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Research paper

Wireless Electroencephalography Based Blood Pressure Monitoring

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Abstract

The number of cardiac patients and aged individuals are at a rise all around the world. Taking care of such individuals is a major challenge these days. In many cases, these patients require special care and regular monitoring of vital signs like blood pressure (BP). Focusing a prevalent idea of wireless brain-computer interface (WBCI), an innovative research work is considered to meet essential routine monitoring of BP for cardiac patients and aged people without any reliance. The research framework involves the use of wireless electroencephalogram (EEG) headset to control wrist BP and arm BP monitors to determine accurate BP readings in the proposed system. An Android application "Smart Home Monitor" is developed that screens the information from the headset. The research framework is tested on ten individuals to examine the precision in BP readings from two different BP monitors. Results specify that both upper arm blood pressure readings i.e. Systolic BP readings (SBP = 119.6 ±5.1 mmHg) and Diastolic BP (DBP = 79.5 ±7.4 mmHg) were found to be better than the wrist BP readings (SBP = 128.2 ±11.7 mmHg and DBP = 83.6 ±10.3 mmHg). This examination assessed that the designed system empowers the framework to be reliable, remote and compact.

Keywords: *Blood Pressure, Wireless BCI, Smart Home, Wireless electroencephalogram, Android Application*

1. Introduction

Systems based on wireless brain-computer interface (WBCI) are prevailing and becoming dominant because of easy accessibility and compactness as the mind is wirelessly interfaced to the gadget to control WBCI framework remotely [1]. There is a lot of development going into WBCI applications such as controlling home automation, computer games, etc. and one of them is the smart medical home system [2]. This allows the user to measure one of their vital signs, for instance, monitoring of blood pressure several times a day without any dependency at home.
Blood pressure (BP) estimations are universally perceived as fundamental parameters for observing change in well-being and disease around the globe [3]. BP essentially alludes to the way blood pushes against the dividing wall of the arteries as the heart pumps. The systolic blood pressure (SBP) exerts power against vessel dividers at the pinnacle of cardiovascular compression or systole, whereas the diastolic blood pressure (DBP) exerts pressure when the heart becomes steady [4]. The abnormality in BP often results in ischemic coronary illness, stroke and heart failure [5]. The reliability and precision of BP readings are therefore essential which in turn relies upon the correct operation of the specific BP estimation device [6].
Several kinds of research have been carried out to measure the accuracy of forearm BP readings and upper arm BP readings. Two analyses compared the automatic wrist BP readings with conventional auscultatory BP readings of upper arm [7, 8]. It was found that the automated wrist estimation was precise and exact [7, 8]. However, BP readings of a wrist and upper arm were also compared with eighty-five (85) subjects and it was concluded that there is a significant difference found among two readings [9]. Overall, it is concluded that wrist BP readings are not that accurate as the upper arm BP readings [10].
In our previous study, WBCI based smart home was designed to manage home automation and medical devices including BP monitor. The wrist BP monitor was used as one of the medical devices to measure BP reading, which was not precise. The overall system was intended to be used for aged and paralyzed patients with respect to routine activities [11]. The biggest challenge to the prior system is the accuracy of BP device used in that system since many clinical decisions are strictly based on the BP measurements with the least possible error [12].
Therefore, this research work is designed to investigate the accuracy of BP measurements by using two automatic BP monitors, based on the oscillometric method placed on the wrist and upper arm respectively [13]. The reason for this work is to decide whether significant differences exist in SBP and DBP in the upper arm when contrasted with the wrist in samples of normal subjects or not. The proposed framework is useful for aged and handicapped patients to monitor their BP readings remotely. This information about the patient's BP can be remotely stored on the cloud and accessed by the patient's doctor in the future.

2. Methodology

In this research work, a wireless electroencephalogram (EEG) based BP monitoring system is designed based on the modification of our prior research work [11]. The stationary part of WBCI was intended to control home utilities at steady state while the mobile part controls handy medical devices such as infrared therapeutic belt and digital wrist BP monitor [11]. Firstly, an EEG headset senses brain signals, which remotely sent the signals to the stationary component and subsequently sent to the portable part. The monitoring of the framework can be visualized on an Android phone. In the modified research work, the stationary part, with a limitation of mobility and portability is removed. Hence, the detected brain signals from the EEG headset are wirelessly transmitted to mobile controller instead of stationary part. The whole system is primarily based on the mobile controller only and the rest of the parts like EEG headset and Android-based cell phone remains same as in the previous system. Therefore, the components associated within the wireless framework for controlling arm BP monitor and wrist BP monitors are presented in Fig 1.

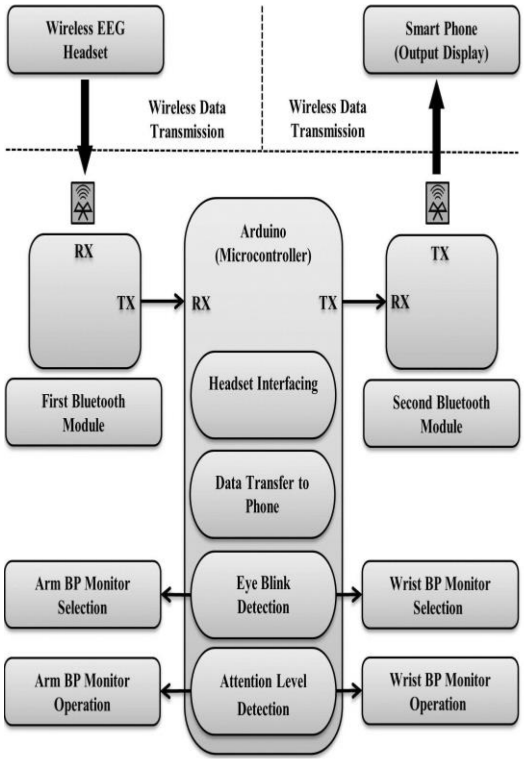

Fig. 1. System architecture of Wireless EEG based BP Monitoring

The headset-mobile controller interface involves wireless connection of headset to the mobile controller of the framework that concentrates data from incoming signals of headset to control both the BP monitors at the same time or either of the monitors as per user's choice and wirelessly transmit it to the cell phone for displaying brain's attention signals and BP monitors status.

The primary components of the entire framework are EEG Headset, Bluetooth (BT) modules, microcontroller (MC) (Arduino UNO), an upper arm BP monitor, a wrist BP monitor, relay circuits and a designed rechargeable battery. The EEG headset measures the brainwaves, converts into digital form and associates with a wide range of applications, home automation, research purpose and mobile games [14, 15]. An eSense, patent algorithm, is used to extract meditation and attention values from separated crude information and identify the eyewinks [16]. The quality of signal is estimated on a scale of 0 to 200, where "0" implies to a strong signal and "200" depicts a poor signal [16]. Likewise, meditation and attention values are estimated on a scale size of 0 to 100 where "0" demonstrates an absence of that parameter and "100" shows overabundance. When BT of headset is in the blending mode, it begins to find the device to connect with mobile controller and transmit headset information. The Arduino UNO module of the mobile controller processes the signals and serves as the power source for both associated HC-05 BT modules. The first HC-05 BT is configured in such a way that it enables the headset to discover and match this Bluetooth naturally.

The BT module 1 of mobile controller is connected to MC (Arduino) through receiver (RX) pin. It transmits the information from the headset to the mobile controller. The portable part of the wireless BCI framework appears in Fig. 1. Both BP monitors are linked to the digitized input-output Arduino pins via two switching circuits. The switching circuit consists of relays and a transistor to give adequate current and compelling control of two BP monitors. The Arduino permits attention level, guidelines and signal strength to be imprinted on serial screen for the client to observe. It additionally operates any two applications, which in our research work are two BP monitors, depending upon the information originating from EEG headset. The Arduino is to be associated with a PC for serial checking, so cell phone is utilized as a serial monitor, which is convenient. Serial information is sent to cell phone from mobile controller by means of second BT appended to Arduino transmitter (TX) pin.

The software is intended to receive information from the EEG headset via primary BT to the Arduino of mobile controller and enable the client to choose the options of selecting either the BP monitor with cuff, wrist BP monitor or both at the same time. As the firmware begins, it allows 8 seconds to the client for blinking of an eye. The eye flickers are needed to choose both devices; one blink for a wrist BP monitor, two for upper arm BP monitor and three blinks for controlling both monitors at the same time. As the device is chosen, patients need to increase attention levels to a range of 60-70 to make the device on, and 70-80 to make the device off. The mobile controller is handy as it allows the client to wear both the monitors to his/her body and carry easily within the BT transmission range. The portable mobile controller of the framework utilizes the information to enable the clients to envision and observe their attention levels, signal strength and the guidelines to use this framework. The flowchart for execution of system's firmware is clear in Fig. 2.

A statistical analysis is performed on 10 subjects to determine the precision in acquiring results of two BP devices using the modified system. By applying statistical tests, mean and standard deviation is calculated using MS Excel to compare arm BP monitor's SBP and DBP with its counterpart i.e. wrist BP monitor.

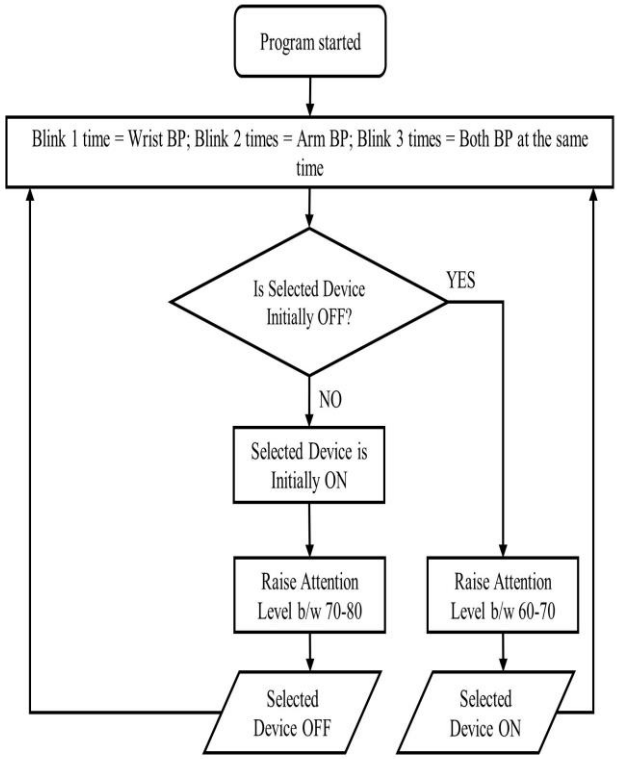

Fig. 2. Flowchart for System's Firmware.

3. Results

The proposed framework comprises of three notable parts; EEG headset, mobile controller and an Android based cell phone. The headset transmits attention values and eye blinks to the mobile controller of the framework wirelessly. The mobile controller processes these signals from the headset, control both BP monitors and wirelessly transmit data to a smartphone. Once BP values were attained from the monitoring devices, an analysis was performed to check the accuracy of our system by examining the difference between the BP values of the wrist and upper arm. The statistical analysis was performed on ten subjects to assess the SBP and DBP values of the wrist and upper arm. After analyzing all mean values of SBP and DBP and standard deviation error bars as shown in Fig. 3, it was found that mean SBP, as well as DBP readings of the upper arm, are more precise than the wrist. The results showed that both SBP and DBP readings were lower in the upper arm in contrast to the wrist.

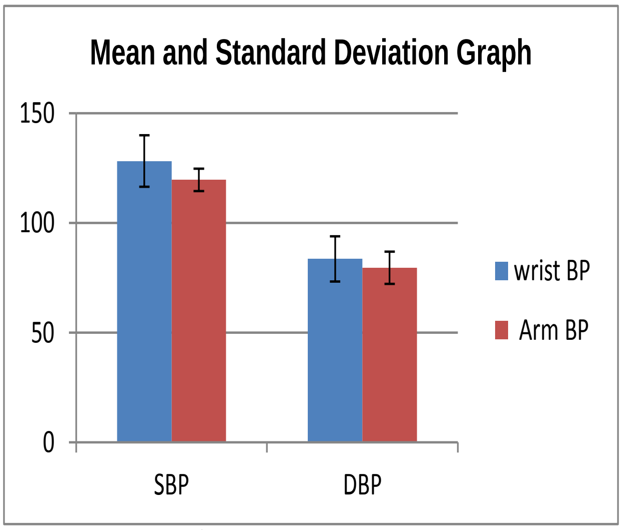

Fig. 3: Comparison of average wrist BP & arm BP along with standard deviation. Blue and Red bar represents wrist and upper arm BP respectively. X-axis indicates SBP and DBP and Y-axis defines SBP and DBP readings in mmHg.

4. Discussions

The analysis illustrates more accurate point of taking BP readings in the proposed system than the blood pressure reading taken from wrist. Fig. 3 shows the comparative analysis of each of the mean systolic and mean diastolic readings that are taken from upper arm and the wrist with standard deviation (SD) error bars. Comparing the blood pressure readings of upper arm and wrist, mean SBP of upper arm (119.6 mmHg) was found to be within the SBP range mentioned in the reference study conducted [17], compared to the mean SBP of wrist (128.2 mmHg), which means SBP taken from upper arm is better than the wrist SBP. Likewise, the mean DBP of upper arm (79.5 mmHg) was found to lie within the DBP range given in the reference study conducted [17], compared to the mean DBP of wrist (83.6mmHg) which signifies that DBP taken from upper arm is better than the wrist DBP. The standard deviation values of arm [SBP (±5.1) mmHg and DBP (±7.4) mmHg] are comparatively lower than the SD values of wrist [SBP (±11.7) mmHg and DBP (±10.3) mmHg] indicating the upper arm BP to be more precise.

The fundamental goal of performing factual examination was to ponder that everybody could utilize this framework and define its reliability and user friendliness. In the previous study, wrist BP monitor was used to acquire BP readings which seemed to have margin of error [3]. Therefore, to increase the reliability of overall system this research work is focused on analyzing the accurate means of taking BP readings. The other scope of this research work is to reduce the hardware size of the system making it more convenient and handier for its end users.

There are a few limitations and conceivable progressions in the proposed framework. The entire framework remotely operates in ten meters of the range that can be expanded by supplanting BT module with Wi-Fi module. The existing framework's power lasts for 4-5 hours, which can be enhanced fundamentally by utilizing more efficient rechargeable batteries. Moreover, the information can be remotely transmitted from BP monitors to the patient's doctor to observe intermittent readings in serious circumstances.

5. Conclusion

A Wireless EEG based BP monitoring framework is proposed to control two different BP monitors. This framework wirelessly receives EEG signals; processes it and permits observation of the information on the cell phone using a smart home monitor application designed via open available source MIT app inventor tool. The low power utilization and energizing capacity of our framework add to its adaptability, so it is viable for controlling different medical devices in addition to existing two BP monitors. The precision of the proposed framework was checked by performing an analysis over blood pressure readings acquired from ten healthy individuals. The proposed system is beneficial for bedridden patients who can wirelessly take their accurate BP reading at home independently to monitor their critical vital sign. Further enhancement of our system may include Wireless storage of BP data on the cloud, which can be retrieved by the patient's physician. The designed system is compact, wearable and user-friendly.

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