

Air brain – the easy telemetric system with smartphone for EEG signal and human behavior

Keita Honda
Kwansei Gakuin University
2-1 Gakuen, Sanda, Hyogo, 669-1316, Japan
Tel/Fax: +81-79-565-7244
keita.honda@kwansei.ac.jp

Suguru N. Kudoh
Kwansei Gakuin University
2-1 Gakuen, Sanda, Hyogo, 669-1316, Japan
Tel/Fax: +81-79-565-7244
snkudoh@kwansei.ac.jp

ABSTRACT

Studies for human-machine interaction such as Brain-Computer Interface (BCI) using EEG has been focused on. Usability in daily life is critical for BCI. Therefore, a convenient portable telemetric EEG system at low cost is required. We developed “Air Brain system”, a portable EEG telemetric system using 3G-network with a smartphone. The feature of the system is recording EEG at low cost, anywhere the system connecting 3G networks. In addition, various sensors on a smartphone are used to sense human behavior during EEG measurement. The system enables us to measure EEG immediately after walking, and we found attenuation of α -wave with eye closing.

General Terms

Measurement, Performance, Experimentation, Verification

Keywords

Electroencephalogram (EEG), 3G-network, telemeter, smartphone

1. INTRODUCTION

Studies for human-machine interaction such as Brain-Computer Interface (BCI) using Electro-EncephaloGram (EEG) has been focused on today. BCI is non-invasive brain monitoring technology and used for prosthetic interactions for the physically handicapped person in clinical medicine. A large part of reported BCI systems is based on EEG [1-5]. EEG has been utilized especially for brain disease detection, such as epilepsy, sleep disorder, and so on. EEG is indeed one of noninvasive, convenient methods for estimating brain state, however, it imposes some physical restriction on a subject by fastening with electrical cables to a large EEG system. Compact wearable EEG systems and telemetry of EEG measurements have been developed [6,7]. The proposed systems with internal storage devices limit continuous recording time for EEG signals, because of its not-enough storage capacity. EEG telemetric systems are able to transport EEG signals to distant storage devices, however, most of the systems are based on Radio Frequency (RF) technology. For example, portable EEG monitoring system was previously proposed based on Wireless Local Area Network (WLAN) [8]. While the system improves the flexibility of EEG recording, area of EEG telemetric is limited to the specific WLAN area. In this study, we focused on using 3G-network for EEG telemetric system. The cellular phone area has

spread over the world, therefore EEG telemetric system using cellular phone has broadest covering area at present. Today, a low cost high-functioning smartphones are common among ordinary people. Therefore with our developed system, EEG telemetric is always possible in daily life with a general smartphone. As another advantage of utilizing smartphones, sensors on smartphone are also available to measure human state. Recent up-to-date smartphones have various kinds of sensors, for example, motion sensor, accelerometer sensor, ambient light sensor, gyroscope, and so on, which are suitable for monitoring human behavior. Location service based on built-in Global Positioning System (GPS) is also useful for detecting human activity. The equipment of the smartphone is useful to realize a telemetric system for EEG and sensing human behavior. Sensor signals of the smartphone are useful to analyze human behavior. In this study, we propose “Air Brain” system, a simple and easy way to build a telemetric system for integrated biological signals and information of human behavior with a smartphone and 3G-network.

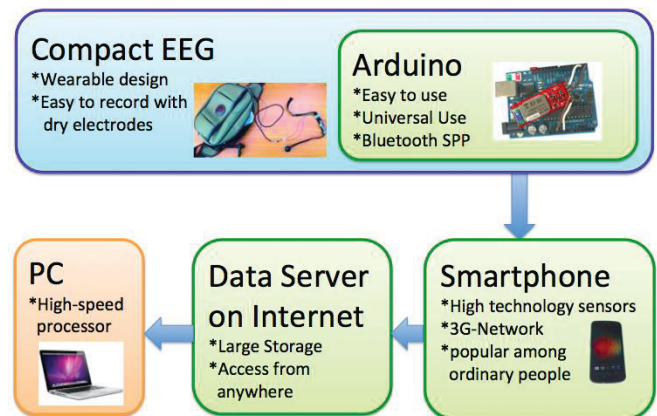


Figure 1. Overview of Air Brain system

2. SYSTEM DESIGN

2.1 Overview of “Air Brain” system

Air Brain system consists of four modules, Compact EEG, a smartphone, a data server and a computer (see Figure 1).

Compact EEG has been developed originally and composed with a simple EEG amplifier circuit and Arduino circuit. Arduino circuit is a system of based on AVR microcontroller for laboratory [9]. Arduino is able to introduce at low cost and has extensible to use. High performance EEG amplifier circuit with active type electrodes is built up using low cost IC. Arduino circuit is used for A/D converting and Bluetooth transmission. Digitized EEG signals are transmitted to a smartphone or directly to PC via Bluetooth communication. The compact amplifier and Bluetooth

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
BODYNETS 2013, September 30-October 02, Boston, United States
Copyright © 2013 ICST 978-1-936968-89-3
DOI 10.4108/icst.bodynets.2013.253918

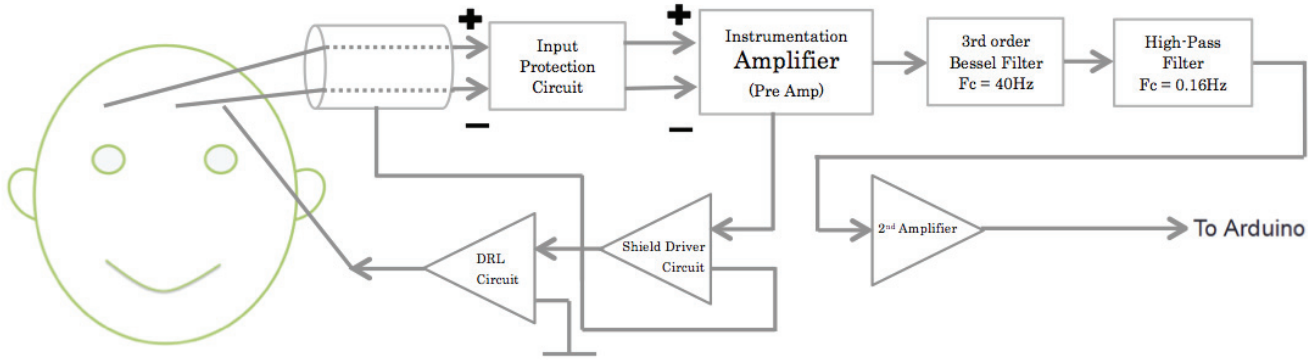


Figure 2. Overview of Compact EEG circuit

communication release the subject from troublesome fastening to the long electrode cables connected to a big EEG measuring instrument. EEG amplifier circuit and Arduino circuit are included in a fanny pack and active type electrode is attached to headband, allowing for users to wear EEG measuring system easily. The up-to-date smartphone has high-technology sensors enough for detecting human behavior and the transmitted EEG data is integrated with the values of several types of sensors. Then integrated signals are transported to the data server on Internet via 3G-network. The data server stores the received data and distributes them to client PCs. Client PCs are also able to receive digitized EEG signals directly from the portable EEG measuring module. In this case, the information about human behavior is omitted, though precise analysis can be performed in a computer powerful than a smartphone.

2.2 Compact EEG circuit

Ag/AgCl electrodes are used as the electrodes for cancelling the non-stable polarized potential. The electrodes are designed as spiral structure for effective measuring. The active electrodes are also composed of voltage follower circuit for high input impedance and located at Fp1 and Fp2 position by International 10–20 system. Contact resistance between electrodes and head skin is reduced by headband holding of the electrodes to head skin without electric conductive gel. The location of electrodes allows us to record EEG signals from the frontal robe, relating to human higher cognitive function. The EEG amplifier is an orthodox bio signal amplifier [10], which has a precision instrumentation amplifier (INA114, Burr-Brown Corporation, U.S.A), cascade of filter circuits and amplifiers consist of operational amplifiers (op-amps). The Compact EEG also has a noise-cancelling circuit to reduce common-mode noise, called Driven Right Leg (DRL) circuit (see Figure 2) [11]. DRL circuit is generally used for modern bio signal measuring. DRL electrode is also putted on headband and located on forehead. Input signal passes through the input protection circuit and then is amplified 26 dB by an instrumentation amplifier. After that, the signal is filtered to reduce DC components by high-pass filter with cutoff frequency of 0.16 Hz. Then, filtered signal is transmitted to the 3rd Bessel low-pass filter with cutoff frequency of 40 Hz for reducing hum noise. Finally, the signal is amplified approximately 60 dB. Total voltage gain of 86 dB is enough to measure weak EEG signal. All op-amps included in the circuit are able to work at low voltage of 4.5V, therefore this EEG measuring module requires only three LR03 batteries. The 1st amplified signals are pulled up by the reference voltage (V_{ref} , =1.5V), given to the instrumentation amplifier in the circuit. A/D conversion of amplified EEG signals

by Arduino circuit with Bluetooth shield is carried out at a sampling rate of 160 Hz and quantization bit rate of 10 bit. Arduino transmit the EEG data via Bluetooth SPP connection at baud rate of 9600 bps.

2.3 Software

Transmitted EEG data is received and saved by smartphone application. In this study, Android smartphone (Galaxy Nexus, Samsung Electronics) was recruited and “Air Brain Mediator” was developed on Java for Android (see Figure 3a) and on LabVIEW for PC (see Figure 3b). “Air Brain Mediator” is able to receive EEG signal form Arduino via Bluetooth SPP communication and displays EEG signal. On Android version, the values of acceleration sensors are also gathered and recorded at the sampling rate of 15 Hz. In addition, the values of pressure sensor and brightness sensor were gathered and recorded at the

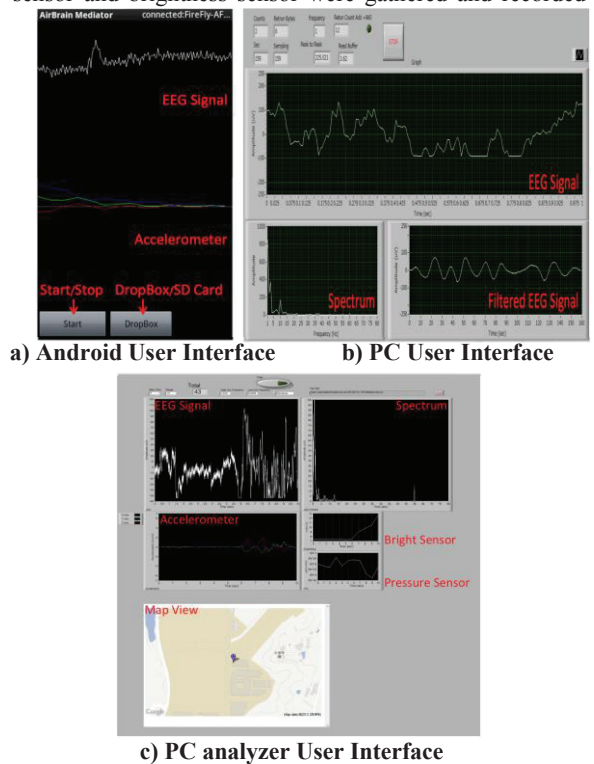


Figure 3. Software User Interfaces
a) Air Brain Mediator for Android, b) Air Brain Mediator for PC, c) Air Brain Analyzer

sampling rate of 1 Hz. EEG signals are integrated with these sensor information and continuously transmitted to the server on the Internet via 3G-network. At this time, Dropbox is recruited as data sever, because Dropbox is free to use and Dropbox API is opened. In the case of PC version, only EEG signal is saved continuously on PC storage. PC has enough processing power for effective analysis such as filtering, independent component analysis, pattern matching, and so on [12,13]. In addition, EEG analyzing software “Air Brain Analyzer” was developed on LabVIEW for PC (see Figure 3c). Air Brain Analyzer can analyze EEG signal frequency, display sensor values are gathered on smartphone and map out location of EEG measuring place.

3. RESULT AND DISCUSSION

3.1 Alpha wave dominance

We focused on α -wave (8-13 Hz) in this study. α -wave is well related to cognitive function and relatively easy to measure, therefore it is suitable for evaluation of novel EEG measurement system. We recruited 5 participants. The participants equipped with Air Brain system and are measured from an electrode on the forehead by bipolar induction. Our experiment has two tasks for each participant. For each task, we have calculated the rate that is based on the amplitude power of α -wave band with eye opening (see Figure 4).

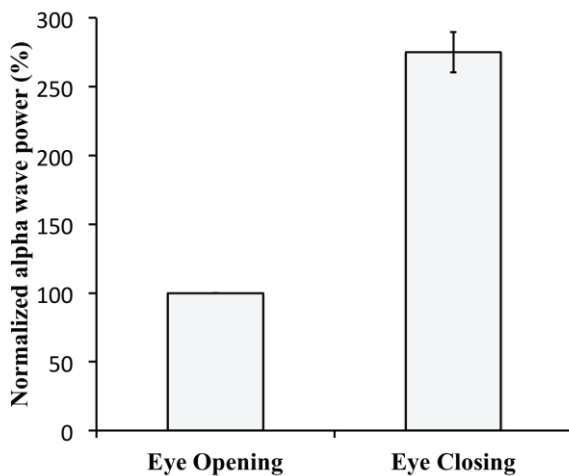


Figure 4. Alpha wave dominance (mean±SE, N=10)

With eye closing, the rate is 275±15% (mean±SE, N=10). The amplitude power of α -wave band increased with eye closing than that with eye opening (alpha wave dominance). In general, α -wave dominance remarkably appears in the occipital area. However, we confirmed by Air Brain system that the α -wave dominance is common phenomenon of EEG measured from frontal robe on resting state.

3.2 Evaluation of Air Brain system

To evaluate Air Brain system, we have compared the system with a commercial EEG measurement system, Active Two (BIOSEMI). In the same experimental environment as the previous section, the α -wave rate against full band (1-80 Hz) with eye closing on resting state was similar among EEG data measured from these two systems (see Figure 5). The EEG signal includes α -wave band at a rate of 7.99±0.37% (mean±SE, N=10) by using Air brain system. That of value by using Active Two system is 7.64±0.32% (mean±SE, N=10). Air Brain system has comparable performance

with commercial EEG measurement system for detection of α -wave.

3.3 Alpha wave dominance after walking

EEG measurement is generally performed on resting state because electrical measurement is difficult during movement with vibration. Air Brain system enable us to record during and immediately after the movement of the subject. In the same

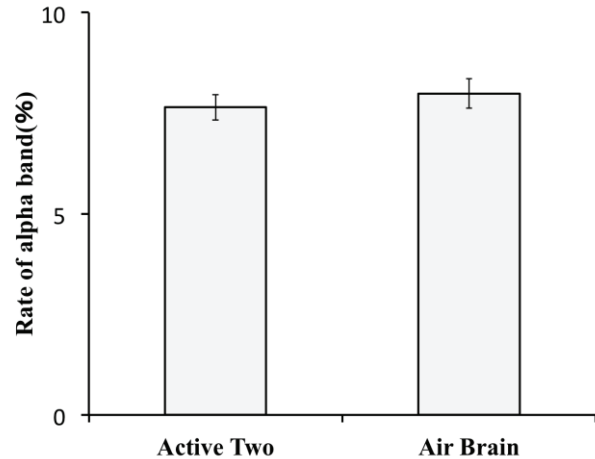


Figure 5. Compare with Air Brain and Active Two (mean±SE, N=10)

experiment environment as the previous section, the participants had been walking for 10 s from a resting state with wearing Air Brain system. For each task, we have calculated the rate of the amplitude power of α -wave band that is based on before walking and compared the power of α -wave on resting state between before walking 10 s and immediately after walking 10 s (see Figure 6). With eye opening, the rate is 184±5.1% (mean±SE, N=10) in immediately after the walking. With eye closing, however, the rate is 101±3.9% (mean±SE, N=10) in immediately after walking.

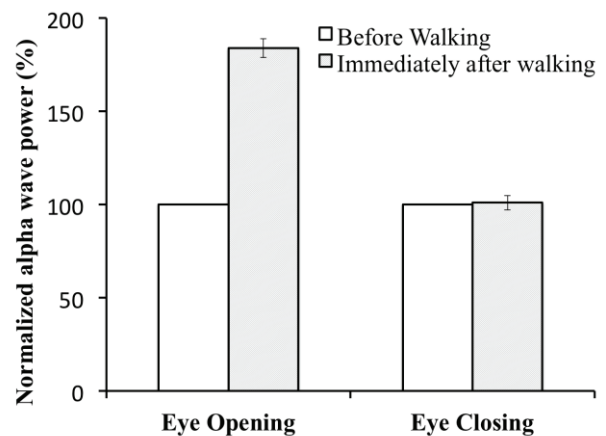


Figure 6. Alpha wave change in walking (mean±SE, N=10)

We found that power of alpha wave immediately after walking is higher than that on resting. In addition, eye closing induced attenuation of alpha wave immediately after walking, which is opposite result on resting state. At this time, we cannot cancel large noises on EEG signal during walking yet. Measured EEG

wave was saturated at the beginning of walking and acceleration sensor values preceded saturation of measured EEG wave (see Figure 7). Therefore, Air brain system is able to detect the vibration before its influences on the EEG wave. We are developing a compensation circuit on compact EEG, which enable us to record EEG signal during movement of the subject, such as walking.

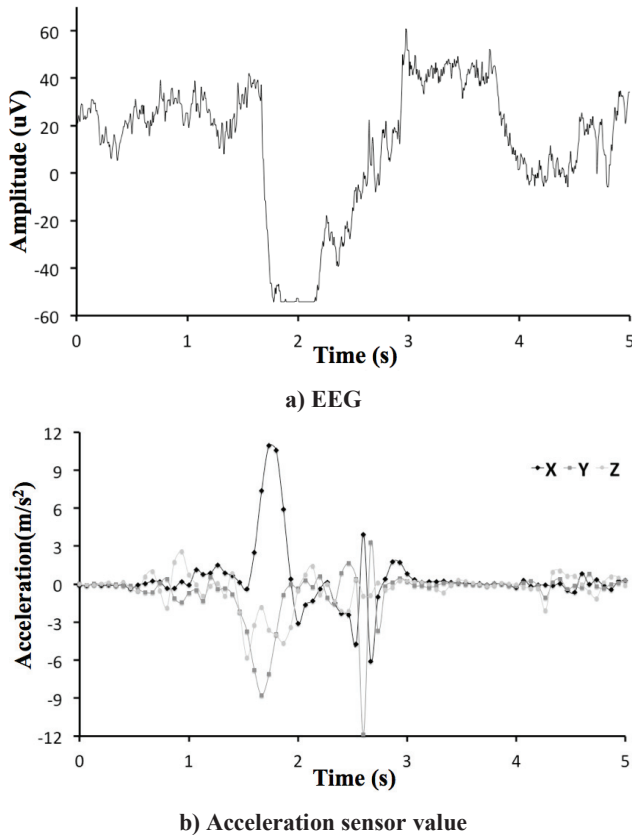


Figure 7. An example of EEG and acceleration sensor value in walking

4. CONCLUSION

We have built up a simple and easy-to-use telemetry system for EEG and human behavior using Arduino module and a smart phone. The feature of the Air brain system is recording EEG anywhere connecting 3G networks at low cost. In addition, various sensors on a smartphone are utilized for detecting human behavior. The system was confirmed to possess enough performance to record EEG signals, comparing to a general EEG amplifier. We found that power of α -wave immediately after walking is higher than that on resting. In addition, alpha wave dominance is appeared with eye opening immediately after walking, which is opposite result on resting state. The system enables us to record EEG signals on novel situation of a subject. The system is able to be applied to various fields, for example, an encephalopathy patient, attention monitoring system during car driving, controller for games, and so on.

5. REFERENCES

- [1] The L.A. Farwell and E. Donchin, 1988. *Talking off the top of your head: Toward a mental prosthesis utilizing event-related brain potentials*, Electroencephalography and Clinical Neurophysiology, 70, 6, 510–523
- [2] G. Pfurtscheller, D. Flotzinger, and J. Kalcher, 1993. *Brain-computer interface A new communication device for handicapped persons*, J. Microcomputer Applications, 16, 293–299
- [3] J. R. Wolpaw, D. J. McFarland, G. W. Neat, and C. A. Forneris, 1991. *An EEG-based brain-computer interface for cursor control*, Electroencephalography and Clinical Neurophysiology, 78, 3, 252–259
- [4] D. J. McFarland, G. W. Neat, R. F. Richard, and J. R. Wolpaw, 1993. *An EEG-based method for graded cursor control*, Psychobiology, 21, 77–81
- [5] N. Birbaumer, N. Ghanayim, T. Hinterberger, I. Iversen, B. Kotchoubey, A. Kubler, J. Perelmouter, E. Taub, and H. Flor, 1999. *A spelling device for the paralyzed*, Nature, 398, 6725, 297–298
- [6] J. A. G. Gnecci, R. D. Ramirez, V. H. O. Peregrino, and D. L. Espinoza, 2010. *Pre-competitive Development of a Portable EEG Auditory Evoked Potential Measurement System, Auxiliary in the Diagnostic of Hypoacusia*, proc. Electronics, Robotics and Automotive Mechanics Conference (CERMA) 2010 (September 28 - October 01, 2010), 597-601
- [7] T. Lim and Y. O. Xu, 2004. *A low-power and low-offset CMOS front-end amplifier for portable EEG acquisition system*, proc. Biomedical Circuits and Systems, 2004 IEEE International Workshop on, 17-20
- [8] H. Chen, D. Ye, and J. Lee, 2007. *Development of a Portable EEG Monitoring System based on WLAN*, proc. the 2007 IEEE International Conference on Networking, Sensing and Control, 460-465
- [9] J. Sarik and I. Kymisses 2010. *Lab kits using the Arduino prototyping platform*, proc. Frontiers in Education Conference (FIE), 2010 IEEE, T3C-1-T3C-5
- [10] Badillo, L. 2003. *low noise multichannel amplifier for portable EEG biomedical applications*” proc. Engineering in Medicine and Biology Society, 2003. Proceedings of the 25th Annual International Conference of the IEEE , 4, 3309-3312
- [11] B. B. Winter and J. G. Webster, 1983. *Driven-Right-Leg Circuit Design*, IEEE Transactions on Biomedical Engineering, 30, 1, 62-66
- [12] B. Blankertz, C. Sannelli, S. Halder, E. M. Hammer, A. Kübler, K. R. Müller, G. Curio and T. Dickhaus, 2010. *Neurophysiological predictor of SMR-based BCI performance*, NeuroImage, 51, 1303-1309
- [13] C. J. James, 2007. *Blind Source Separation in single-channel EEG analysis :An application to BCI*, proc. Proceedings 28th Annual International Conference IEEE Engineering in Medicine and Biology Society (EMBS)