CONTROLLING ELECTRICAL APPLIANCE BY THINKING IN MIND

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ABSTRACT: *Brain-Computer Interface (BCI) technologies open up a world of possibilities. They use signals recorded from the brain (e.g., EEG: Electroencephalography) to apply miscellaneous controls and communications without using any external devices or muscle intervention. Their applications include but not limited to: (i) Brain to device control, (ii) Device to brain control, (iii) Brain to Internet communications with an infinite amount of information storage and retrieval, (iv) Mind to mind communication, (v) Memories and feelings transformation, and (vi) Brain to brain control. However, BCI technologies are still in its emerging stages. This paper demonstrates a brain to device control application for controlling electrical appliances by deeming mind thinking a signal of the EEG.*

Keywords: Appliance, Arduino, Brain-Computer Interface, EEG, Light Bulb, Neurons.

1. INTRODUCTION

The human brain is a multiprocessing system consisting of billions of neurons. It receives information from our peripherals, processes it and controls our actions accordingly. It has the capability of multiprocessing and learning. Thus people are always interested to know more about it since time immemorial. Neuroscience, artificial intelligence, and cognitive science are developed to understand its functionalities in various depths. Nowadays, BCI technologies are used to record and display of brain activities. BCI allows the user to control various programs e.g., video games [1], computational software [2], web browsers [3], silent speech communication [4], thought translation devices [5], and spelling applications [6]. The new researches on BCI technologies are opening a world of possibilities. The study of BCI requires knowledge of biology, computer science, engineering, image and signal processing, physics, psychology, neuroscience, and medical science. A typical BCI system includes a signal acquisition system, signal processing techniques, and an output device. Signal acquisition can be performed in three ways: invasive, non-invasive, and semi-invasive. Invasive techniques involve signal acquisition via penetrating microelectrodes in the area where neurons exist in the brain to record brain signals of higher quality and greater strength than in non-invasive approaches [7]. For example, Electrocorticography (ECoG) or iEEG)intracranial Electroencephalography uses electrodes that are implanted at the outer layer of neural tissue. In semi-invasive approaches, electrodes are placed beneath the scalp but not in the gray matter. Non-invasive techniques involve placing electrodes on the scalp without harming the brain tissue. Miscellaneous non-invasive techniques have been adopted to acquire brain waves e.g.,EEG Magnetoencephalography (MEG), Magnetic Resonance Imaging (MRI), and functional MRI (fMRI). Normally, MEG provides good spatiotemporal resolution and it is not severely affected by muscle artifacts. The fMRI identifies the changes in the oxygen flow of the blood or blood oxygen level-dependent [8]. The SPECT (single-photon emission computed tomography) is a nuclear medicine technique that uses gamma rays to study the brain. The Positron Emission Tomography (PET) is another non-invasive approach. It measures the functionality of the brain by injecting a nuclear substance-emitting positron. It records the chemical changes occurring in the brain before the symptoms of the disease are visible. The fNIRS (functional Near Infrared Spectroscopy) [9] uses light from the near-infraredregion of the electro-magnetic spectrum to study the oxygenation and deoxygenation of hemoglobin in the brain. Non-invasive techniques are widely utilized in research activities, as these techniques are not prone to any damage to the human brain tissues. In this paper, the Arduino UNO microcontroller is used to manipulate the EEG brain waves captured by the brain sensor. The obtained brain waves are signal strength, attention, meditation, delta, theta, low alpha, high alpha, low beta, high beta, low gamma, and high gamma. The attention signal of the brain sensor is thresholded to control various electrical appliances. If the attention signal goes enough to cross a defined threshold limit, then it sends a signal to the relay to turn-on or turn-off the appliance. The rest of this paper includes EEG, hardware components with coding, main experimental results, and conclusion.

2. ELECTROENCEPHALOGRAPHY

The neuron is the key working unit of the brain. Neurons are cells within the nervous system that transmit information to other nerve cells, muscle, or gland cells. Usually, a neuron has a cell body, an axon, and dendrites (e.g., Fig. 1 (a)). There are a few billion neurons in the brain communicating with each other using the electrochemical signal. Neurons consume a lot of oxygen and glucose. Neurons send messages electrochemically. Chemical key ions are sodium (Na^+), potassium (K^+), calcium (Ca^+), and chloride (Cl^-). If a neuron does not send a signal, it is at rest state. If a neuron gets a chemical message at one of its dendrites, it may transfer the signal through its axon to another neuron. The electrochemical signal traveling along an axon is called action potential. There are many negatively charged ions exist inside the axoplasm (intracellular. fluid). Those ions cannot be moved out. Inside of neurons is slightly negative (e.g., about -70 mV). So any positive ion would try to move across the membrane and into the cell due to Coulomb's law. There are many channels on the cell membrane. The cell membrane allows some chemicals to pass through, while others are prevented from entering or leaving the cell. For example, K^+ can move freely. Thus K^+ concentration builds up inside the cell. The electrical gradient is experienced if there is a force on K+ to move into the cell because of the electrostatic attraction by negative charges. The chemical gradient is experienced if there is a force on K^+ to move out of the cell due to the difference in concentration across the cell membrane. If both forces are equal, an electrochemical equilibrium is reached. Similarly, there is a force on Na^+ to move into the cell. But the cell membrane is not very permeable for Na+. Hence Na+ ions remain outside the cell in a state that is far from their normal equilibrium. Under resting conditions, there are many Ka^+ ions inside the cell as compared to the outside. They are close to the equilibrium state. There are many Na^+ ions outside the cell than inside, and there is a net force on them to go inside the cell. If a stimulus (e.g., heat, light, mechanical pressure, etc.) opens Na^+ channels, then Na^+ ions enter and membrane depolarizes (becomes more positive). If the stimulus opens Na^+ channels, then K^+ ions exit across the membrane and the membrane becomes more negative (hyperpolarized). The ongoing changes (e.g., Fig. 1 (b)) in these signals, which are measured using scalp electrodes, are recorded as continuous changes in voltages over time, called the EEG (e.g., Fig. 1 (c)). Applications of EEG include: medical (e.g., epileptic seizure), education (e.g., concentration level of study), research (e.g., cognitive science), entertainment (e.g., video games - improving mood and decreasing stress), smart home (e.g., intention recognition) [10], and person identification (e.g., intention recognition).

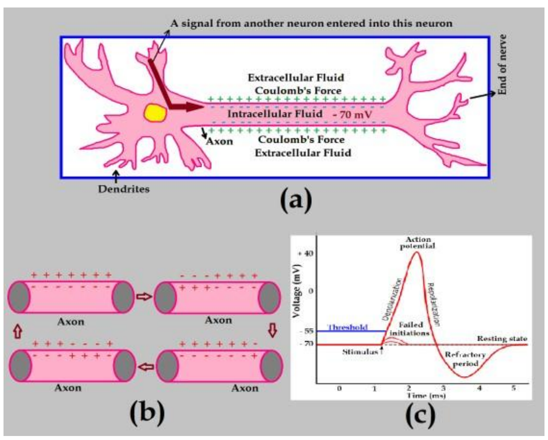

Figure 1. (a) A neuron and its activities, (b) Periodic exchange of ions, (c) EEG brain wave.

Our brain waves change according to what we are doing and feeling. For example, brain waves of lower frequencies are dominant if we feel tired, slow, sluggish, or dreamy; whereas higher frequencies are dominant if we feel wired or hyper-alert. Five simple periodic rhythms (alpha, beta, delta, theta, and Gamma) with frequencies (in Hertz) and amplitudes (in microvolts) are recorded in the EEG. Alpha waves are dominant during quietly flowing thoughts. Beta brainwaves dominate our normal waking state of consciousness. Delta brainwaves are generated in the deepest meditation and dreamless sleep. Theta brainwaves occur in sleep. Gamma brainwaves are related to the simultaneous processing of information from various brain areas. Brainwaves are detected using brain sensors placed on the scalp. Popular brain sensors include Mindwave Mobile from Neurosky, Brain sensing headband from Muse, and EPOC+ 14 Channel Mobile EEG from EMOTIV.

3. HARDWARE AND CODING

Hardware components include a brain sensor, Bluetooth module, Arduino UNO micro-controller, SPDT relay, jumper wires, electrical cable, power supply, and an electrical appliance (e.g., light bulb, electric oven, refrigerator, air conditioner, etc.). A relay is an electrical switch that controls (switch on and off) a high voltage circuit using a low voltage source.

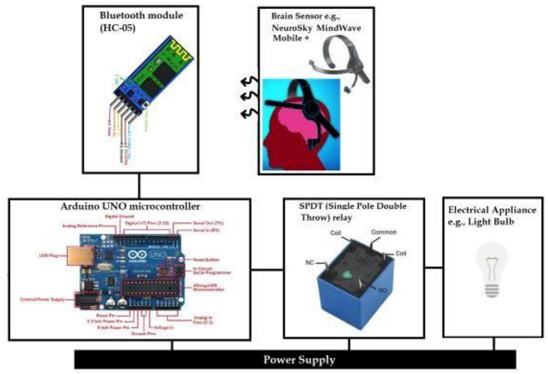

Figure 2. Block diagram of our proposed approach to control electrical appliances just by thinking in mind.

Fig. 2 shows a general circuit diagram of our approach. Our brain. always emits brain waves. These brain waves can be captured by a brain sensor. If we think special thing one of the emitted brain waves is predominated over others. The Arduino UNO micro-controller manipulates the brain waves captured by the brain sensor.

```
#include<Brain.h> // Include Arduino brain library
const int AppliancePin = 10, deval = 50, Threshold = 70; // Define
constants.
Brain brain(Serial); // Setup brain parser to hardware serial object.
int OurAttention = 0; // Set brain attention value to zero.
int ApplianceState = 0; // Initialize appliance state.
void setup(){ // Activate pins and hardware serial.
pinMode(AppliancePin,Output); // Set input and Output pin mode.
Serial.begin(9600);} // 9600 bits per second be the default value of Arduino.
void loop(){ // Expect packets about once per second.
if(brain.update()) // Update brain data.
{Serial.printIn(brain.readErrors()); // If there is no error then print most
recent brain
Serial.printIn(brain.readCSV()); // data to the serial port as human-
readable ASCII text.
if(brain.readAttention()>Threshold){ // Get attention value and use
threshold on it.
if(ApplianceState == LOW) // If the appliance is switched off,
{digitWrite(AppliPin, HIGH); // then turn it on now.
ApplianceState = 1; // Appliance is switched on now.
delay(deval); } // Pauses program in miliseconds as specified in deval.
else
{digitWrite(AppliPin, LOW); // Switch off the appliance.
ApplianceState = 0; // Appliance is switched off now.
delay(deval); }} // Pauses program in miliseconds as specified in deval.
    delay(deval); }} // Pauses program in miliseconds as specified in deval.
```

Listing 1. Coding to control electrical appliances (e.g., a light bulb) by thinking in mind.

The obtained brain waves of the Arduino Brain Library are signal strength, attention, meditation, delta, theta, low alpha, high alpha, low beta, high beta, low gamma, and high gamma. The function *Serial.println (brain.readCSV())* of Arduino Brain Library returns a string (well, char*) listing the most recent brain data with an order of signal strength, attention, meditation, delta, theta, low alpha, high alpha, low beta, high beta, low gamma, high gamma. However, the attention signal of the brain sensor is used to control an electrical appliance. If this signal rises enough to cross a fixed threshold value, it sends a signal to the relay to turn the appliance either on or off. Listing 1 illustrates the coding of how to control electrical appliances by thinking in mind using hardware components as shown in Fig. 2.

4. EXPERIMENTAL RESULTS

The attention values of EEG vary on how a person thinks in his/her mind. Figure 3 demonstrates the sample output of the algorithm in Listing 1 having an application of mind-controlled light bulb. The threshold value of attention can be changed. For an instant, the attention threshold value of a person's mind is given 70. The electrical light bulb turned on when the obtained attention value of the brain went above the given threshold value 70. The bulb turned off when the obtained attention value of the brain went below 70.

Figure 3. Sample output: Light bulb switched-on if attention value exceeded 70, else remained switched-off.

Consequently, a person can control electrical appliances (e.g., light bulb, air conditioners, dishwashers, clothes dryers, drying cabinets, freezers, refrigerators, kitchen stoves, water heaters, washing machines, trash compactors, microwave ovens, and induction cookers) just by thinking in his/her mind. Smart home and city applications expect to control all kinds of electrical appliances. Besides a long list of medical applications, our current method possesses very high potential to be used in smart home and city applications in the long run. The brain activities are very sophisticated and rapidly varying. The EEG signal can capture some information through the discrete sampling of electrochemical signals. Consequently, only the EEG signal is less informative for an accurate outcome of an application. In the future, a combination of EEG, iEEG, MEG, and FMRI signals would be used to enhance the accuracy [11] of mind-controlling electrical appliances. Our proposed approach may efficiently control electrical appliances e.g., electric ovens, refrigerators, air conditioners, electric space heaters, and whatnot. Nevertheless, it cannot control computers, smartphones, mp3 players, radios, and cameras. As a result, future work would adopt the method for controlling such electronic appliances.

6. CONCLUSION

BCI technologies manage the sending of messages from human brains and decoding their silent thoughts. Using BCI technologies, we proposed an approach to control electrical appliances just by thinking in mind. A light bulb experiment was presented to show the algorithm's effectiveness. A list of electrical appliances can be controlled by our approach. In the future, EEG with other signals can be combined to get better performance.

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