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Eye Blink Pattern Controlled System Using Wearable EEG Headband

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***Abstract*— Electroencephalography (EEG) is a scientific way to detect the brainwaves, these signals are generated by means of the interactions of the human brain. These signals are at the minuscule level of micro-electrical voltage. In recent years there is increasing trend for wearable EEG technology. These devices can actively help individuals to conquer anxiety and rise concentration levels. Biofeedback is the method of having better cognizance about how the human body functions by controlling mind conditions. By undertaking so, a human can acquire the technique of how to control the body and brain at will. A few decades old research-grade EEG acquisition techniques are much bulkier and impose skilled support during the research. Such experimental tools are big, overpriced, and operated by people who are aware of how to use it. In recent years due to the thrust of wearable EEG technology, anyone can perform the similar activities by means of easy to wear, low-priced and easy to use wearable devices. Even though, outcomes and research scenarios in the wearable EEG field are not yet fully explored. Here, we introduce a methodology for eye blink pattern-controlled system with the help of wearable EEG devices offered in the consumer market. This method can be applied to control many systems as like as home appliances, robots, wheelchair, etc. with the help of EEG signals captured at the scalp for proposed eyeblink pattern-controlled system.**

Keywords— Brainwaves, Electroencephalography, Wearable EEG technology

I. Introduction

There has been very limited work done so far for brain-controlled systems. Although comparatively there is a much technological advancement in assistive peripherals for physically defied people. There has been an advent of systems incorporating computer-controlled activities. By taking into consideration physically challenged persons, there are various modes available for controlling a system like a joystick, hand-gesture, tongue movement, voice control, jaw movement, eye movement, etc. [1]. These control movements are captured so that upon interaction with the system, it can send a command to the computer or can move a robot or can manage the direction of the wheelchair. In most of the cases for capturing these movements and performing the related task is done by a Brain Computer Interface (BCI) technique [2]. This technique is well known and used in many applications due to its real-time complex task manipulation with high efficiency and reliability.

Because of the introduction to dry EEG Electrodes, many companies have been in development of low-cost EEG detection systems. Most of the companies in the market offer Software Development Kit for investigators to access the raw EEG data for investigation purposes. With the help of a portable EEG system like Neurosky Mindwave headband and Bluetooth enabled computer system, investigators can conduct Event-Related Potential (ERP) research with ease and has a chance for out spreading the use of the wearable EEG devices for ERP in a variety of novel contexts [3].

II. EEG Signals

The human brain is mostly composed of a key biological cell type called neurons and a human brain is usually consists of millions of such neurons. Neurons interlock in one another by their cable-like structure, also known as axons to form a complex communication network of neurons. Whenever some human activity performed biofeedback signals are generated at the microscopic level of electrical signals. These signals are spread from one neuron to other connected neurons to decide and control further activities.

Microscopic electrical activities happening because of communications amongst millions of neurons is gathered together and can be observed in EEG experimentation [4]. EEG is a practice of taking micro-voltage variations generated at scalp due to a communication of huge numbers of neurons in the brain [5]. The brain activities observed using EEG are in general in-depth and complex. Also, it depends upon the portion of the brain under consideration.

For an eyeblink, a spike is observed in EEG signals which can be treated as the control signal to drive the systems. Using proposed methodology, systems which can be designed based on such EEG signal eyeblink pattern are discussed here.

III. System design and Components

In this section system design overview is discussed to implement an eyeblink controlled system by means of wearable EEG headband and Arduino UNO. Here Android mobile having a Bluetooth connectivity act as a mediator to communicate with both of these devices. Fig. 1 shows the overview of system design followed by a key components explanation.

Fig. 1. Overview of system design

A. Wearable Dry EEG Sensor Headband

The choice of the wearable EEG headband will be based on area of investigation defined by a researcher. The choice can be dependent on several aspects such as research budget, how much in-depth details of EEG signals required, ease of use, how many electrodes required and support for application development, etc. Here, we have used EEG Headband manufactured by NeuroSky Inc. for system design. NeuroSky is amongst well-known producers of Brain-Computer Interface (BCI) kit in the consumer market. NeuroSky Mindwave as shown in Fig. 2 is a wearable EEG headband technology featuring an inexpensive dry sensor which makes it inexpensive. The headband comprises integrated electrical noise reducing software/hardware and uses the embedded procedure for signal observation to output.

Fig. 2. Wearable EEG Sensor headband – Neurosky Mindwave

These kinds of wearable EEG devices have got an advantage over old EEG hardware setups due to fact that there is no need of applying conductive gel for multiple number of electrodes getting in contact with the scalp. [6]

The Neurosky Mindwave EEG headband is capable of sensing attention as well as meditation levels. It can detect eye blinks as well. Eye blink detection is done by using Electrooculography (EOG) which measures the electrical potential for electrodes positioned in the ocular region or near the eye. Blink detection with EOG follows the notion that whenever a person blinks, in the EOG data a spike can be observed. Fig. 3 shows a sample spike in the EOG data when a blink occurs. [7]

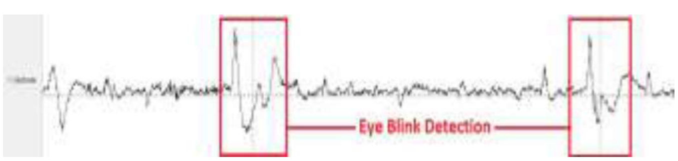

Fig. 3. Eye blink detection

For our intended purpose, eye blink detection is achieved using the eye blink listener module in Neurosky's Android SDK. It gives the eye blink strength value whenever the eye blink occurs. This value ranges in-between 0-255. Harder Blinking or a forceful blink will generate a larger value while a normal eye blink will have a smaller value. As this system is majorly driven by eye blink patterns, people with blink disorders may find this approach difficult and are advised not to practice the same. Initially observing multiple sample test values and taking their average threshold value can determine a forced blink and normal blink of a person. An algorithm then can take action according to the blink patterns observed.

B. Arduino UNO

Arduino, a company which is popularly known for open source designs and manufactures single-board computer system based on microcontroller. It also deals with numerous projects based on microcontroller and has a great user community. Arduino is mainly popular for constructing digital systems and collaborating projects that can control things in the daily life.

C. Eyeblink Controlled System

A system which capable to enact based on the response of observed through EEG signals acquired through wearable EEG headband. These signals are processed by an Android mobile application and sent to the decision-making unit such as Arduino UNO. This unit generates the control signals to operate systems which may include controlling a robot, giving direction to a wheelchair, turning home appliances ON/OFF, etc. [8]

IV. Methodology

In this section, we discuss the methodology for building prototype of an eyeblink-controlled system model in detail which can be considered as a base example for development of a wheelchair, a robot, etc. This system model receives the control signals from Bluetooth enabled Android mobile application depending upon brainwave signals of an eye blink observed by EEG Headband.

A. Hardware Components

Table I enlist the hardware requirements to build an eyeblink controlled system model. Neurosky Mindwave EEG Headband which is key component and other components are basically used for building system model prototype which can be treated as wheelchair, robot, etc.

Fig. 4 shows the block diagram of an assembled hardware system. Fig. 5 demonstrates the detailed circuit diagram for assembly and Fig. 6 shows the complete hardware setup of the same circuit design to accomplish eyeblink controlled system model. As an optional component potentiometer can also be connected with Arduino UNO in order to have better control over the speed of DC motors.

TABLE I. HARDWARE REQUIREMENTS

Component	Count
Neurosky Mindwave EEG Headband	1
Arduino UNO	1
Motor Driver L298N	1
Bluetooth Module HC-05	1
DC Motors	4
ON-OFF Buttons	2
Toy Car Chassis	1
1.5V AA Batteries	8
9V Battery	1
Jumper Wires	30
Snap Connector for 9V battery	1
8AA count Cell Socket	1

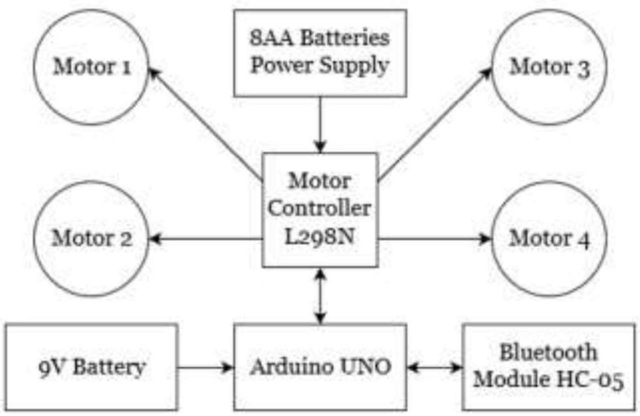

Fig. 4. Block diagram of implemented system model

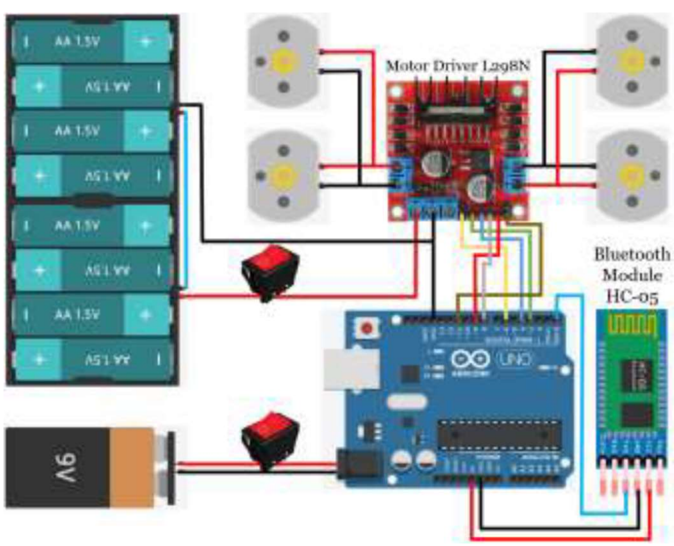

Fig. 5. Circuit Connection diagram for implemented system model

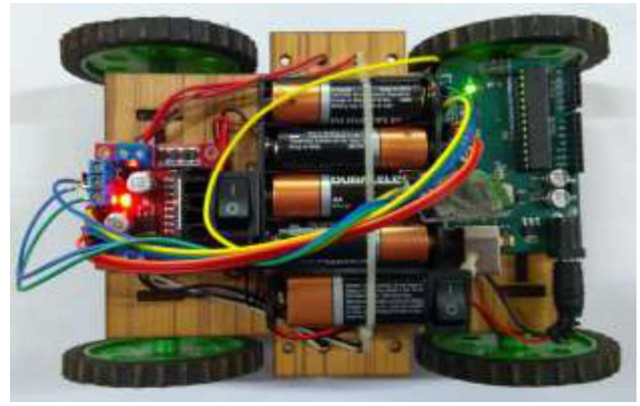

Fig. 6. Hardware Setup for implemented system model

B. Software Components – Android Application

An Android application is created by using Neurosky's SDK for Android development. This SDK provides algorithms for acquiring the values of Attention, Meditation and Blink Strengths from Neurosky Mindwave EEG Headband. The Android application has two buttons - one to connect the app to Bluetooth module the HC-05 which is connected with Arduino UNO and the other to connect the app to the Neurosky Mindwave EEG Headband.

At startup, the connect button for the Neurosky Mindwave EEG Headband is disabled, it can only be enabled once a connection with the HC-05 Bluetooth module is established. Once Neurosky Mindwave EEG Headband and the Arduino's Bluetooth module establish a connection with an installed Android application, then this application starts fetching the signal value. The signal value will be not noticed if the user is not wearing the Neurosky Mindwave EEG Headband, also signal quality is marked as poor if there is no proper contact of the forehead point with the EEG sensor, acquiring signal value will be medium when there is a partial contact of the EEG sensor, and signal quality is marked as good when there is full contact of the EEG sensor with the forehead.

For safety precaution, when the EEG signal value is not good, a stop command will be sent to the system model preventing any unwanted actions. When the quality of EEG signal becomes good, immediately Android application starts to listen to the EEG signal data for force blink detection using the Neurosky Mindwave EEG Headband.

Fig. 7 shows the of Android Application interface and flowchart in Fig. 8 demonstrates the overall execution of the Android application to control and operate implemented hardware 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 predefined threshold of 90 are discarded. Whenever a forceful blink or blink having its signal strength above the predefined threshold value, here it is set to 90 if detected then control shifts into command mode. This threshold value can vary person to person and needs to be set during the application build.

2) Command - The Android application starts the rotating direction values – Initially a system starts in Standby mode, then at every 2.5 seconds it switches, one after another forward (F), reverse (B), left (L), and right (R) on the total interval of 10 seconds. Here, the 10-second rotating window of direction is known as command mode.

In the command mode, actively Android application keeps on listening for two successive blinks. When it notices a double blink occurrence by the user, the rotating of directions locks and whichever direction is locked in the cycle due to double blink will be the selected direction. For considering blinks so as to be successive the time passed between two blinks must be less than or equal to 400 milliseconds.

3) Focus - When a direction is set, the Android application goes into the focus mode. Here it starts to listen the attention values from the Neurosky Mindwave EEG Headband. Values of Attention levels are observed by the Neurosky Mindwave EEG Headband for every second and if it reaches values of threshold, here set at 50 or more, the flow of Android application will switch to the running mode. This threshold value can be set in an Android application program as per user and the application builds will contain whichever value is set.

4) Running – In running mode, it sends a command to the Arduino which is set based on the direction locked earlier. For every direction, there has been a predefined Bluetooth signal that will be sent to and processed by the Arduino in the system model. To exit from running mode user needs to double blink so as to switch back again to standby mode. This cycle gets repeated whenever the user wants to operate the system model once again.

Fig. 7. Android Application Interface

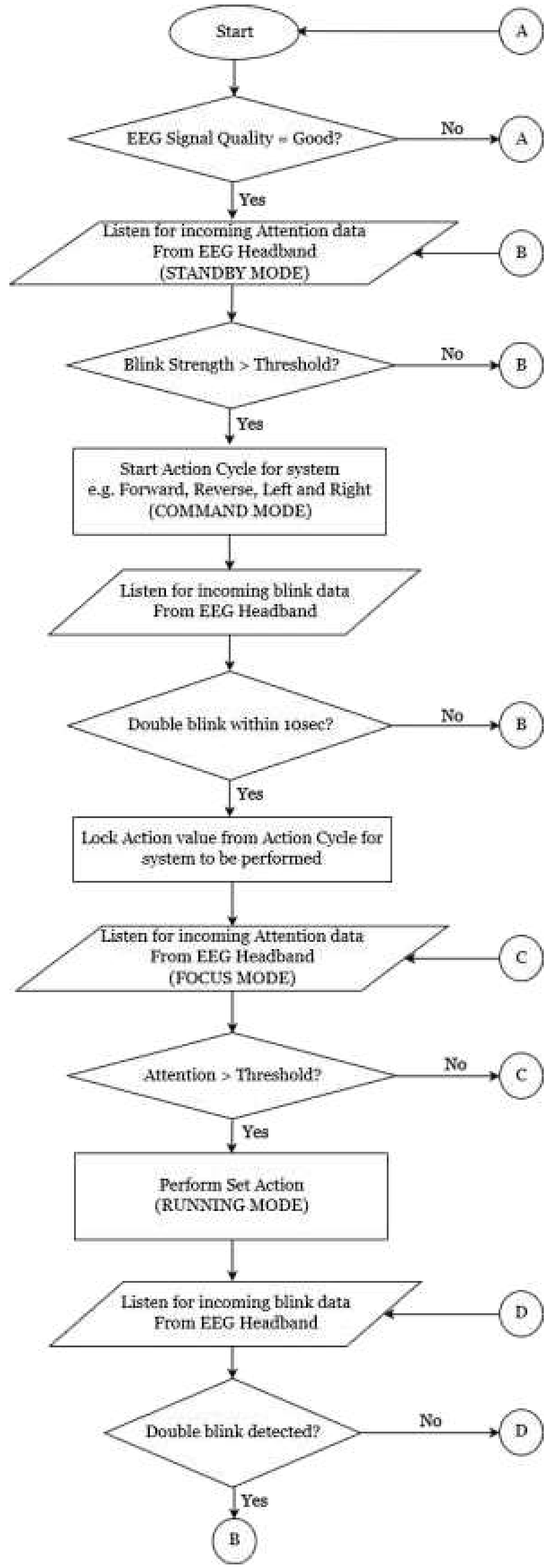

Fig. 8. System Control Flowchart

V. FUTURE SCOPE AND LIMITATIONS

While this proposed work allows driving the eyeblink controlled system prototype but will require the training of the user to operate the controls. Blink detection through the wearable EEG devices is still not perfectly accurate, and novice user will find it difficult to have a control over eyeblink pattern. However, total control of brain activity and EEG signal will remain impossible. Also, due to fact that this system is mainly operated by eyeblink pattern, persons with will eyeblink disorder are not suitable for users of this system.

Neurosky Mindwave EEG related issues like Bluetooth connectivity and requirement of the firm touch of EEG sensor to the forehead that causes it to unexpectedly stop functioning sometimes. Over such problem, a user or researchers hold no control and would need to find a way to deal with such issues.

This project can be extended further to provide the control for prosthetic organs, Virtual Reality controls, mind-controlled gaming, wheelchair control for paralyzed persons, etc. In a future with the advancement of the processing power of processors, algorithms and communication techniques in this system can become more sophisticated to use and can get placed in day to day life.

VI. CONCLUSION

Using this approach, a system can be controlled using eyeblink pattern and most of the other wearable EEG headbands available in the market. As demonstrated here by using prototype model of a system model, this method can be incorporated for controlling robotic arms, movements of wheelchairs, control of home appliance switches, etc. With the help of eyeblink pattern, such systems can give an opportunity to physically disabled person who is incompetent to use a system as a usual person does.

This approach can embrace the potential for future system implementation using wearable EEG and mind-controlled products. Over the time there is great scope for development of Brainwave technology and will certainly get improved over the time. In near future these technologies will be easily available and will be in use of day to day life and everyday products.

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