Thesis for Master’s Degree

A Quick and Easy Brain-Computer Interface Speller System for Android Mobile Application

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석 사 학 위 논 문

안드로이드 모바일 어플리케이션을 위한 빠르고 쉬운 뇌-컴퓨터 인터페이스 문자 입력기 시스템

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정 보 통 신 공 학 부

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Abstract

An electroencephalography (EEG) based brain computer interface (BCI) is an alternative communication and control channel between human and external devices. The EEG is an input source signal which is recording of electrical activity of the brain recorded with electrodes on the scalp. This new communication technique allows human to control not only electronic equipment like computer, mobile devices but also vehicle like car, wheelchair using brain signal which is measured from a user for entertainments, games, medical engineering, rehabilitation, and daily life.

The biggest change in development of mobile devices, including smartphones, tablets has been made over the past few years. In the BCI research, a variety of the BCI speller systems already have been developed with the aim of improving quality of lives and used in real life, hospital and research area. However, most of the conventional BCI speller systems are experimented with large display like computer monitor and consist of English and number. Also, it takes a long time to spell a full sentence which user wants to input.

Along with development of mobile devices, we develop a BCI speller system for android mobile application to resolve the difficulties of the conventional BCI speller systems In this speller system, we use the Emotiv EPOC+ which is kind of wireless BCI measurement device of EMOTIV Company. Our BCI speller system mainly consists of Emotiv EPOC, android mobile application part, Java console program part and web database part. The console program is written by Java language with Eclipse tool. The android mobile application of speller was made in the Android Studio tool.

In this thesis, we perform some of experiments with 5 subjects to evaluate the performance of our proposed BCI speller system. From the results, we can verify that our speller system shows respectable accuracy.

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1 Introduction

A Brain-Computer Interface (BCI) establishes direct communication connections between human brain and external devices. Electroencephalography (EEG) is an input source signal which is recording of electrical activity of the brain recorded with electrodes on the scalp. With the BCI, a brain signal of human is recorded and used for enabling the human to interact with the external devices without the need for speech, gestures and any muscular activity. Originally, the BCI have been aimed at helping disabled people. But as time goes on, the BCI is widely used in various field including entertainments, games, medical engineering, rehabilitation, and daily life.

Most of the BCI systems are consist of signal acquisition part, signal processing part and application part as shown in figure 1. In the signal acquisition part, subject's EEG signal is acquired by the recording electrodes and then amplified with filters and digitized via an analog-to-digital converter [1]. The signal processing part consists of feature extraction part and classification part. In the feature extraction part, the digitized signal goes through a variety of feature extraction procedure such like spatial filtering, voltage amplitude measurements and spectral analysis. Through the feature extraction process, we can distinguish the proper signal characteristic from raw EEG signal and represent signal characteristic in a more meaningful and informative form, which is easy to interpreted by human and computer [2]. The BCI can use signal features which are in the time-domain or the frequency domain using feature extraction algorithms. For instance, amplitude and frequencies are important features of sensorimotor rhythms and SSVEP which are kind of EEG signals [3]. In the classification part, each of the EEG signals which is passed by feature extraction algorithm is classified according to group via translation algorithms. After that, the BCI classifies certain brain signal patterns and translates them into appropriate commands for BCI applications [3]. For most of BCIs, computer screen, mobile devices and the other appliances are correspond to the output devices and selection of targets, letters, characters and icons are correspond to the output. In the output part, signal which is processed by signal processing algorithm is used in computers, mobile devices and healthcare devices after converting refined signal to instructions for the output devices.

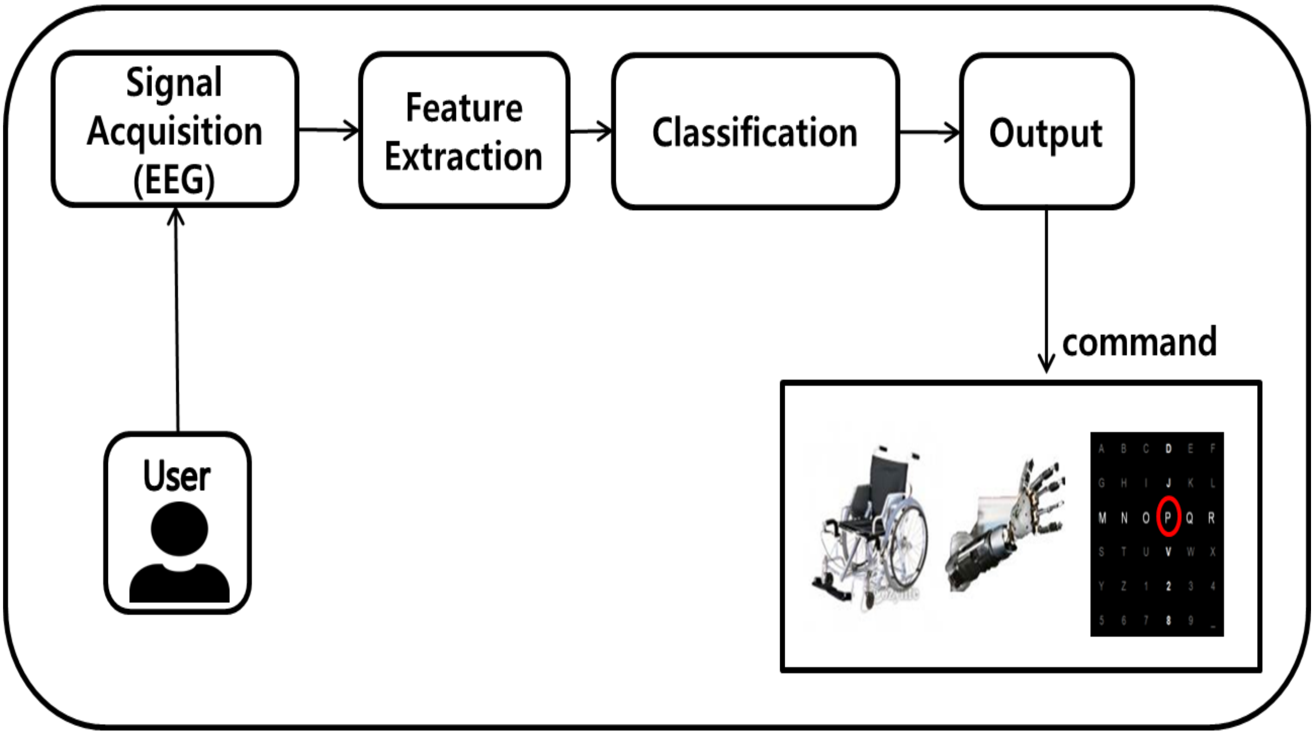


Figure 1. EEG based BCI system

In the past decades, a variety of BCI speller systems have been researched with the aim of improving quality of lives. So far, most of BCI speller systems have been developed with P300 signal, which is an event-related potential (ERP) elicited by infrequent, task-relevant visual stimuli [4]. Figure 2 shows the P300 based BCI speller system. Additionally, there are BCI speller systems in various ways with steady state visual evoke potentials (SSVEP) signal, hybrid P300-SSVEP and motor imagery signal. However, most of the BCI speller systems ever developed by a number of researchers, research institute and laboratory have been experimented with large display like CRT monitor screen.

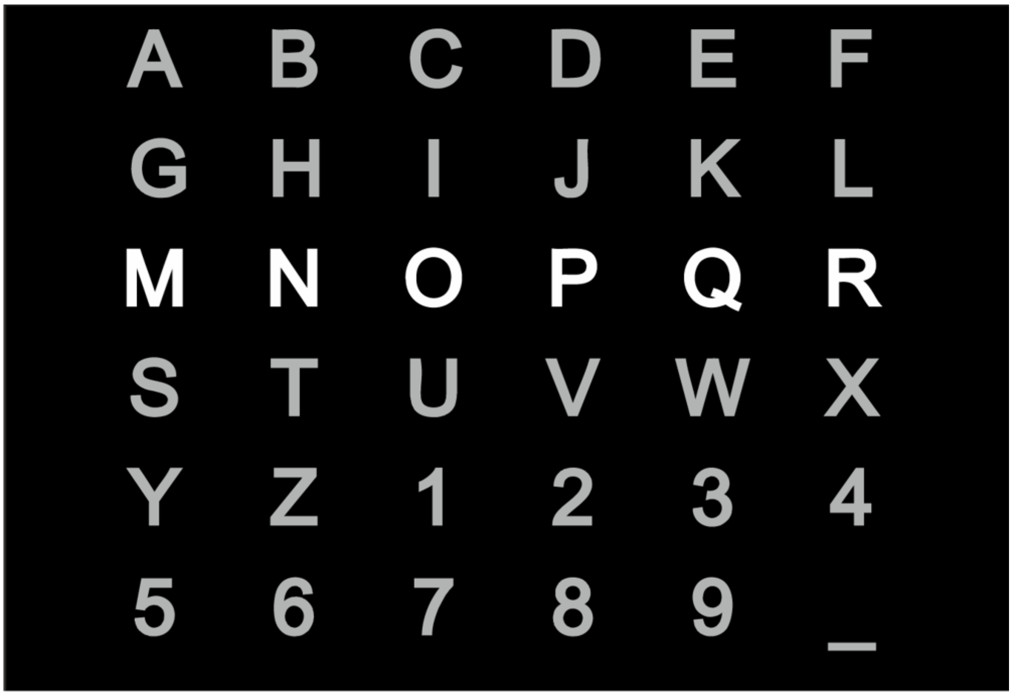


Figure 2. P300 based BCI speller system

The biggest change in development of mobile devices, including smartphones, tablets has been made over the past few years. Originally, mobile phones used to be extremely limited devices that were best used for making phone calls and sending text messages [5]. Today's mobile phones have more powerful performance and functions than previous ones. With the development of mobile devices, the number of mobile application development tool and application is also rapidly growing. This new generation enables developers to create various mobile applications more easily and quickly with knowledge of programming language and software development tool.

We propose an application of Brain-Computer Interface speller system for communication with people using the mobile devices. We use the Emotiv EPOC which is kind of wireless BCI measurement device of EMOTIV Company. This application system was made by the Android studio tool to operate application in Android smart phone.

This paper will be divided into the following seven subchapters: Introduction, Motivation, Research Contents, Related Works, Research Process, Results, Conclusion and Future works.

2 Motivation

In the past decades, a variety of BCI speller systems have been researched with the aim of improving quality of lives and inputting text rapidly. Consequently, the conventional BCI speller systems have accomplished a great deal and BCI area also has progressed a lot. But, there are several problems with the conventional BCI speller system. Firstly, most of the conventional BCI speller systems which are already developed only consist of English and number. Secondly, most of the previous developed BCI speller systems are experimented with large display such like computer CRT monitor screen. Thirdly, people who have to use BCI speller uses only a few of sentences in several situation such like emergency room, patient's room and their home. It takes a long time to spell a full sentence which user wants to input.

A variety of mobile devices with powerful performances and various functions, including smartphones, tablets have been released over the past few years. Along with development of mobile devices, we develop a BCI speller system for android mobile application to resolve the difficulties of the conventional BCI speller systems. In our BCI speller system, we adopt Hangul (Korean language), not English.

Mobile devices such like smart phone and tablet have a limited display size to adjust conventional BCI speller paradigm. Structure of Hangul also makes adjusting conventional BCI speller paradigm difficult for our BCI speller system. Table 1 shows the structure of Hangul. One syllable of Hangul consists of the sequence of a Choseong, a Jungseong and a Jongseong [6]. If BCI Hangul speller adopt conventional BCI speller paradigm like P300, it requires too much time and large display size.

Component	Character
Initial consonant (Choseong)	ㄱ , ㄲ , ㄴ , ㄷ , ㄹ , ㅁ , ㅂ , ㅃ , ㅅ , ㅆ , ㅇ , ㅈ , ㅉ , ㅊ , ㅋ , ㅌ , ㅍ , ㅎ
Middle vowel (Jungseong)	ㅏ , ㅐ , ㅑ , ㅒ , ㅓ , ㅔ , ㅕ , ㅖ , ㅗ , ㅘ , ㅙ , ㅚ , ㅛ , ㅜ , ㅝ , ㅞ , ㅟ , ㅠ , ㅡ , ㅢ , ㅣ
Final consonant (Jongseong)	ㄱ , ㄲ , ㄳ , ㄴ , ㄵ , ㄶ , ㄷ , ㄹ , ㄺ , ㄻ , ㄼ , ㄽ , ㄾ , ㅀ , ㅁ , ㅂ , ㅄ , ㅅ , ㅆ , ㅇ , ㅈ , ㅊ , ㅋ , ㅌ , ㅍ , ㅎ

Table 1. Structure of the Hangul

Figure 3 shows our proposed BCI speller system paradigm. First, the Hangul characters (Choseongs) are arranged in both sides of android mobile application screen. A white quadrangle which is located in right side of screen is flickered at 7.5 Hz frequency. If user wants to select right side of character, user just only needs to gaze at right side of white quadrangle. Otherwise, if user wants to select left side of character, user just only needs to close eyes. And then, signal processing process is progressed and classify the signal whether character which user wants to select is a left or right. The above process is repeated until 2 Choseongs are selected. After 2 Choseongs are selected, android application searches full sentence corresponding to 2 Choseongs based on already stored full sentences. Finally, the selected full sentence is typed on the android application display as shown in figure 3. Our speller system enable user to spell a full sentence just by spelling a 2 Choseongs and help user rapidly to spell a full sentence which they want to select in mobile devices.

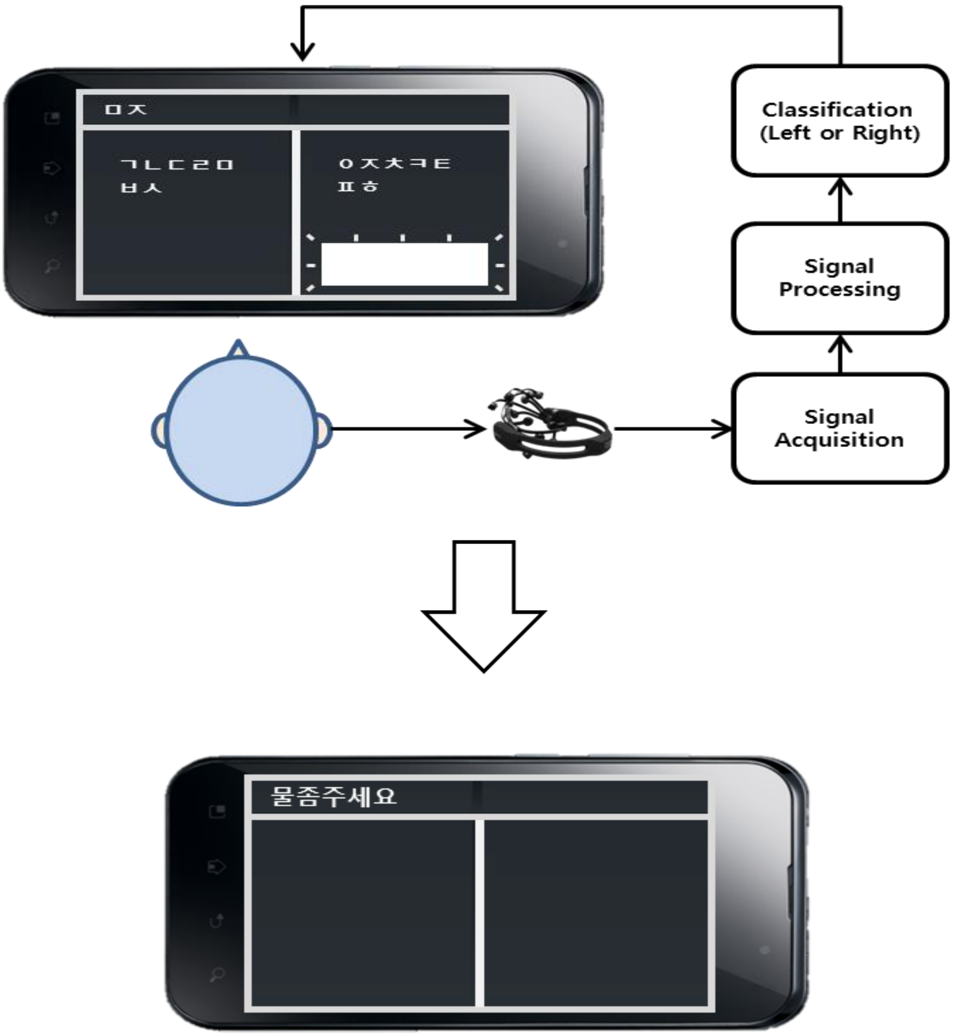


Figure 3. Proposed BCI speller system paradigm

3 Research Contents

In this thesis, we develop BCI speller system according to following 5 major steps. The first step for our research is hardware selection. Since EEG technology has become more accessible and robust over the past few years, a variety of EEG measurement devices already developed. So, we decide the type of signal which is used in our BCI speller system because there are many kinds of brain signal. We select a proper product among the already released EEG measurement devices. The second step is software development. To transfer raw EEG signal from the EEG measurement device to the mobile device, several of program are required. In this step, we consider the programming language and integrated development environment (IDE) for program development. The third step is speller development. Development of signal processing algorithm and character search algorithm in android mobile device are required. Also, development of android application‘s function is required to receive raw EEG signal from the EEG measurement device. The fourth step is system integration. In this step, we integrate each part of the above into one system. Final step is demonstration. After integration process, we perform some of experiments with subjects to evaluate the performance of our proposed BCI speller system.

4 Related Works

The EEG brain activity patterns which are used in BCI systems are categorized into four different types: event–related desynchronization/synchronization (ERD/ERS) [8], steady state visual evoked potentials (SSVEP) [9], P300 [10], and slow cortical potentials (SCPs) [9]. In this chapter, I introduce conventional spellers and which are using P300, SSVEP and Hybrid signal.

Compared to other signals based BCI systems, P300 and SSVEP based BCI system has the advantage of having higher accuracy and information transfer rate (ITR). In addition, short/no training time and fewer EEG channels are required [7]. Two important factors of BCI system are ITR and training time. A general comparison of different BCI approaches is shown in figure 4 [7].

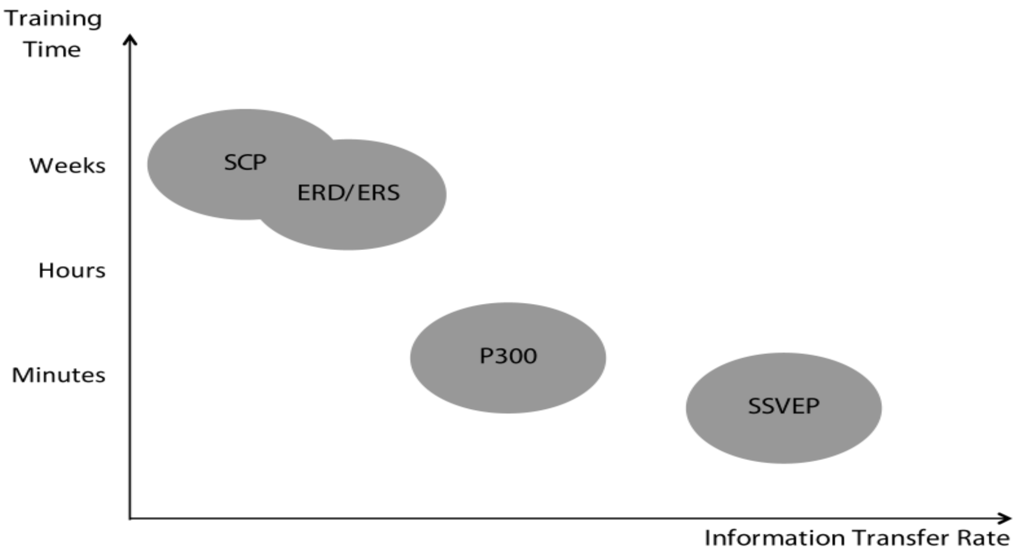


Figure 4. Comparison of different BCI approaches [7]

4.1 P300 BCI Systems

Event related potential (ERP) are the measurement of brain response to specific cognitive, sensory or motor events. P300 is one of the most used components of an ERP. A positive peak in the EEG, 300msec after onset of the stimulus is produced by the presentation of stimulus in an oddball paradigm [7]. The stimulus can either be visual, auditory or somatosensory. This evoked response in EEG is called P300 component of ERP [7]. Figure 5 shows conventional P300 speller paradigm. This original paradigm for P300 BCI speller is originally proposed by Farwell and Donchin in 1988 [11]. In this speller paradigm, user was presented with 6 by 6 matrix of characters. All rows and columns of matrix are successively and randomly intensified. Consequently, two out of 12 intensifications of rows or columns contain the target character (i.e. one particular row and one particular column) [12]. Signals evoked by stimuli that did contain the desired character are different from those evoked by the stimuli that did not contain the desired character. The non-flashing rows and columns of matrix not contribute in generating P300 [12]. After averaging several responses, the desired row and column is determined and the desired character is selected.

Figure 5. Conventional P300 speller paradigm

The spatial amplitude distribution is strongest in the occipital area of brain and is symmetric around central location Cz recorded based on the 10-20 international system [7]. Electrode channels that P300 is typically recorded from are shown in the Figure 6.

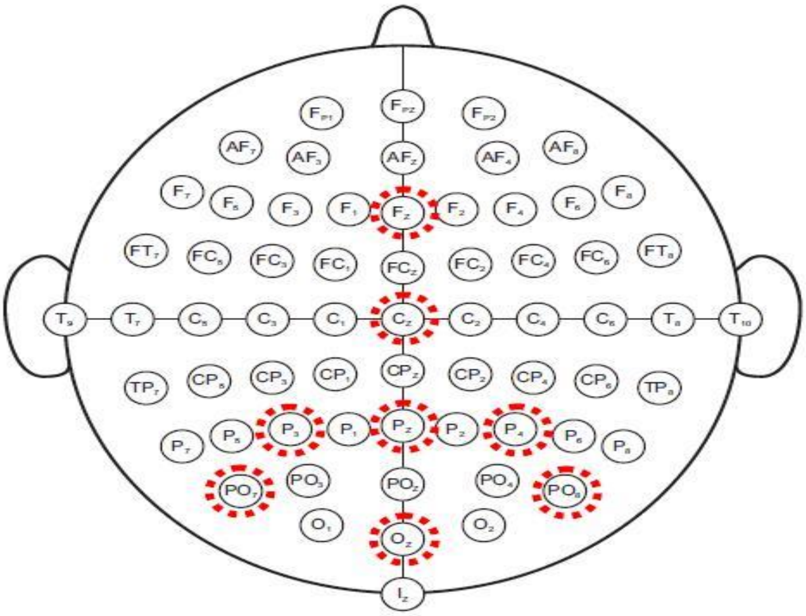


Figure 6. Electrode position for P300 detection [13]

Figure 7 shows P300 based Hangul input system which is introduced by research group of Korea university in South Korea. Previous stimulus presentation paradigm has been well suited to the English and it not optimal for a Hangul [6]. Because Hangul has a hierarchical structure: initial consonant, vowel, final consonant. This system is progressed according to block diagram of figure 8. In figure 7 (a), clusters of 'ㄱ', 'ㄲ', 'ㅋ' are grouped. So, user wants to select 'ㄱ', user firstly have to gaze at 'ㄱ' in figure 7 (a). And then screen of figure 7 (a) is shifted to figure 7 (c). Consequently, they effectively reduce window size of the interface using unique hierarchical structure of Hangul.

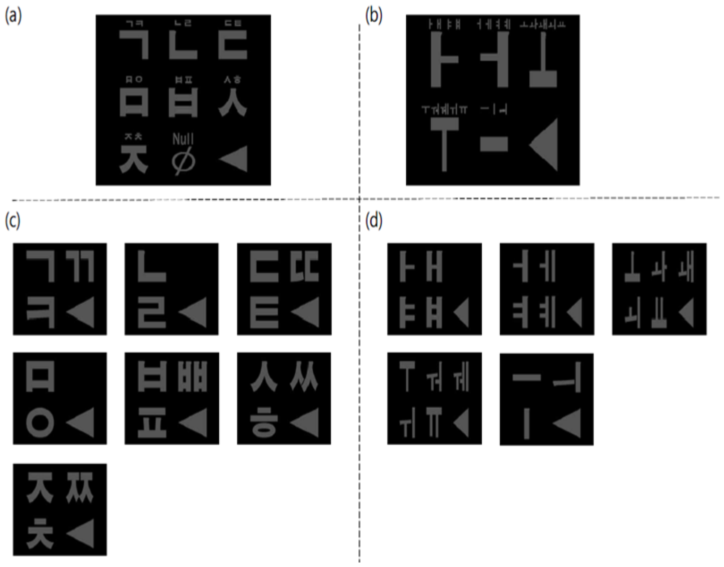


Figure 7. P300 based Hangul input system 1 [6]

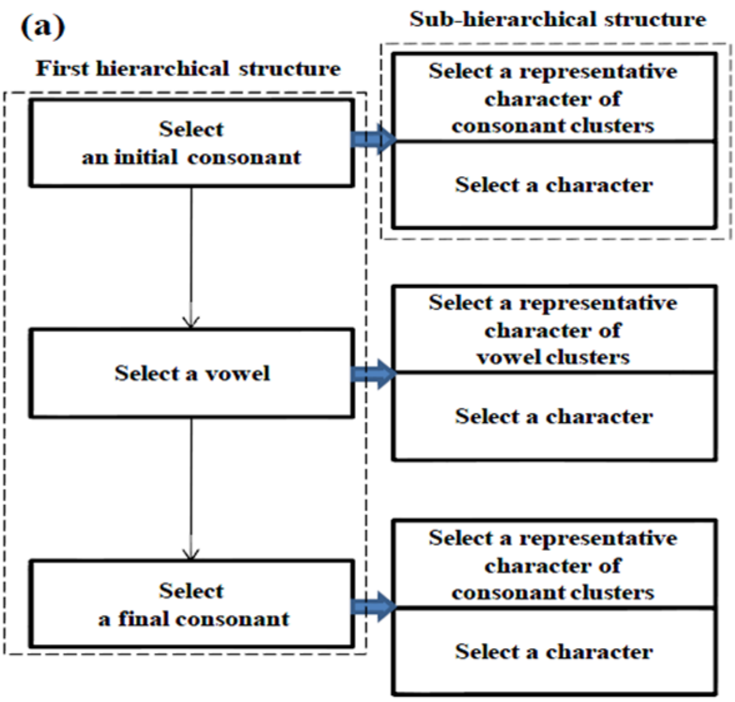


Figure 8. P300 based Hangul input system 2 [6]

4.2 SSVEP BCI systems

Electrophysiological studies results demonstrate increase in neural activity elicited by human gazing at stimulus. Visual evoked potentials are elicited by repetitive visual stimuli would generate stable voltage oscillations in EEG.

SSVEP is a continuous visual cortical response evoked by repetitive stimuli with constant frequencies [14]. The SSVEP contains the same fundamental frequency as the stimulus and some harmonics of the fundamental frequency [7]. When eye is stimulated by 3.5 Hz to 75 Hz frequency of repeated stimuli, the brain generates an electrical activity at the same frequency of the visual stimuli. This type of stimulus is a powerful indicator in the diagnosis of visual pathway function. In SSVEP BCI system allows no training or short time training for classifier. Also, patterns are clearly distinguishable by frequency [22]. SSVEP BCI system has high reliability of recognition.

A light-emitting diode (LED) for flashing is used in typical SSVEP based BCI system. The occipital area of brain is the area where SSVEP feature is generated more clearly. The most well-used signal processing technique to extract the SSVEP features from the raw EEG signal is power spectral density (PSD) using FFT of a data window with a fixed length [23][27]. Other methods which attempt to improve on robustness upon the FFT-based methods are autoregressive spectral analysis, and the frequency stability coefficient (SC) which has been shown to be better than power spectrum for short data windows; although training is necessary for building the SC model [7][25]. Furthermore, CCA is also an efficient method for online SSVEP-BCI, as the required data window lengths are shorter than those necessary for power spectrum estimation [7][24].

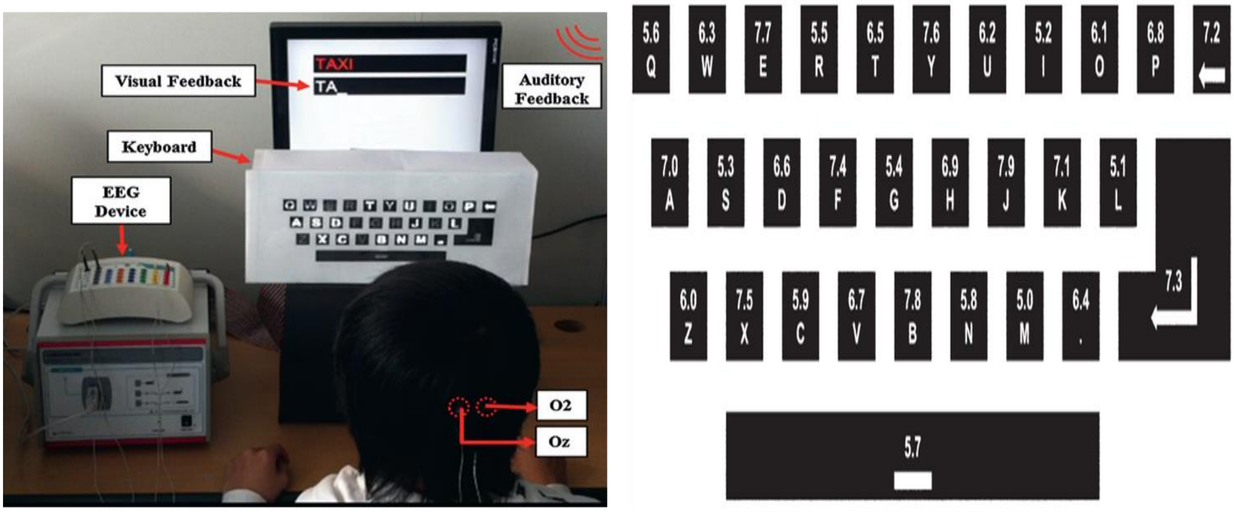


Figure 9. QWERTY style LED keyboard [4]

Figure 9 shows SSVEP based QWERTY-style LED keyboard from Hanyang University in South Korea. In the conventional SSVEP BCI spellers, target selection process is complicated because user has to conduct continuous commands to select target character. In this speller, user not requires need for multiple step process of the conventional SSVEP BCI speller. Proposed system enables the user to spell one target character per each target selection process [4].

4.3 Hybrid BCI systems

During development of BCI speller for past decades, there are some obstacles for BCI system performance of applicability, reliability, low ITR, high accuracy for all different subjects. In recent years, an extensive amount of work in BCI system has been invested based on utilizing the combination of different types of BCI systems, called hybrid BCI systems [7]. The main goal of hybrid BCI system is overcoming the limitations and difficulties of the conventional BCI systems.

4.4 Other BCI systems

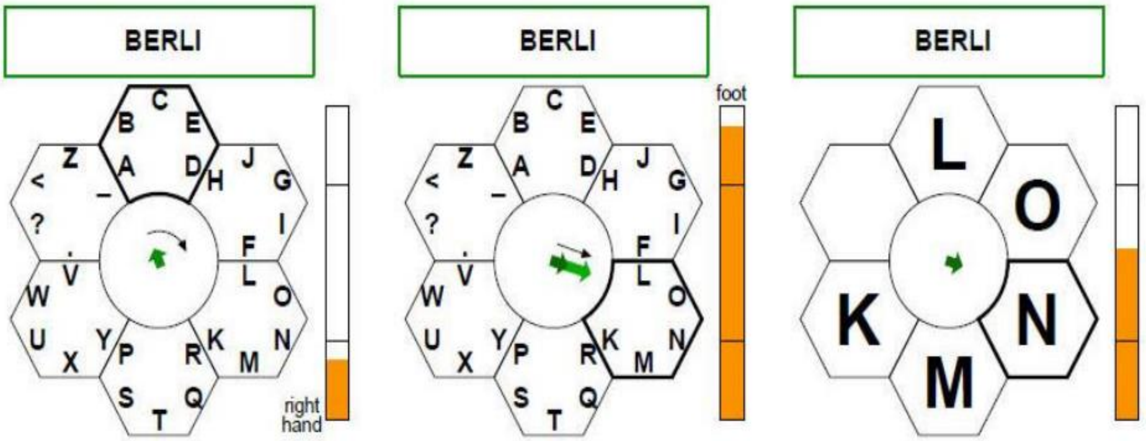


Figure 10. Hex-o-spell [15]

Figure 10 shows motor imagery based Hex-o-spell BCI speller. This speller developed by BCI group from Fraunhofer FIRST IDA, Germany. This system is controlled by two kinds of mental states: imaging right hand movement and imaging foot movement. If user wants to right direction of rotating arrow, the user has to imagine a right hand movement. Otherwise, if user wants to left direction of rotating arrow, the user has to imagine a foot movement.

5 Research Process

5.1 Hardware selection

In our speller system, we use two kinds of signal: SSVEP signal and Alpha rhythm. Because patterns of SSVEP signal and Alpha rhythm are clearly distinguishable by frequency [ ]. SSVEP we use is signals which coming from the brain in response to the visual stimuli in a particular frequency. In this thesis, we use the SSVEP signal to assess EEG capability of the measurement device. When human's eye is stimulated by from 3.5 to 75 Hz frequency repeated stimuli, a signal of the same frequency in the brain is produced. SSVEP is mainly measured at occipital lobe and relatively robust to the noise of the outside. Alpha rhythm we use is neural oscillations in the frequency range of from 8 to 12 Hz. Alpha rhythm also mainly measured at the occipital lobe as well. During the relaxed mental state, where the subject is at rest with eyes closed, strong alpha waves were found.

Since EEG measurement device technology has become more accessible and robust over the past few years [16]. A variety of EEG measurement devices are primarily found in markets for controlling games, toys, applications, mental training, research and rehabilitation area. Figure 11 and Table 2 show already produced EEG measurement devices which are the most user-friendly EEG devices now on the market. The comparison result shows that Emotiv EPOC is proper EEG device for our speller system. Because SSVEP signal and Alpha rhythm are measured at the occipital area. Devices except for Emotiv EPOC no have proper the number of electrodes and proper position. And Emotiv EPOC has good price compared to others.

(a) Nurosky Mindwave [17]

(b) Emotiv EPOC [18]

(c) Nurosky Mindset [17]

(d) PLX XWave [19]

(e) MyndPlay Brainband [20]

(e) Quasar DSI 10/20 [21]

Figure 11. EEG measurement devices

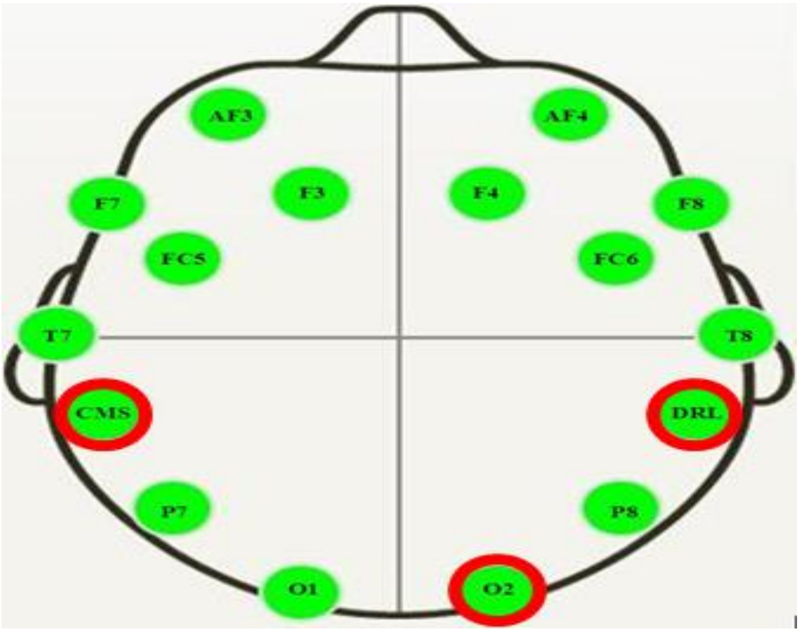
Device	Company	Electrodes	Price
Mindwave	Neurosky	1	$ 99.95
EPOC	Emotiv	14	$ 299
Mindset	Neurosky	1	$ 199.95
XWave	PLX devices	1	$ 90
Braindband	Myndplay	1	$ 205
DSI 10/20	Quasar	21	$ 19,995

Table 2. A list of EEG measurement devices

Table 3 shows specifications regarding Emotiv EPOC. The Emotiv EPOC headset is EEG-based input device, which is connected wirelessly to a PC. This allows the user to move freely without any connected cables. EPOC EEG sensors have to equipped with felt pads. These felt pads have to be moistened using a saline solution as a contact agent to the skin. EPOC has 14 channels and 2 reference channels. So, we can measure SSVEP signal and Alpha rhythm with EPOC. The channel name of the EPOC is based on the international 10-20 locations. Also EPOC has 128 sampling rate.

	EEG headset
Number of channels	14 (plus CMS/DRL reference, P3/P4 locations)
Channel names (International 10-20 locations)	AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, AF4
Sampling method	Sequential sampling, Single ADC
Sampliing rate	128 SPS
Resolution	14 bits 1 LSB = 0.51 uV (16 bit ADC, 2bits instrumental noise floor discarded)
Bandwidth	0.2 – 45 Hz, digital notch filters at 50 Hz and 60 Hz
Filtering	Built in digital 5th order Sinc filter
Dynamic range (input referred)	8400 uV
Coupling mode	AC coupled
Connectivity	Proprietary wireless, 2.4 GHz band
Battery life	12 hours
Impedance Measurement	Real-time contact quality using patented system

Table 3. Emotiv EPOC Specifications [18]



(a) Electrodes position of Emotiv EPOC

(b) USB dongle and saline

Figure 12. Electrodes position and accessories for Emotiv EPOC

After selecting the EEG measurement device, we conduct several of experiments to verify the SSVEP signal and Alpha rhythm with Emotiv EPOC. To verify Alpha rhythm, subject is asked to close eyes for 16 seconds. We can check the peak at the 10.51 Hz frequency domain through fast fourier transform (FFT) algorithm. Figure 13 shows the peak at the 10.51 Hz frequency.

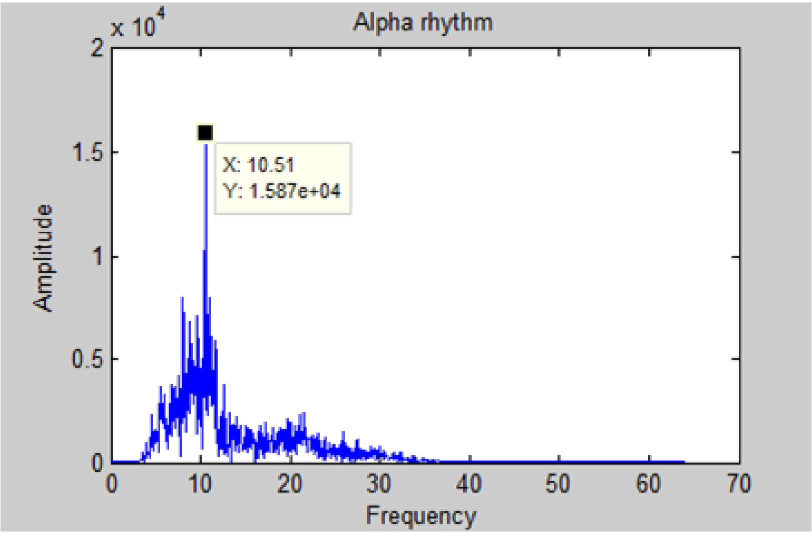


Figure 13. Peak at the 10.51 Hz frequency

And then, we conduct another experiment to verify the SSVEP signal. In this experiment, subject is asked to gaze 7.5 Hz blinking animation of android application for 16 seconds. We can check the peak at the 7.57 Hz frequency domain through FFT algorithm. Figure 14 shows the peak at the 7.57 Hz frequency.

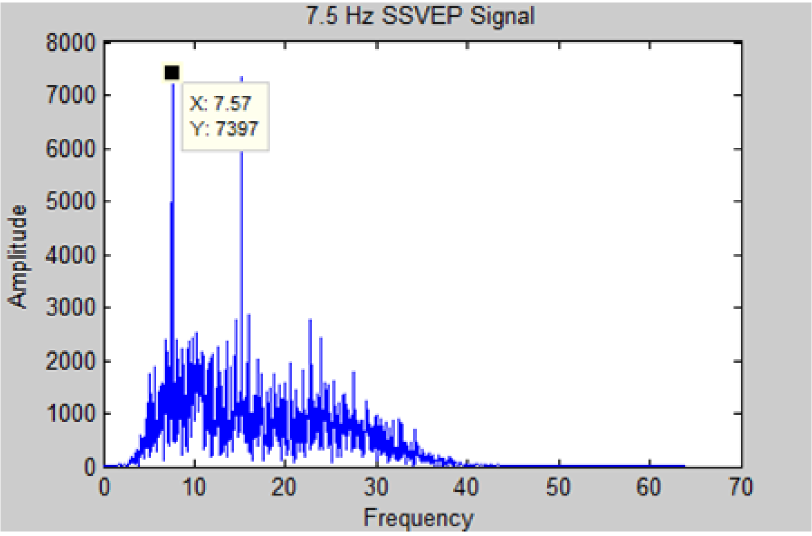


Figure 14. Peak at the 7.57 Hz frequency

5.2 Software Development

In this step, we have to send raw EEG signal from the measurement device to the web database. We developed a Java language based program in Eclipse which is kind of software development tools. Figure 15 shows diagram of the software development step of our speller system.

Figure 15. Block diagram of the software development step

EEGLog.java performs the following features. First one is interconnection between the Java based console program and Emotiv EPOC headset. After interconnection process, EEGLog.java receives 128 raw EEG signals from Emotiv EPOC headset per 1 second because Emotiv EPOC has 128 sampling rate. As soon as EEGLog.java receives 128 raw EEG signals from Emotiv EPOC, EEGLog.java upload 128 raw EEG signals to web database. Figure 16 shows ready state of EEGLog.java. When USB dongle is inserted into USB port of laptop, EEGLog.java waits for raw EEG signals. As soon as Emotiv EPOC headset power is turn on, EEGLog.java receives 128 raw EEG signals per 1 second. Figure 17 shows console program state of EEGLog.java after receiving EEG signals for 16 seconds. In console window of EEGLog.java, each line indicates 128 raw EEG signals per 1 second.

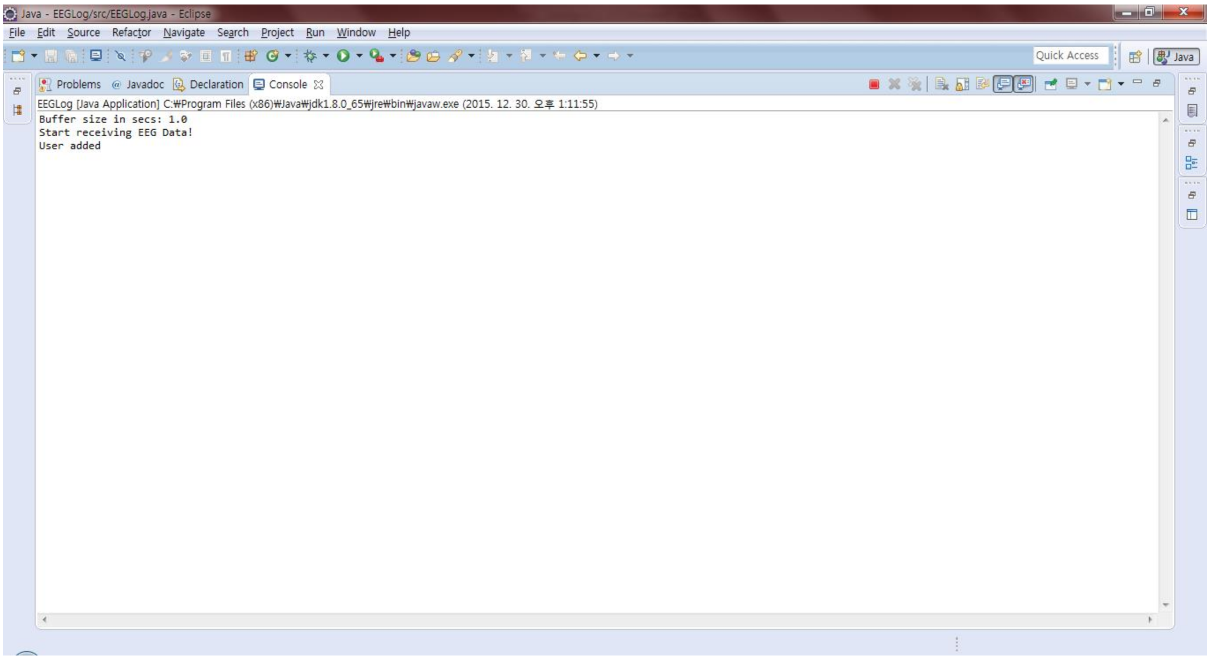


Figure 16. Ready state of EEGLog.java

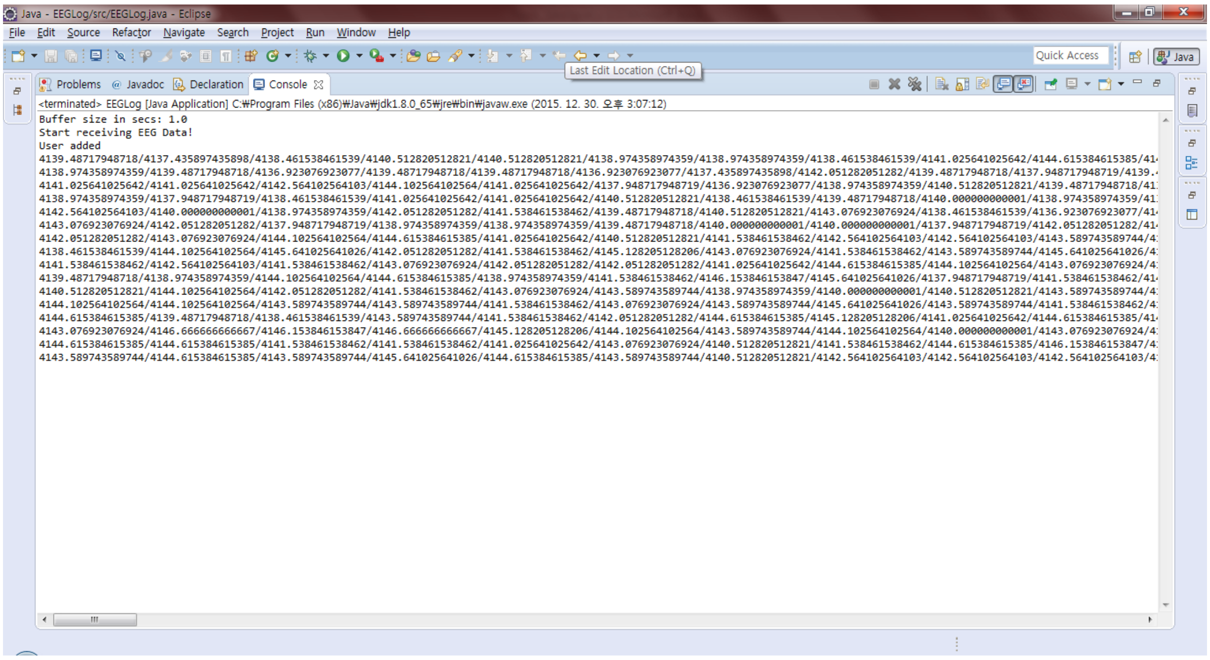


Figure 17. Reception state of EEGLog.java

5.3 Speller Development

In speller development step, we have to receive raw EEG signals from web database to the mobile device and develop android application for speller. Android application is developed by Android studio which is IDE for developing for the Android platform. Android studio is announced on May 16, at the Google I/O conference. Speller development step is developed according to following block diagram shown in figure 18.

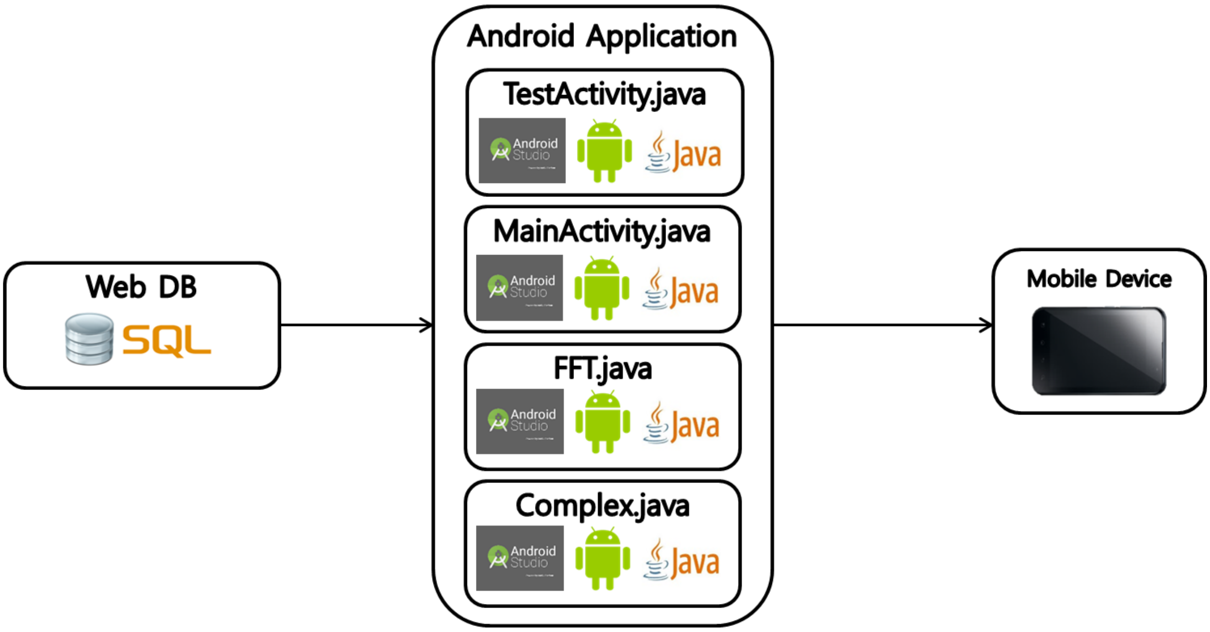


Figure 18. Block diagram of the speller development step

Our Android speller application is divided intoTestActivity.java, MainActivity.java, FFT.java and Complex.java. TestActivity.java receives 128 raw EEG signals per 1 second from web database and has function of blinking animation at 7.5 Hz frequency. Functions of Choseong search and binary classification are also included in TestActivity.java. In addition, event processing for android application and majority of functions in our android speller application are contained. In

MainActivity.java, beginning screen of android speller application and final output result screen are defined. Our android speller application uses FFT algorithms to find frequency corresponding to left or right side of screen. FFT.java and Complex.java perform returning maximum magnitude and frequency corresponding to maximum magnitude against raw EEG signals which are received from web database for 16 seconds.

5.4 System Integration

In system integration step, we integrate Emotiv EPOC, Java console program, web database and Android speller application into one system. Figure 19 shows block diagram of our integrated system. An Emotiv EPOC, Java console program 'EEGLog.java' and web database correspond to signal acquisition and transmission part. In this system, user can get a visual feedback through output result of mobile device.

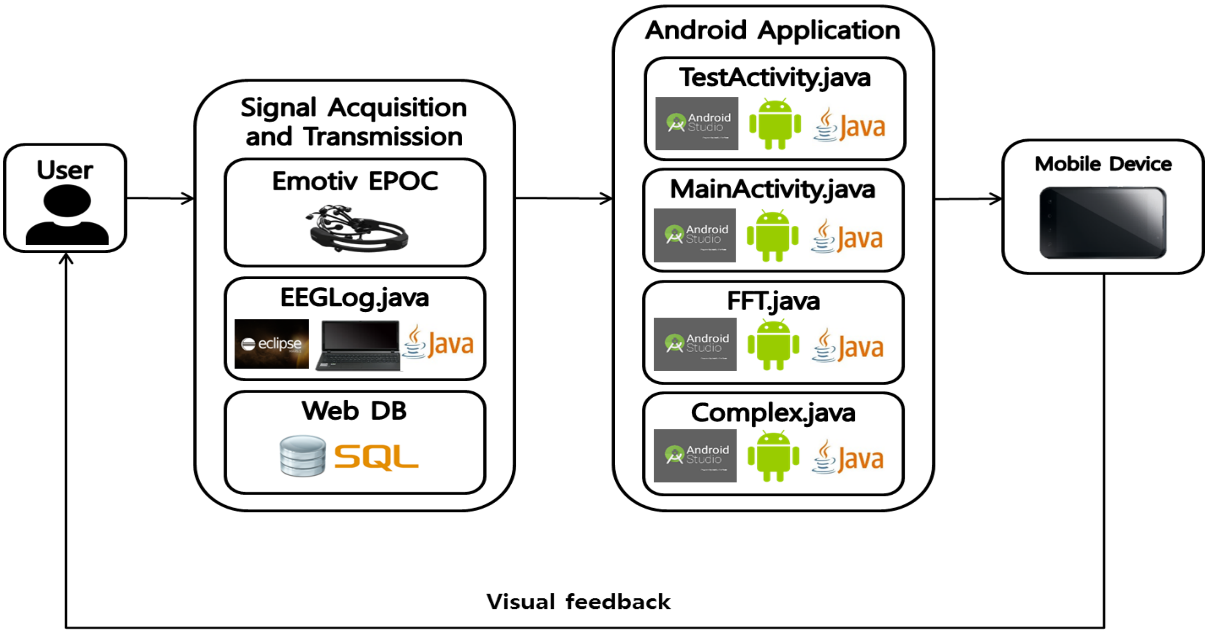


Figure 19. Block diagram of our integrated system

Figure 20 shows flow diagram of our speller system. At first, if user presses start button, Android speller application has 6 seconds as waiting time for preparation. After 6 seconds, user either has 16 seconds gazing blinking animation on the android speller application or closing eyes to select Choeseong which user wants to select. After 16 seconds of selection time, mobile device begin to vibrate for a moment. Newly arranged Choeseong application display is also presented at the same time. Namely, classification and vibration are progressed simultaneously. User has 6 seconds of waiting time for next selection. Until 2 Choseongs are selected, above process is repeated.

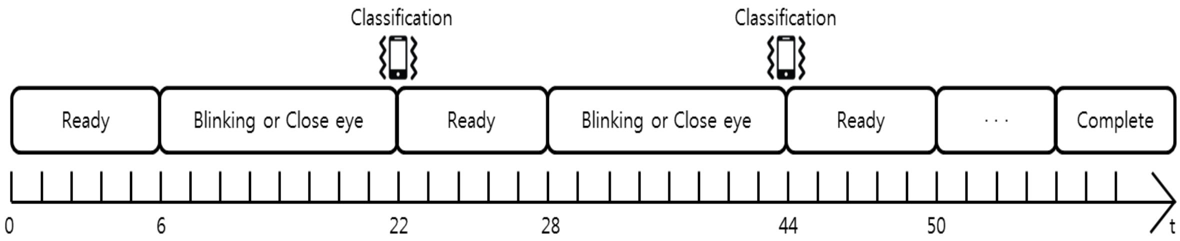
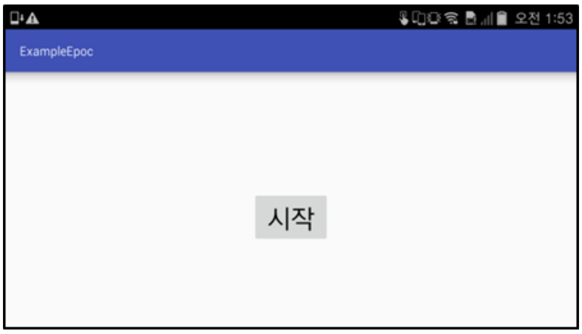


Figure 20. Flow diagram of speller system



(a)

(b)

(c)

(d)

(c)

Figure 21. Android application display changes 1

Figure 21 shows our Android speller application display change when user want to select Choseong ‘ㄱ’. Figure 21 (a) shows beginning screen of our application. If user presses start button, Android speller application is started. Through figure 21 and figure 22, selection process of 2 Choseongs : ‘ㄱ’, ‘ㅊ’ is described. If user presses the start button in previous step, Android application screen changes as shown in figure 21 (b).Choseong characters are arranged in both sides in group of 7. If user close eyes for 16 seconds, application screen changes like figure 21 (c). After application screen change like figure 21 (c), user has 6 seconds of waiting time. And if user closes eyes for 16 seconds once more, screen changes like figure 21 (d). In this android application screen, if user closes eyes for 16 seconds, Choseong ‘ㄱ’ is consequently selected as shown in figure 21 (e).

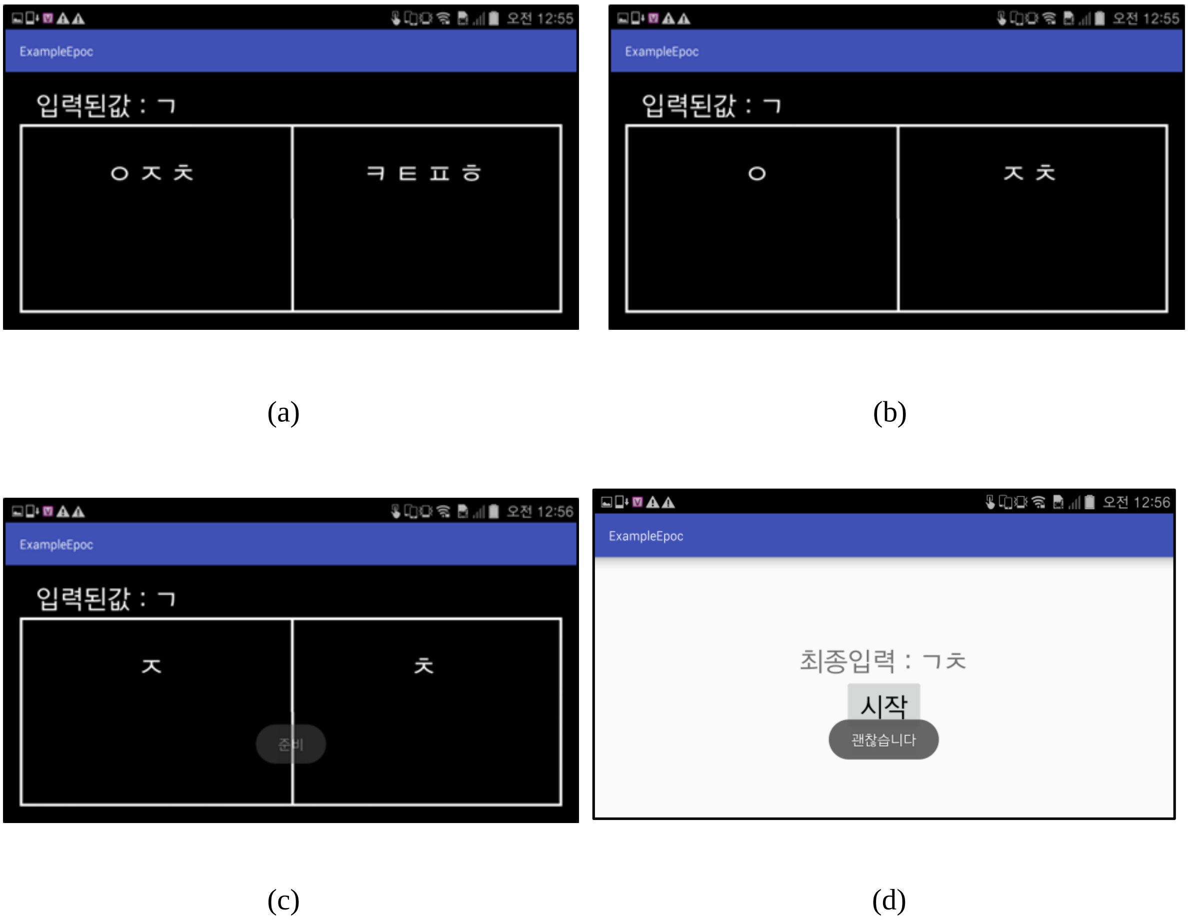


Figure 22. Android application display changes 2

From the figure 21(e), user start to select next target character ‘ㅊ’. Screen of arrangement of Choseongs of the figure 21 (e) turns into figure 22 (a). Finally, screen of figure 22 (d) is appeared.

5.5 Demonstration

After integration process, we perform some of experiments with subjects to evaluate the performance of our proposed BCI speller system. There are 13 full sentences in our BCI speller system. We conduct experiment with subjects and ask them to spell full sentences as shown in Table 4.

Choseongs	Full Sentence
ㅁㅈ	물좀주세요
ㅇㅈ	약좀주세요
ㄱㅈ	가족에게 연락해 주세요
ㅇㅅ	의사좀 불러주세요
ㄱㅎ	간호사좀 불러주세요
ㄱㅊ	괜찮습니다
ㅂㅍ	불편합니다
ㅎㅈ	화장실 가고 싶습니다.
ㅁㅇ	몸이 아픕니다
ㅌㅂ	티비좀 켜주세요
ㅁㅅ	무슨 약 인가요?
ㅇㄷ	어떻게 먹나요?
ㄴㄱ	나가고 싶습니다.

Table 4. Full sentence list of our system

6 Results

In this thesis, our experiment is conducted with VEGA POP-UP NOTE IM-A920S by PANTECH. Experiments are experimented with 5 participants of 5 men in 18 to 33 years old to verify the feasibility of our BCI speller system. The experiments are progressed in the room with darkroom. Subjects are engaged in experimentation with seated condition. Before starting experiment, subject are instructed how these application works. Finally, subjects are asked to spell Choseongs ‘ㄱ’, ‘ㄴ’,’ㄷ’, ‘ㄹ’, ‘ㅁ’, ㅂ’, ‘ㅅ’, ‘ㅇ’, ‘ㅈ’,. ‘ㅊ’, ‘ㅋ’, ‘ㅌ’, ‘ㅍ’, ‘ㅎ’ in regular order.

	Gender	**Age**	**Total**	**Correct**	**False**	**Accuracy**
Subject 1	Male	33	7	7	0	100 %
Subject 2	Male	28	14	13	1	92.86 %
Subject 3	Male	28	14	12	2	85.71 %
Subject 4	Male	18	14	14	0	100 %
Subject 5	Male	18	14	10	4	71.43 %
Total			63	56	7	88.89 %

Table 5. Experiments results 1 [26]

	Gender	**Age**	**Total**	**Correct**	**False**	**Accuracy**
Subject 1	Male	33	27	27	0	100 %
Subject 2	Male	28	54	52	2	96.3 %
Subject 3	Male	28	54	48	6	88.89 %
Subject 4	Male	18	54	54	0	100 %
Subject 5	Male	18	54	43	11	79.63%
Total			243	224	19	92.18 %

Table 6. Experiments results 2

Among the 5 participants, only 2 participants are well aware of the BCI and the other participants are not familiar with the BCI. In the table 5, we can check total accuracy is 88.89 %. Except for subject 5, most of the participants show good accuracy. In the table 6, we analyze another results based on experiments of the table 5.It takes total 3 classifications to spell Choseongs 'ㄱ', 'ㅇ'. Also, it takes total 4 classifications to spell Choseongs 'ㄴ','ㄷ', 'ㄹ', 'ㅁ', ㅂ', 'ㅅ', 'ㅈ',. 'ㅊ', 'ㅋ', 'ㅌ', 'ㅍ', 'ㅎ'. Based on the above this, we conduct another analysis. In the table 6, we can check total accuracy is 92.18 %.

7 Conclusion & Future works

In the past decades, a variety of BCI speller systems have been researched with the aim of improving quality of lives and inputting text rapidly. Consequently, the conventional BCI speller systems have accomplished a great deal and BCI area also has progressed a lot. But, there are several problems with the conventional BCI speller system.

A variety of mobile devices with powerful performances and various functions, including smartphones, tablets have been released over the past few years. Along with development of mobile devices, we develop a BCI speller system for android mobile application to resolve the difficulties of the conventional BCI speller systems. In this thesis, we propose a quick and easy BCI speller system for Android mobile application. In this system, we use two kinds of signal ‘SSVEP signal’ and ‘Alpha rhythm’.

In this thesis, we develop BCI speller system according to following 5 major steps; ‘Hardware selection’, ‘Software Development’, ‘Speller Development’, ‘System Integration’, ‘Demonstration’.

After 5 major steps, some of experiments are experimented with 5 participants of 5 men in 18 to 33 years old to verify the feasibility of our BCI speller system. And we can get an average of 88.89 % accuracy. Also, we can get an average of 92.18 % accuracy in another analysis.

In this thesis, since we focus on high accuracy of classification, information transfer rate (ITR) would be somewhat low. So, we attempt to reduce blinking animation time and closing eyes time for selection from 16 seconds to 10 seconds. If we successfully reduce blinking time and closing eyes time for selection, time to spell 2 Choseongs is effectively decreased. Consequently, we can spell a full sentence in less time than current system.

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