# Development of a Virtual Keyboard System Using a Bio-signal Interface and Preliminary Usability Test

Kwang-Ok An, Da-Hey Kim, and Jongbae Kim

Korea National Rehabilitation Research Institute(KNRRI), Seoul, Korea
anko04@korea.kr, dlfpdls87@naver.com, jbkim@nrc.go.kr

**Abstract.** People with severe speech or language problems rely on augmentative and alternative communication (AAC) to supplement existing speech or replace speech that is not functional. However, many people with severely motor disabilities are limited to use AAC, because most of AAC use the mechanical input devices. In this paper, to solve the limitations and offer a practical solution to disabled person, a virtual keyboard system using a bio-signal interface is developed. The developed system consists of bio-signal interface, training and feedback program, connecting module and virtual keyboard. In addition, we evaluate how well do subjects control the system. From results of preliminary usability test, the usefulness of the system is verified.

**Keywords:** augmentative and alternative communication, bio-signal interface, preliminary usability test, virtual keyboard system.

## 1 Instruction

Supporting disabled person's communication is an important factor that influences a person's ability to express their needs, participate in decision-making about their care, and maintain meaningful relationship within their community. Augmentative and alternative communication (AAC) can to compensate for communication problems related to disabilities thereby contributing to increased quality of life and independence. In the majority of existing AAC, mechanical input devices such as switch, keyboard and joystick have widely used because those are widespread available, robust and operationally simple [1]. However, many people with severe motor disabilities such as the amyotrophic lateral sclerosis, brainstem stroke, cerebral palsy, and spinal cord injury are limited, uncontrollable, or no hand or arm movement to use the mechanical input devices.

Recently, many advances have been made in interface technologies, by means of bio-signal [2-8]: infrared sensing, electromyography, electrooculogram, computer vision, and brain wave. Especially, brain computer interface (BCI) can be an alternative approach to those who are lack any useful muscle control or even locked-in. It can be served by using various imaging technologies such as electro/magneto-encephalography (E/MEG), positron emission tomography (PET), functional

M. Kurosu (Ed.): Human-Computer Interaction, Part V, HCII 2013, LNCS 8008, pp. 3–9, 2013.

magnetic resonance imaging (fMRI), and optical imaging. Among them, MEG, PET, fMRI, and optical imaging are still technically demanding and expensive. Furthermore, PET, fMRI, and optical imaging, which depend on blood flow, have long time constants and thus are not suitable for rapid communication. For now, therefore, scalp-recorded EEG is the main interest due to its advantages of relatively low cost, convenient operation and non-invasiveness [9].

BCI using scalp-recorded EEG up to present, however, have been primarily used in laboratory and medical fields owing to some limitations: 1) wet electrodes - most recording systems use wet electrodes, in which electrolytic gel is required to reduce electrode skin interface impedance. Using wet electrodes is uncomfortable to wear. 2) multi-channels - the recording system with multi-channels requires a long preparation time, thus are unsuitable for real-life applications. Moreover, a large amount of channels make the system quite big, complex and expensive.

On the other hand, some companies have released practical BCI headsets such as EPOC (Emotiv), neural impulse actuator (OCZ Technology), and mindset (Neurosky) [10-13]. These headsets have brought the field of BCI out of its infancy (clinical trials of invasive BCI technologies) into a phase of relative maturity through many demonstrated prototypes in gaming, PC applications, automotive, and robotics industries.

In this paper, to solve the limitations of conventional interfaces and offer a practical solution to disabled person, a real-time bio-signal interface that includes one dry sensor, wireless transmission, and signal processing is developed. Then, a virtual keyboard system using a bio-signal interface is developed. In addition, we evaluate how well do subjects control the developed system. 6 subjects (2 able-bodied subjects, 2 subjects with severe motor disabilities due to spinal cord injury, 2 subjects with amyotrophic lateral sclerosis) participated in preliminary usability test. From the results, the usefulness of the system is verified.

## 2 The Virtual Keyboard System

Fig. 1 shows the virtual keyboard system. It consists of bio-signal interface, training and feedback program, connecting module, and virtual keyboard.

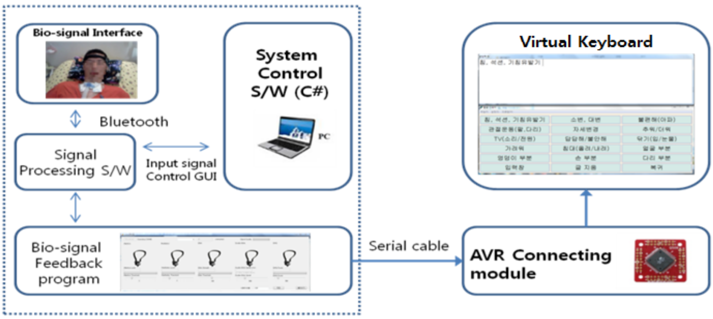


**Fig. 1.** The configuration of the developed system

### 2.1 Bio-signal Interface

In developed process, we considered the following issues: 1) for convenient use, one dry sensor technology and wireless transmission are needed. 2) To obtain stable performance, recorded signal should be intensive to interference. 3) It is difficult for people with severe motor disabilities to adjust the contact of sensors without the help from others when the poor contact is occurred. To solve the problem, the structure that sensors can be firmly attached to the forehead of the user is required. 4) To apply the developed system to a large number of users with diverse range of disabilities, detection of various signals including brain wave is needed. Then we co-developed the bio-signal interface with Neurosky. Fig. 2 shows the developed bio-signal interface. It includes the sensor that touch the forehead, reference points located on ear-clip and on-board chip that processes all of the data.

The developed interface collects bio-signals that are intended by subject. Then obtained signal are classified into 5 different control signals: attention (the level of mental "focus" of "attention"), meditation (the level of mental "calmness" or "relaxation"), eye blink, double blink, and jaw clench. Each control signal can be used like a on/off switch using the threshold set by the subject.

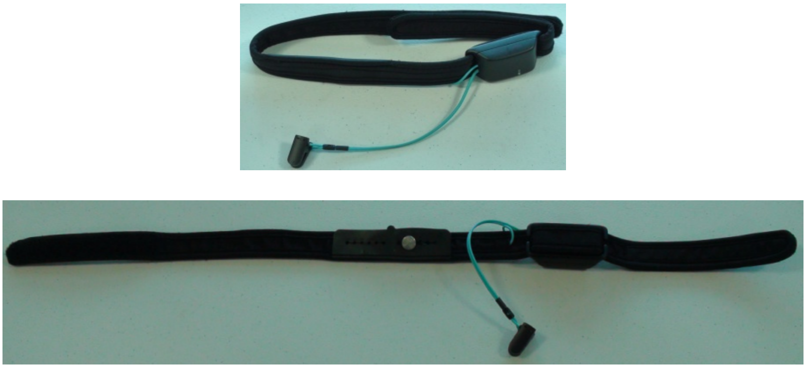

**Fig. 2.** The developed bio-signal interface

### 2.2 Training and Feedback Program

We developed the training and feedback program like as Fig. 3. The visual feedback is provided to the subjects to monitor performance results. In addition, during training, the level of thresholds can be adjusted based on the subject's condition. If the level of each control signal is greater than the threshold set by the user, the light bulb will turn on.

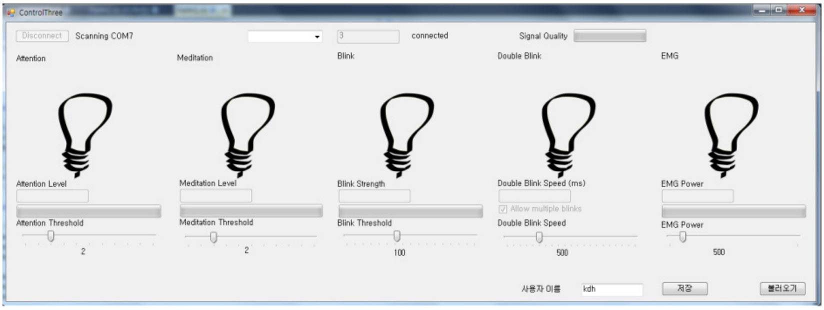


**Fig. 3.** The training and feedback program

## 2.3 Connecting Module

The connecting module uses 8-bit MCU to control the virtual keyboard according to PS/2 keyboard protocol. It sends 'Tab' key to PC whenever the light bulb turns on.

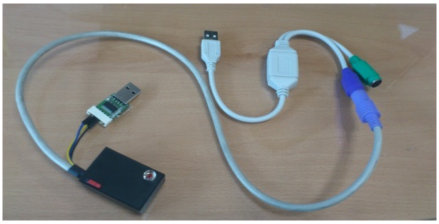

**Fig. 4.** The connecting module

## 2.4 Virtual Keyboard

A virtual keyboard presents an image of a keyboard on the computer screen and the subject selects the keys on the screen image. The name of virtual keyboard used in this paper is 'Clickey'. In scanning mode, lights scan letters and symbols displayed on computer screen. The subjects use the bio-signal interface to make selection.


**Fig. 5.** Clickey

# 3 Preliminary Usability Test

## 3.1 Subjects

6 subjects (2 able-bodied subjects, 2 subjects with severe motor disabilities due to spinal cord injury, 2 subjects with amyotrophic lateral sclerosis) participated in preliminary usability test. None of them had ever utilized the developed system. They assisted to their informed consent to participate in the test.

## 3.2 Test Setup

The objective of the test is to assess the possibility of practical use and obtain a wide variety of opinions on improvement. So, we lend the developed system to participants for 10 days and perform the usability test three times (1st day, 5th day, and 10th day). Fig. 6 shows ALS subject using the developed system.

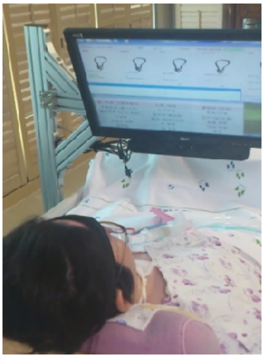

**Fig. 6.** ALS subject using the developed system

The following are the procedure of the usability test.

1. The headband is oriented so that the forehead sensor is facing the subject and ear-clip is on the left. Then, the headband is placed towards subject's head and the band is wrapped around head with a secure fit.
2. According to the subject's properties, the thresholds of control signals are adjusted.
3. In case of the first test, training with feedback can be continued for up to 30 minutes.
4. In each session, the subject is instructed to activate control signals 5 times in random order. Subject's task is to turn on the light bulb of target control signal. In case of an incorrect activation, subjects have to continue the given instruction. Each subject perform three sessions on the same day with 5-minutes breaks between the sessions to minimize fatigue.
5. After 10-minutes break, the subject selects the kind of control signal. Then the subjects is instructed to write 25 letters by using virtual keyboard.

6. We conduct a survey about the appearance of the system, performance degree, level of satisfaction, intention of purchase. Each item is scored by the subject according to a ten-point scale.

### 3.3 Results

The Table 1 shows the results of test. From the results, we are known that the developed system could be a practical solution because all the participants completed the test more than twice and they showed a high understanding of the developed system. Besides, there is little difference between able-bodied and disabled subjects. On the other hand, intra-subject variability (the degree of variability between control signals for each participant) and inter-subject variability (the degree of variability among participants in each control signal) were slight high. This high intra- and inter-subject variability denoted that they had different properties according to control signals and they activated the control signal on their own way. Therefore, it is very important that every person has to know which control signal is right for him or her by using training program.

Especially, according to the survey on intention of purchase, subjects with amyotrophic lateral sclerosis showed higher interest in that system. In addition, we obtained a wide variety of opinions on improvement (feelings of wearing, accuracy, and so on).

**Table 1.** The results of test

| | | Able-bodied subjects | | SCI subjects | | ALS subjects | |
|---|---|---|---|---|---|---|---|
| | | Sub 1 | Sub 2 | Sub 1 | Sub 2 | Sub 1 | Sub 2 |
| Appearance of the system | 1st | 7 | 7 | 2 | 7 | 5 | 9 |
| | 5th | 7 | 8 | 4 | 7 | 5 | 8 |
| | 10th | 7 | 7 | 5 | 8 | 6 | 8 |
| Performance degree | 1st | 5 | 8 | 4 | 8 | 8 | 6 |
| | 5th | 3 | 8 | 7 | 7 | 6 | 9 |
| | 10th | 8 | 8 | 3 | 8 | 6 | 9.5 |
| Level of satisfaction | 1st | 5 | 8 | 4 | 8 | 8 | 8 |
| | 5ht | 5 | 8 | 7 | 6 | 5 | 9 |
| | 10th | 6 | 8 | 4 | 7 | 5 | 9 |
| Intention of purchase | 1st | 8 | 7 | 5 | 8 | 9 | 8 |
| | 5th | 8 | 7 | 8 | 7 | 10 | 9 |
| | 10th | 8 | 7 | 7 | 8 | 10 | 9 |
| Mission time (25 letters) | 1st | 29:30 | 23:51 | 16:54 | 16:25 | 11:06 | - |
| | 5th | 12:21 | 14:59 | 12:39 | - | 21:03 | 18:53 |
| | 10th | 16:36 | 09:29 | 09:17 | 26:36 | - | 15:22 |

## 4 Conclusions

In this paper, the virtual keyboard system is proposed in order to solve the limitations of conventional AAC and offer a practical solution for disabled person. It consists of bio-signal interface, training and feedback program, connecting module, and virtual keyboard. To apply the developed interface to users with diverse range of disabilities, it can measure bio-signals and obtained signals are classified into 5 different control signal. In addition, to help subjects modulating the control signal activation, training and feedback program is developed.

The developed system was validated by 6 subjects (2 able-bodied subjects, 2 subjects with severe motor disabilities due to spinal cord injury, 2 subjects with amyotrophic lateral sclerosis) in preliminary usability test. In the future, we will improve the developed system based on the results of survey.

**Acknowledgments.** This research was supported by a grant (code #12-A-01, #13-A-01) from Korea National Rehabilitation Research Institute.

## References

1. Cook, A.M., Hussey, S.M.: Assistive Technologies: principles and practices, 3rd edn. Mosby (2008)
2. Tai, K., Blain, S., Chau, T.: A review of emerging access technologies for individuals with severe motor impairments. Assit. Technol., 204–209 (2008)
3. Schalk, G., et al.: BCI 2000: A general-purpose brain-computer interface (BCI) system. IEEE Trans. Biomed. Eng. 51, 1034–1043 (2004)
4. Lin, C.-T., et al.: Development of wireless brain computer interface with embedded multitask scheduling and its application on real-time driver's drowsiness detection and warning. IEEE Trans. Biomed. Eng. 55, 1034–1043 (2008)
5. Kauhanen, L., Jylanki, P., et al.: EEG-based brain-computer interface for tetraplegics. Comput. Intell. Neurosci., 1–11 (2007)
6. Barreto, A.B., et al.: A practical EMG-based human-computer interface for users with motor disabilities. Journal of Rehabilitation Research and Development 37, 53–64 (2000)
7. Lturrate, I., et al.: A noninvasive brain-actuated wheelchair based on a P300 neurophysiological protocol and automated navigation. IEEE Trans. Robot. 25, 614–627 (2009)
8. Muller-Putz, G.R., Pfurtscheller, G.: Control of an electrical prosthesis with an SSVEP-based BCI. IEEE Trans. Biomed. Eng. 55, 361–364 (2008)
9. Graimann, B., et al.: Brain-Computer Interfaces, ch. 8. Springer, Heidelberg (2010)
10. Wolpaw, J.R., et al.: Brain-computer interfaces for communication and control. Clin. Neurophysiol. 113, 767–791 (2002)
11. Emotiv. EPOC neuroheadset, http://emotiv.com http://www.emotiv.com/apps/epoc/299
12. OCZ Technology. NIA game controller, http://ocztechnology.com, http://www.ocztechnology.com/nia-game-controller.html
13. Neurosky, mindset, http://neurosky.com, http://neurosky.com/Products/MindSet.aspx