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An Approach Towards Brain Controlled System Using EEG Headband and Eye Blink Pattern

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***Abstract*— Electroencephalography (EEG) is a technique to capture the brainwaves, which are generated due to the activities of the human brain on the scale of micro-electrical voltage. In recent times there is growing demand for wearable EEG technology, which helps people to suppress anxiety and increase concentration. Traditional research-grade EEG recording techniques are bulky and require skillful assistance during experimentation. Such experimental kits are typically big, costly, and handled by people who are trained on how to use them. Since the introduction of wearable EEG technology, one can record the similar activity by means of easy-to-use, inexpensive and much smaller wearable devices. Although, benefits and research opportunities in wearable EEG technology are yet to be fully discovered. It's helping society to monitor health and fitness with ease, where one can see and interact with the body in innovative and exciting ways. Still, a lot of people are unaware of wearable EEG technology benefits and usage. Here, we discuss an approach to a brain-controlled system using wearable EEG technology devices available in the market. This approach can be implemented to control various systems such as wheelchair, robots, home appliances, etc. with the help of brainwaves which are generated on eye blink.**

***Index Terms*—Electroencephalography, Wearable EEG technology, Brainwaves**

I. INTRODUCTION

There has been a little development happened for brain-controlled systems even though there is a relatively fast technological improvement in systems for physically challenged people. In recent times there has been an emergence of systems having computer-controlled movements such as “WALKY”, “KD smart chair” and “Tin Man”. For physically challenged people there are a number of different systems controlling modes which are existing such as eye movement, hand-gesture, tongue movement, voice control, joystick, etc. [1]. These systems are arranged in such a way that upon interacting it can control computer operations or movement of the robot or direction of the wheelchair. The most preferred method for controlling movement and direction of such systems is BCI technique, due to its high efficiency, reliability and response time.

Since the introduction of dry EEG Electrodes, there has been a growth of low-cost EEG recording systems. While most of the systems on the market offer SDK allowing researchers to access the raw data for research purposes. A portable EEG system such as the Neurosky Mindwave headband and computer system with Bluetooth connectivity, one can conduct Event-Related Potential (ERP) research with simplicity giving an opportunity for extending the use of the wearable EEG devices for ERP in a variety of novel contexts [2].

II. EEG SIGNALS

The human brain is predominantly composed of a primary cell type called neurons and the brain has millions of such neurons. Neurons interconnect with each other through their cable-like structure known as axons to form a dense communication network of neurons. For every human activity performed a biofeedback signal are generated as microscopic electrical signals. These signals are propagated from a single neuron to other neurons to control and decide further activities.

Electrical activities happening due to interactions between millions of neurons is aggregated and can be measured in Electroencephalography experimentation [3]. EEG is a technique of capturing micro-voltage fluctuations generated at scalp due to an interaction of enormous numbers of neurons in the brain [4]. The brain activities captured using EEG can be very exhaustive and complex. It also depends on the part of the brain under consideration. Few of the most common scenarios where brainwaves are observed and categorized in different bands as highlighted in Table I.

TABLE I. EEG SIGNAL BANDS

Band of waves	Observed in situations
Delta	The sleep of Newborns, less observed in adults. Dreamless deep sleep.
Theta	Dreams in sleep, meditation, and self-hypnosis.
Alpha	Watching TV, daydreaming and relaxed.
Beta	Fully awake person. Doing some activities and having conversation.
Gamma	In the highly alert mental state.

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III. SYSTEM DESIGN AND COMPONENTS

In this section overview of system design is discussed to implement brainwave controlled systems using wearable EEG headband and Arduino UNO with the help of computer/mobile system having a Bluetooth connection to communicate with both. Fig. 1 shows the system design and flow followed by main components description.

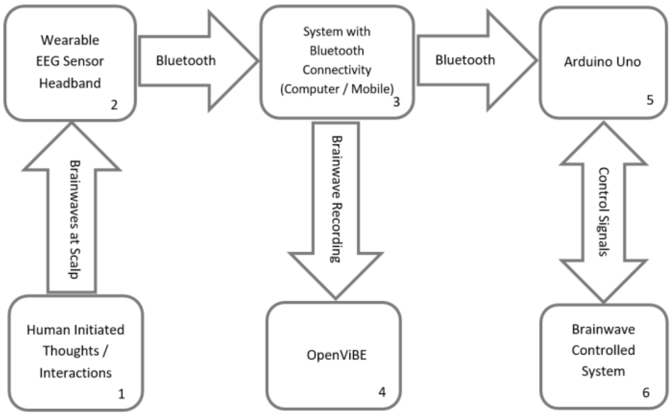

Fig. 1. *Overview of system design*

A. Wearable EEG Sensor Headband

Choice of the headset will be subject to what a researcher intends to use it for. The solution will depend on various factors such as budget, interest, project idea and the number of electrodes required. Here, for system design EEG Headband from NeuroSky Inc. is used. NeuroSky is one of the well-known manufacturers of Brain-Computer Interface (BCI) equipment for consumer product and applications. NeuroSky Mindwave shown in Fig. 2 is an EEG headband technology, which is low cost and having an inexpensive dry sensor. The headband also incorporates built-in electrical noise reduction software/hardware, and use the embedded technique for signal measurement and output.

Fig. 2. *Wearable EEG Sensor headband – Neurosky Mindwave*

Such wearable EEG devices have advantages over older EEG hardware setups as there is no need of applying of a conductive gel for the number of electrodes and in contact scalp. Here, Mindwave Mobile Headset is used to capture EEG Signals. [5]

The Mindwave Mobile is capable of detecting attention and meditation levels also it is able to detect eye blinks. Eye blink detection is accomplished by using Electrooculography or EOG. EOG measures the electrical potential between electrodes placed at points near the eye or in the ocular region. Blink detection with EOG follows the concept that whenever a person blinks, a resulting spike in the EOG data will happen. Fig. 3 shows such the resulting spike in the EOG data when a blink occurs. [6]

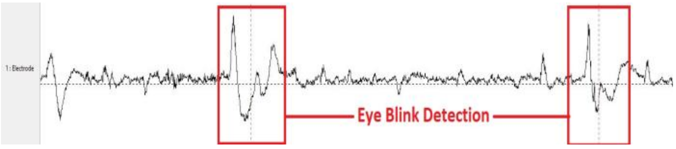

Fig. 3. *Eye blink detection*

For this project, blink detection can be achieved using the eye blink listener in Neurosky's Android SDK. It outputs the blink strength value of the blink event whose value ranges within 0-255. Blinking harder or with more force will output a larger value while blinking with less force will output a smaller value. It is for this same reason that people with blink disorders are not advised to use this approach. Using multiple tests to determine the average threshold value of forced blinks and normal blinks, an algorithm was found to distinguish between the two.

B. OpenViBE Software Platform

OpenViBE is a community-driven program which is free and available as open-source to construct, experiment and simulate BCI scenarios [7]. Broadly, it has two components:

1) *Acquisition Server* - This server is responsible for acquiring EEG data from external devices such as wearable EEG Headband.

2) *OpenViBE Designer* - Provides GUI to construct the anticipated BCI scenarios from preconfigured processing modules.

OpenViBE server grabs EEG signal from connected EEG peripheral and then it sends this data to one or more acquisition clients. In many of the BCI experimentations, OpenViBE designer acts as a client. Here, OpenViBE is used for visualization and to record EEG data.

C. Arduino Uno

Arduino is a very well-known and popular open source company that designs and produces microcontrollers based single-board computer system. Also, it deals with various development projects based on microcontroller and has very large user community. Arduino is mostly popular for building digital systems and interactive stuff that can control items in the day to day world.

D. Brainwave Controlled System

A system which can be controlled depending on the response of brainwaves. EEG signals which are acquired through wearable EEG headband are processed by computer/mobile and sent to processing unit such as Arduino UNO to produce control signals for these systems. Such systems include applications for controlling wheelchair, robots, home appliances, etc. [8]

IV. Brain Controlled System Model Implementation

Following are the hardware components and their key features which are the main building block for application of brain-controlled system model. Fig. 4 gives the block diagram of an implemented system.

1) Arduino UNO - It is ATmega328 microcontroller based board having a power jack which can be powered through AC to DC adaptor or 9V battery. A USB connection to program the microcontroller. It has six analog inputs and fourteen digital input/output pins, and a button to reset board.

2) Motor Driver L298N – It is based Dual H-Bridge Motor Driver IC L298 which allows for easy control and can control independently two motors in both directions. This module is mostly suitable for robot based designs.

3) Bluetooth Module HC-05 – It is an easy to setup Bluetooth module, implemented for wireless communication over Bluetooth. This Bluetooth Module can be used in a Master or Slave configuration, making it a great solution for wireless communication. Here, HC-05 is used in SLAVE mode only to accept control signals and forward those to Arduino.

4) DC Motors - A DC motor is a rotary electrical device which operates on DC power source and generates rotating mechanical movement. Most common types of DC motors consist of magnets which are placed in specific positions to generate a magnetic field. Depending on polarity, a change in the rotation direction can be achieved.

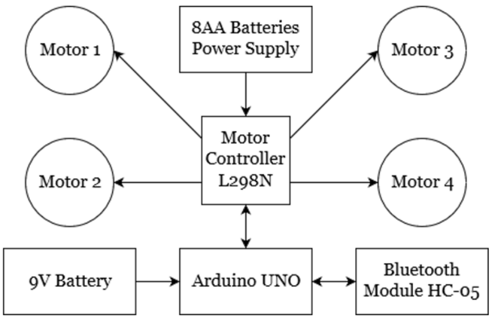

Fig. 4. *block diagram of implemented system model*

B. Circuit Connection and Hardware setup

Fig. 5 shows the detailed circuit connection design and the implemented hardware setup for the same design of circuit is as illustrated in Fig. 6

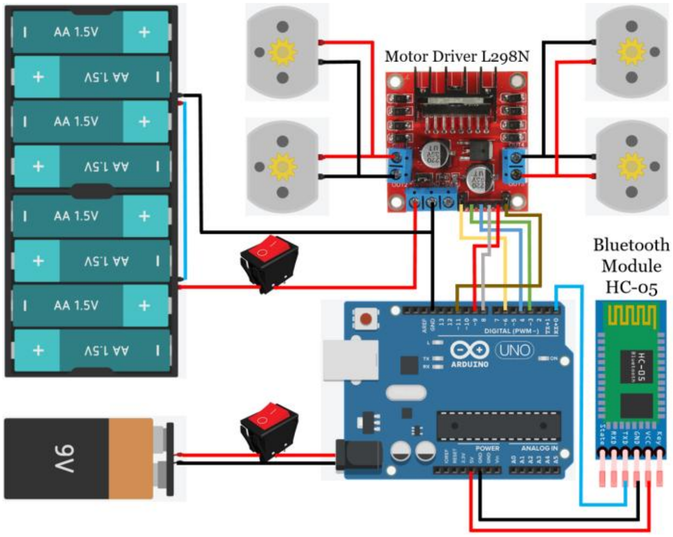

Fig. 5. *Circuit Connection diagram for implemented system model*

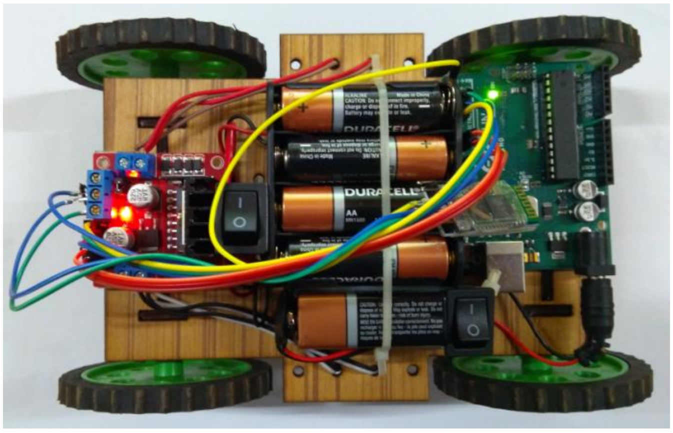

Fig. 6. *Hardware Setup for implemented system model*

To hold all hardware modules in place and to set up the circuit connection properly a toy car chassis was used. Jumper wires and soldering was done wherever required to ensure proper connection. 8AA batteries used to power four DC motors and a 9V battery is used to power Arduino board.

C. System Control Flowchart

An Android application can be developed using Neurosky's SDK which provides algorithms for getting values of Attention, Meditation and Blink Strengths from Neurosky Mindwave EEG Headband. The Android application can have two buttons - one to connect the app to the HC-05 Bluetooth module and the other to connect the app to the Mindwave Mobile. On startup, the connect button for the Mindwave Mobile would be disabled, it will only be enabled once a connection with the HC-05 Bluetooth module is established. After both the Mindwave Mobile and the Arduino's Bluetooth module establish a connection with the Android application, the Android application begins fetching the signal quality value.

The signal quality will be not detected when the user is not wearing the Mindwave Mobile, poor if almost no contact is made by the forehead skin with the dry sensor, medium if partial contact with the dry sensor, and good if the dry sensor makes firm contact with the forehead.

As an added safety precaution, when the signal quality value is not good, a stop command can be sent to system model preventing any unwanted motion. Once the signal quality value turns into good, the Android application begins listening for any incoming force blink data from the Mindwave Mobile.

Fig. 7 illustrates the overall flow of the Android application to control and operate implemented system model. A sequential operation loop having four different modes, each representing a state of the system model. These modes are:

1) Standby – In this state, normal blinks or blinks whose blink strength values are below the threshold value of 90 are discarded. When a force blink or a blink whose blink strength value is above the threshold value of 90 is detected control shifts into command mode. This threshold value can vary person to person and needs to be set during application build.

2) Command - The Android application begins cycling direction values – forward, reverse, left, and right for 10 seconds with a 2-second interval in between changing the direction value. This 10-second direction-cycle window is known as command mode.

During command mode, the Android application listens for two consecutive blinks, otherwise known as a double blink event, from the user. When it detects a double blink event, the cycling of directions stops and whatever direction is shown in the cycle at the moment of the double blink event will become the chosen direction. For blinks to be considered consecutive, the time elapsed between two blink events must be less than or equal to 400 milliseconds.

3) Focus - When a direction has been chosen, the Android applications shifts to focus mode where it starts listening to any incoming attention data from the Mindwave Mobile. Attention values are outputted by the Mindwave Mobile once every 1 second and once it goes to 50 or more, the Android application switches to running mode. This threshold value can be set in a program as per user and application build will contain whichever value is set.

4) Running – In running mode it sends a command to the Arduino based on the direction chosen earlier. Each direction has a respective Bluetooth command that will be transmitted to and interpreted by the Arduino residing on the system model.

Similar to command mode, the user exits running mode by blinking consecutively to go back to standby mode. From then on, the whole operation loop is should get repeated whenever the user wants to operate the system model once again.

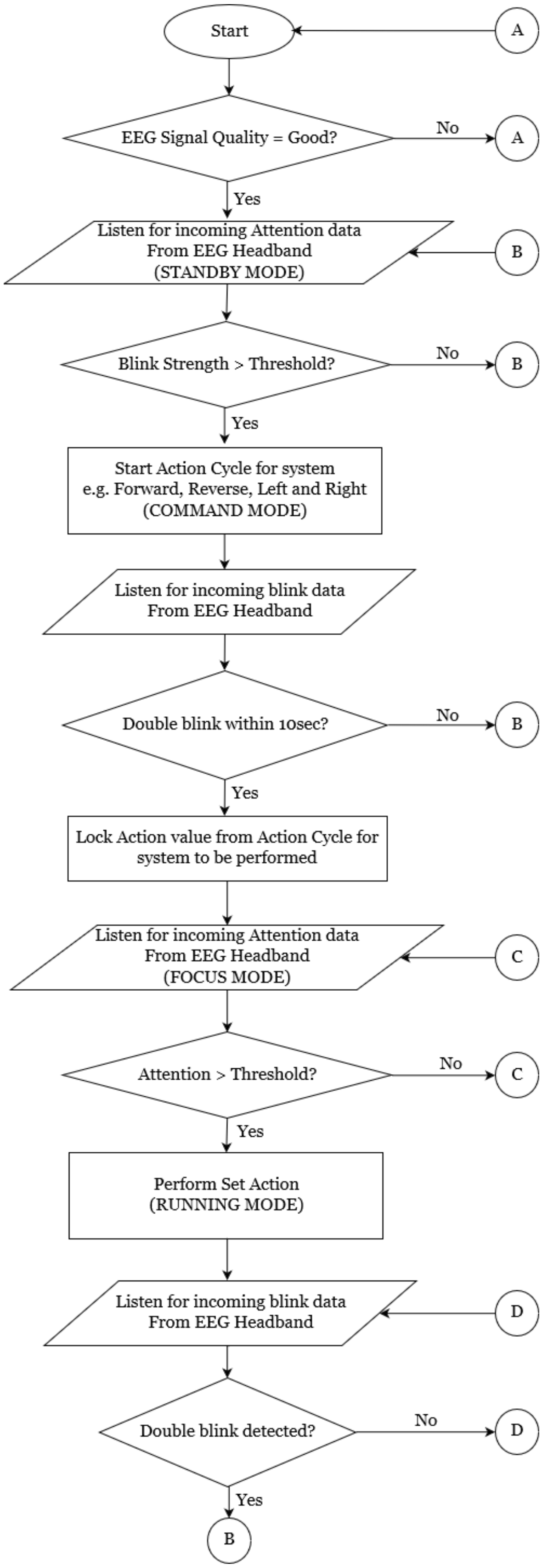

Fig. 7. *System Control Flowchart*

V. CONCLUSION

Using this approach, a system can be controlled using most of the wearable EEG headbands available in the market. As demonstrated here using a system model prototype, this approach can be implemented for robots, wheelchairs, etc. With the help of brainwaves, such systems can give an opportunity to physically disabled person who is incapable to use a system as a normal person does.

This approach can hold promise for the future of EEG and brainwave related products. Brainwave technology will undoubtedly get better over time and we are very confident that the day will come when they can be effectively integrated into everyday products.

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