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Design of a Wireless EEG System for Point-of-Care Applications

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Abstract

This study aims to develop a wireless EEG system to provide critical point-of-care information about brain electrical activity. A novel dry electrode, which can be installed rapidly, is used to acquire EEG from the scalp. A wireless data link between the electrode and a data port (i.e., a smartphone) is established based on the Bluetooth technology. A prototype of this system has been implemented and its performance in acquiring EEG has been evaluated.

Keywords

wireless EEG; dry electrode; point-of-care

I. Introduction

EEG is a powerful non-invasive diagnostic tool in neurology and neurophysiology. It is of paramount significance in differential diagnosis of adults with unexplained acute alteration of mental status [1, 2]. Recently, the requirement of emergency EEG is dramatically increasing in critical care of patients with neurological diseases. It is established that accurate diagnosis and timely treatment will bring great benefits to patients. However, the current EEG technology cannot be utilized quickly and conveniently in the point-of-care settings because of a complex procedure for installing and maintaining multiple EEG electrodes. It is thus highly desirable to have a convenient EEG system that can be attached to the patient quickly and acquire EEG reliably.

Currently, different types of dry electrodes have been proposed and investigated because no electrolyte is necessary for installation of dry electrodes. However, the skin-electrode impedance for most dry electrode (e.g., the SAHARA electrode) is very high, which requires a specific high-impedance amplifier to obtain EEG data with an acceptable quality [3]. In addition, adhesive tapes or caps must still be utilized to fix the electrode on the scalp. To solve these problems, our group has developed a self-adhesive dry electrode, called skin

screw electrode. Its impedance, as demonstrated in our previous studies [4], is comparable to the traditional wet electrode. The installation of a skin screw electrode only takes approximately one second. Therefore, based on this new electrode, we developed a wireless EEG system that can be applied in emergency situations. This system can be used to monitor brain function immediately after an acute neurological disease or an injury, and record data continuously throughout the patient transportation process and various patient care procedures.

II. System Design and Implementation

A. Overall Design

This ultra-portable EEG system consists of three components: a set of EEG electrodes, a central control unit, and a data port. The skin screw electrodes record EEG signals; the central control unit amplifies the signals and wirelessly transmits them to the data port; the data port, placed near the patient, is used to process, store and display the acquired information. In the current configuration, three electrodes (i.e., a ground, a reference, and a signal electrode) are used to acquire an EEG signal. The concept is illustrated in Fig. 1.

B. Skin Screw Electrode

Our skin screw electrode has a cylindrical shape (approximately 1cm in both diameter and height) with micro teeth along the bottom rim (Fig. 2(a)). When the electrode is twisted clockwise, these teeth can penetrate hair and hook on the painless top layer of the scalp (Fig. 2(b)). This kind of electrode does not require the application of electrolyte, and can be applied to or removed from the scalp very quickly.

C. Central Control Unit

The role of the central control unit is to acquire and transmit the EEG signal to the data port wirelessly. The major electronic function blocks inside the unit, also shown in Fig. 1, include: (a) a high-impedance, low noise differential amplifier; (b) a micro controller; and (c) a Bluetooth wireless communication circuit.

D. Data Port

The data port is used for data storage, display, and telemetry. The EEG data is processed and recorded on a flash memory card for continuous or time-divided wireless transmission. If a network connection via a mobile network or a Wi-Fi router is accessible, the data port is able to transmit the acquired EEG to the destination facility for pre-arrival diagnosis, remote monitoring, and preparing treatment for the patient.

E. Prototype Implementation

Figure 3(a) shows the prototype of the central control unit. A newly developed integrated circuit chip for biopotential measurement (ADS1294, Texas Instruments) was utilized for EEG acquisition [5]. It contains multiple channels of built-in amplifiers with programmable gain, and a set of 24-bit analog-to-digital converters. All these and other components are integrated within a 6mm×6mm chip. The power consumption of the chip is only 0.75mW per channel, allowing a long-term operation for a portable EEG system powered by a

battery. We used an RN-42 Bluetooth Module (Roving Networks, Inc) to transmit data to the data port in a short range, and an ultra-low power, 16-Bit microcontroller (MSP430, Texas Instruments) to control signal acquisition and transmission.

The data port has been developed based on a commercial smartphone (Samsung Galaxy S II Skyrocket, see Fig. 3 (b)) which provides a standard Bluetooth interface for wireless communication. A user-interface was programmed to allow display of EEG waveforms.

III. System Evaluation

A. Evaluation of the Wireless Communication

Four segments of sawtooth signal were sent to the central control unit as a test signal. The length of each segment was 1,120 data points. A segment of signal received by the data port is plotted in Fig. 4 where some transmission noises can be observed.

B. System Evaluation

Two skin screw electrodes were used to record EEG from a human subject. One traditional electrode was placed on the subject's forehead as the ground. The sampling rate of the system was 225Hz. The subject was asked to sit quietly in a chair and respond to instructions of eye opening/closing, blinking, or teeth grinding. Four segments of recorded EEGs corresponding to these events are shown in Fig.5.

IV. Conclusion

A new point-of-care EEG system has been developed, including a gel-free electrode, a portable amplifier module, a microcontroller with a Bluetooth data link, and a smartphone. This system acquires, processes, and displays EEG signals, suitable to support mobile data acquisition at the site of first care and during the process of patient transportation.

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Figure. 1.

Skin screw electrode (red) records EEG signal and the system transmits data wirelessly to a data port for processing and display.

(a)

(b)

Figure. 2.

(a) Prototype of skin screw electrode; (b) Installed electrodes.

(a)

(b)

Figure. 3.

(a) Prototype of the central control unit; (b) Data port

Figure. 4.
A typical segment of wirelessly recorded sawtooth signal

Figure. 5.
Wirelessly recorded EEG waveforms under different events