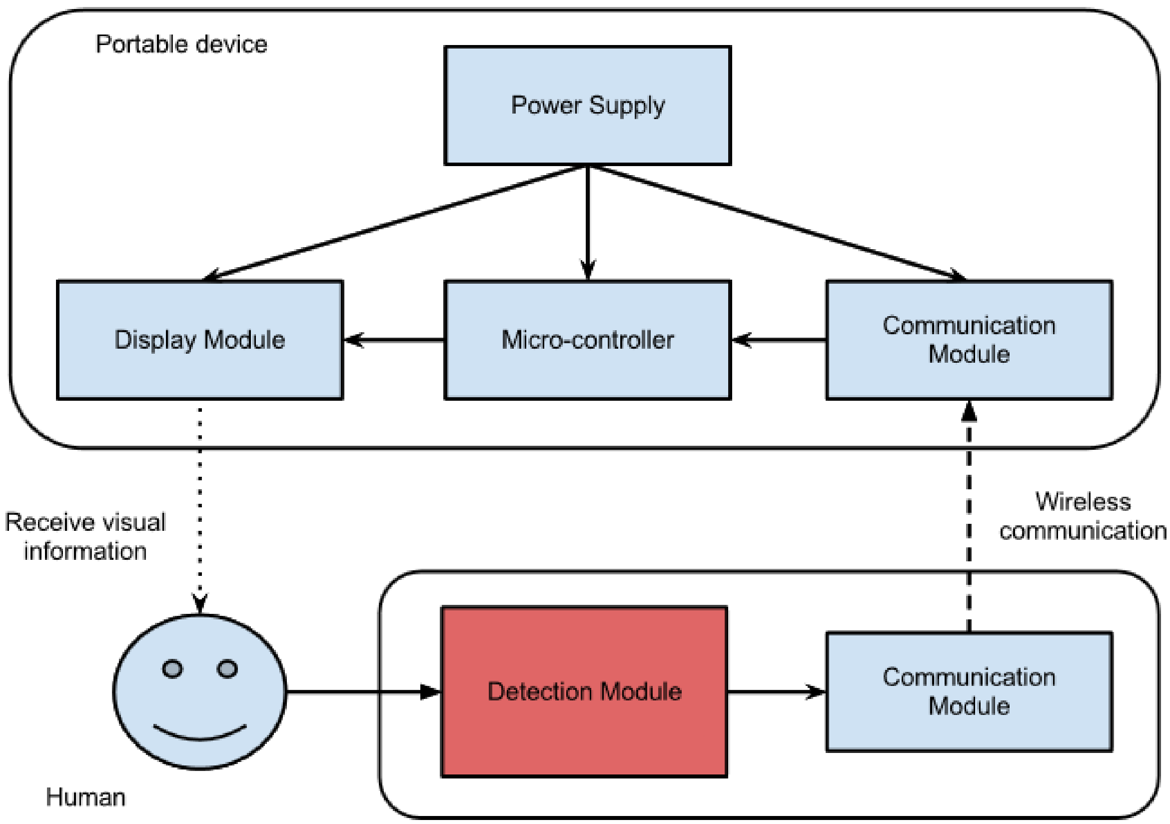

Figure 1. Overall Block Diagram

2.2 Block Descriptions

Microcontroller:

We use the Arduino Mega 2560 microcontroller board to analyze wireless signals and drive a LCD display with digital I/O pins. It is programmed to react to different commands (selection of different regions on the LCD display) analyzed from input signals from the user's brain, execute the command accordingly or provide the next list of commands for the user to select from by updating the LCD display. The board is powered by the 9V external power supply.

Display module:

A SainSmart 3.2" TFT LCD touch screen is used. It displays multiple regions with varying flashing frequencies. By looking at one of these regions, the brain will generate signal that can be distinguished by the detection module through EEG. In this way, the regions act as menus that can be selected by brain. The TFT display has integrated power and a 40 pins interface and SD card reader design. It is relatively convenient to program and provides vivid graphics, which serve as the primary reason for choosing this device.

Communication module:

The communication interface realizes wireless transmission of signal data from detection module to micro-controller. This allows synchronization between the generation of EEG signals along the scalp and the computation of microcontroller in order to update displays as well as next set of displays based on user's intention. The chip we are using is XBee 802.15.4 Modules, operating on 2.4 GHz with a data rate of 250 Kbps. It provides a wireless personal area networks designed for low-power, cost-efficient, and low duty cycle applications. It is supplied by 3V battery and the receiver end is connected to the microcontroller using UART.

Detection module:

The detecting and analyzing modules capture the EEG signals from user by recording brain's spontaneous electrical activity over a short period of time with EEG sensors attached along the scalp. The signals detected are then amplified so that they can be wirelessly transmitted to microcontroller and applied to the algorithms of classification and computation. This module is provided by James Norton and his group.

2.3 Performance Requirements

1. Present at least two regions on screen blinks at brain-distinguishable frequencies without visual interference among different regions
2. Sufficient amplification on raw signals in order to differentiate blinks/commands
3. Instantaneous (< 0.5 second) response on a single selection from brain to display
4. Wireless module supports sufficient communication distance (~ 1500 meters)
5. Accurate and fast transmission of data and information
6. Considerable battery life time (> 4 hrs of operation)

3.0 Verification

3.1 Testing Procedures

Microcontroller:

The requirement of controller is that it can process the received signals accurately and instantaneously. In order to realize its accuracy, we have to make sure that the software system has correct logistics and fluent control flow. The microcontroller is only attached with the LCD display. By using the touch panel as the input method, the LCD screen along with its updated displays as output, we are able to test whether or not the structure of the software system as well as the control logistics are functioning correctly as expectation. The next step is to test whether the received signals can be processed and transformed into control commands correctly. We can do so by simulating some control signals (without the use of EEG machines) into the microcontroller to see if it will have the corresponding reactions.

Display Module:

The testing of the basic functions of display module, such as displaying correct content from microcontroller and updating new content after user inputs, has already been clarified in the testing procedure of microcontroller. The focus here is to test if the display module can correctly interact with human user. To achieve that, detection module should be used as well. First we will measure the frequency range of blinking in which human brain can generate EEG signal that can be detected. A list of frequencies from small to large will be hardcoded to the display module. Once we get the range, we will increase the number of regions that the screen is divided into, starting from 2. Each region will blink at different frequency. At each case, user will stare at all regions to make sure all regions can generate detectable signal in human brain. For example, if the LCD screen is divided into 4 regions, each region with different frequencies. To test if this configuration is valid, user will have to first stare at region 1. If detection machine detects EEG signal, then user changes to stare at region 2, and so on. If detection fails at any point, that means 4 region configuration is not practical and we will stop testing. This can give us the maximum partition a screen can have. This value along with the frequency range, is a reference of how embedded system should be designed.

Communication Module:

To test the effective connectivity of the network, we will put the transmitter and receiver far away enough from one another. The transmitter end is connected to a computer which sends test signals that mimics the actual signal from the EEG detection module. This signal intends to select a specific region on the LCD screen. The receiver end, along with the Arduino microcontroller board and LCD display, is placed around 1500 meters away. We will examine the received signal from the Arduino output ports and check if certain region on the screen is successfully selected as intended.

Power supply:

Connect 9V power to the microcontroller and the TFT display with constantly flashing regions. We can estimate the operating battery life by recording how long the device could last up to. And make sure that the screen does not dim out until 4 or more hours later.

3.2 Tolerance Analysis

The most critical part in our design is the interaction between the brain and the display. The response time from brain signals to the display should be as fast as 0.5 second. However, due to bad connectivity or signal interference, this response time might be longer than expected. We decide to set the tolerance level to 2 seconds.

Our design should function correctly in various environment. When testing indoors, it is supposed to pass the test all time of the day, that is, no matter what the lighting condition in the room is, it shouldn't affect the interaction between display and the brain. When testing outdoors, it should pass the test in most of the weather except sunny days, since sunlight can be so bright that it will affect the display.

Human factor is another aspect to consider about. The user may use the device without paying full attention, such as staring at the display while listening to music. Limited by the current EEG technology, the tolerance standard for human condition should be a well functioning interaction when user is paying full attention. This means, no subconscious detection is required. As long as interaction works when user stares at the stimulation, the tolerance requirement is met.

The wireless communication is another important part since it enables portability. The communication should be stable and fast. The RF signal strength will be tested at a distance of 1000m and a tolerance level will be set on signal strength, within which the wireless connection is reliable and fast.

Since we are building a portable device, the power supply has its lifespan. The battery should last for more than 4 hours. Later we will perform tests to get an average battery lifetime on a continuously flashing screen. For now, our tolerance level is set to be 70%-80% of the average lifetime. This percentage can change depending on the standard deviation of the lifetime data to be collected.

4.0 Cost and Schedule

4.1 Cost Analysis

4.1.1 Labor

Name	Hourly Rate	Total Hours	Total = Hourly Rate x 2.5 x Total Hours
Yujie Chen	$40.00	120	$12,000
Shiyang Liu	$40.00	120	$12,000
Xuanyu Zhong	$40.00	120	$12,000
Total			$36,000

4.1.2 Parts

Item	Quantity	Cost($)
Arduino Mega 2560	1	45.69
SainSmart 3.2'' TFT LCD display and touch panel	1	17.99
XBee 802.15.4 module	1	39
9V power adaptor	1	5.99
9V battery	4	9.45
3V battery	2	2
Total		120.12

4.1.3 Grand Total

Section	Total
Labor	$36,000
Parts	$120.12
Total	**$36120.12**

4.2 Schedule

Week	Task	Responsibility
2/4	Design overall block diagram	Yujie Chen
	Finalize and hand in proposal	Shiyang Liu Xuanyu Zhong
2/11	Order Arduino Mega 2560 and TFT display	Yujie Chen
	Prepare for Design Review	Xuanyu Zhong
	Install Arduino development kit and look into datasheet	Shiyang Liu
2/18	Design connection interface between the microcontroller board and display	Yujie Chen Shiyang Liu
	Learn to program the displays	Xuanyu Zhong
2/25	Assemble microcontroller and display unit for test Learn to program touch panel on the screen	Yujie Chen
	Write simple test program for controller and display	Xuanyu Zhong
	Design specific control flow for software system	Shiyang Liu
3/4	Order parts for wireless module	Xuanyu Zhong
	Integrate and embed software system into microcontroller	Shiyang Liu
	Test over the software system using touch screen	Yujie Chen
3/11	Go to James Norton's lab and learn more about the detection device and design wireless interface to realize wireless data transmission between the detection module and control module	All
3/18	Test over TFT display and signal detection module	Yujie Chen
	Test wireless communication module alone	Shiyang Liu
	Design and integrate communication software module into software system of controller	Xuanyu Zhong
3/25	Assemble control and display modules with communication module	Yujie Chen Shiyang Liu
	Test/Debug over the assembled modules	Xuanyu Zhong
4/1	Connect detection module with other modules of the portable device	Yujie Chen Xuanyu Zhong
	Test/Debug over the assembled modules	Shiyang Liu
4/8	Do overall testing and debugging	All
4/15	Do overall testing and debugging Prepare for demo	Yujie Chen
	Improve performance of software system and control flow on microcontroller	Shiyang Liu
	Improve performance of wireless communication interface	Xuanyu Zhong
4/22	Demo	All
	Prepare for presentation	All
4/29	Presentation	All
	Finalize final paper	Shiyang Liu Xuanyu Zhong
	Check in Supplies	Yujie Chen