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Smart Wearable EEG Sensor

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Abstract

Currently, traditional and ambulatory EEG systems are beyond ideal for patients suffering from different brain diseases. Traditional monitoring of electrical activity in a diseased brain is limited to the clinical environment where patients being put away from natural environment in which provoking factors of abnormalities in the electrical activity of the brain are more likely to occur. Similarly, ambulatory EEG systems have a drawback of being cumbersome and impose some restrictions on the patient, such as not being able to show in public due to the social acceptability of wearing such a head-mounted device. The will of the patients to not publicizing their disorder or illnesses is a major drawback for current EEG system to be widely adopted. This paper presents an attempt to develop a wearable EEG prototype using off-the-shelf components to record EEG signal from the ear and display the obtained brain signals in the LabVIEW software. The developed prototype was able to record Ear-EEG in real-time.

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Keywords: Electroencephalography; Ear-EEG; LabVIEW

1. Introduction

The study and monitoring of a diseased brain using neuroscience modalities such as electroencephalogram (EEG) have a great potential in helping clinicians and psychiatrists in understanding the function of the diseased brain as

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well as preventing cognitive impairment. Within the clinical environment, the EEG is a sophisticated technology for the monitoring of brain diseases and any abnormal activities within the brain[2]. However, clinicians often face the problem of patient follow-up. Patients have a barrier of hesitation and reluctance to continued treatment. This situation could be very dangerous and may lead to extreme cases of the patient harming others or himself. The patient may become a social burden for people around him. In this regards, it is required that, a psychiatrist or an automated system to continuously monitor the patient and his or her mental condition. Moreover, the portability and availability of such facilities to remote areas is a challenge. In addition to that, the availability of such facilities in the rural and remote areas may cause a change in the treatment management for such a disease or depression. In fact, latest researches and developments towards wearable EEG technology similar to what shown in Fig. 1[6] allows monitoring the behavior and the functionality of the diseased brain beyond the clinical and laboratory environment.

(a) (b)

Fig. 1. (a) Example of EEG within the clinic ; (b) Ambulatory EEG

In order to fully exploit the EEG technology, it should be able to be utilized while carrying out daily life activates. In addition to that, patients who need this technology have to look at it as a nonvisible alternative to monitor their health. To achieve this, EEG technology has to be shifted from wired, cumbersome and stationary systems to wearable, comfortable, convenient, wireless systems that can be used without the assistance of the experts.

In order for continuous monitoring of a patient's status, it is necessary for the EEG device to be comfortable and discrete. Due to a large number of electrodes used in traditional on-scalp EEG, continuous monitoring of the patient is impractical. Instead, Ear-EEG techniques are utilized to vastly reduce the EEG device's size in order to make it portable and wearable[3,4]. Ear-EEG has the ability to be integrated into a system similar to a hearing aid. On-scalp EEG uses the 10-20 system for the placement of up to 256 single electrodes, which cover the whole brain and show a very high spatial resolution. However, on-scalp EEG is susceptible to signal attenuation from the skull as well as increased noise from the environmental factors such as 50/60 Hz electrical noise. Ear-EEG can be placed in the ear canal and inner ear, resulting in almost similar Signal-to-Noise-Ratio (SNR) at the cost of lower overall signal amplitude[4, 5].

Ear-EEG has several advantages when compared with the existing On-Scalp EEG. Using Ear-EEG, it will be possible to develop a simplified device that can be made wearable for daily usage. Currently there is no available EEG devices which can record EEG in a completely discrete method, and thereby all devices that are available now are not suitable to continuously monitor the status of patients[3]. This gives the motivation to develop in the ear real-time EEG recording system.

2. Methodology

Fig. 2 shows the block diagram of the proposed EEG acquisition system. It consists of three electrodes, one to obtain the EEG signal from the ear and two electrodes behind the ear acting as reference electrode. The IC on the MyoWare chip performs the amplification and filtering of the signal. The Arduino board acts as microcontroller to access the analog signal for a pc or laptop. The components of the system will be explained in details in the following subsections.

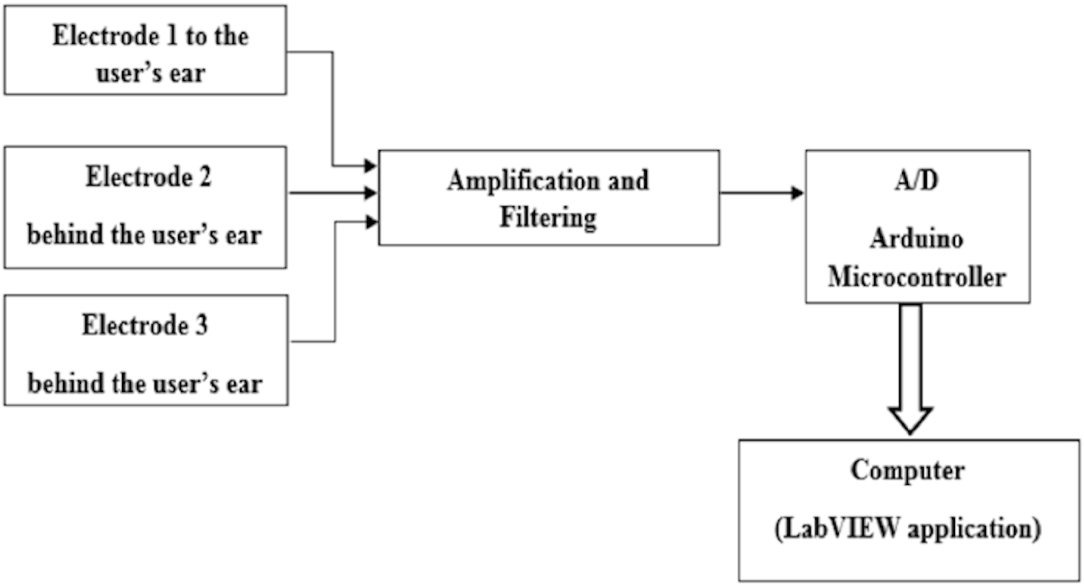

Fig. 2. Proposed block diagram of EEG acquisition system

2.1. EEG Electrodes

In order to measure and record the potentials from the body, it is necessary to provide interface between body and potential measuring electronics apparatus. The EEG signal form the brain is acquired using the MyoWare sensor, the two electrodes are placed behind the ear and the third electrode will be placed inside the ear. The typical electrodes used for this acquisition are made up of Silver-Silver Chloride (Ag-AgCl). These electrodes are used in the EEG signal acquisition since they have low impedance, low offset voltage and low noise with high stability. The electrodes are gel contained and the ear needs to be cleaned by ethanol for better signal acquisition.

2.2. Arduino (Microcontroller)

The Ear-EEG system is embedded on Arduino. The data acquisition is performed in an array structure for data coming from the analog port and apply the initial filtration in the system. The signal pre-processed by averaging and filtering out any noise. Third, the analog values are being sent over the serial port, which is Tx and Rx of the microcontroller. For the serial communication, the 9600 bps and the non- parity data bits and 8 bits data is being sent. The Arduino software provides the C++ protocol of the programming as in each step of the programming there is embedded libraries for it. As in this project, the mainly the wire library is being which mainly used to establish the communication with the microcontroller and the PC.

2.3. LabVIEW Interface

The interface is developed in LabVIEW shown in Fig. 3. The VISA driver provides the flexibility for data acquisition from RS232 serial port.

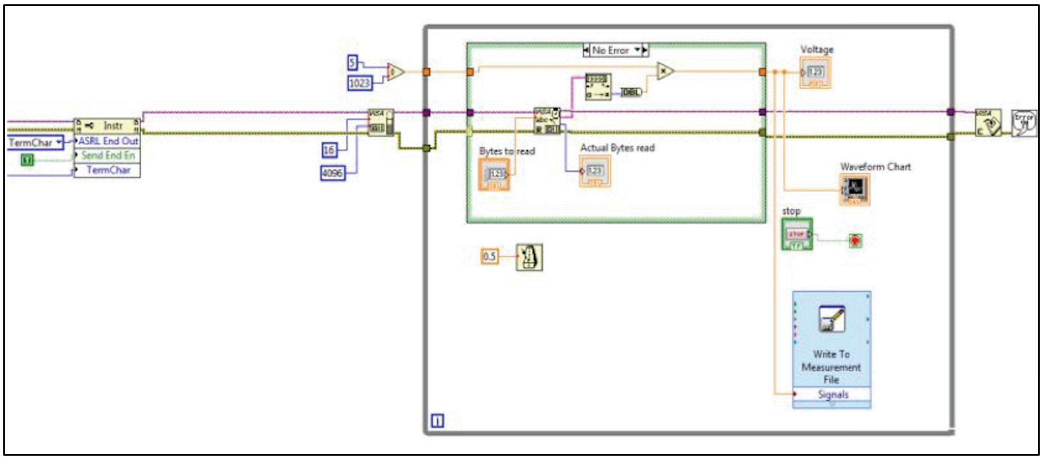

Fig 3: LabVIEW block diagram

3. Results & Discussions

A simple prototype has been developed for experimental purpose as shown in Fig 4. The electrode position, it mainly refers to the skin capacitance factor, which means either to use the capacitance factor on hear or toes or any part of the body, the factors almost the same. But the only thing change is the muscle or the bone part that is not applicable in this project. The concept in this project is to collect the data from the ear internal canal that consists of the skin. Electrodes act as the transmit a little amount of current the zero voltage factor and skin with the nerves of the ear response based upon the surface area of the electrode. As the gel on the electrode act as a medium to speed up the transmission it helps to improve the single quality meanwhile rest of the signal processing is performed on board which has an internal amplifier and the filters. While the additional filters are being used in the C++ coding.

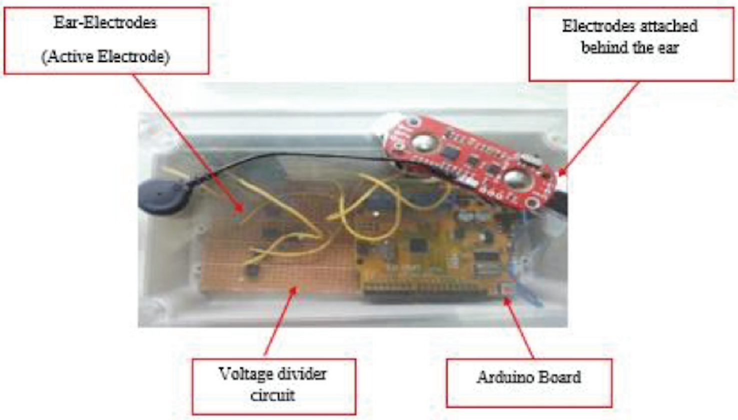

Fig 4: Wearable Ear EEG Prototype

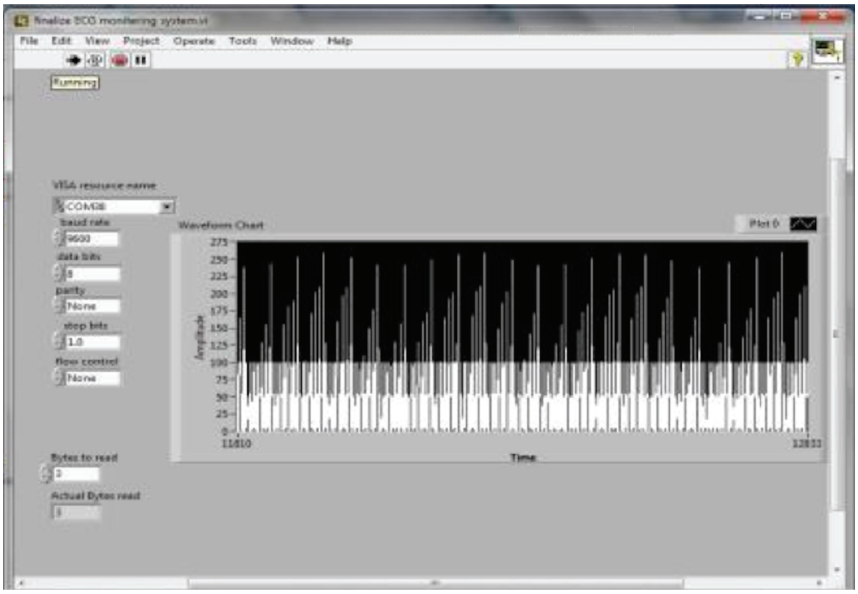

Fig 5: Raw EEG acquired from the Ear EEG prototype

From the graph shown in Fig 5 the displayed signal is not an EEG. Displayed signal is moving fast which opposite to the nature of the EEG signal. In addition to that the signal is constant over a period of time, it does not change according to current activity of the brain. The reason for this, is the interference between Arduino and the LabVIEW need to be modified to obtain EEG signal. DAQ cards manufactured by National Instruments which is more compatible with LabVIEW than the Arduino board can replace the Arduino board for easier interference and data acquisition.

The prototype developed in this research is a primitive one to show that a simple device can be used to record ear-EEG. However, for future use, the device can be made with more features. The device can be made wireless by using Bluetooth. The amplifier can also be customized for this application for onboard amplification and pre-processing. A more comfortable and easier to use electrode can be developed using 3D Printing that can fit more comfortably inside the user's ear.

4. **Conclusions**

A wearable, less visible Ear-EEG recording prototype device is developed. The proposed device was able to record Ear-EEG in real-time. Only raw data was recorded that can be analyzed for further investigation for any particular neural disorder.

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