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

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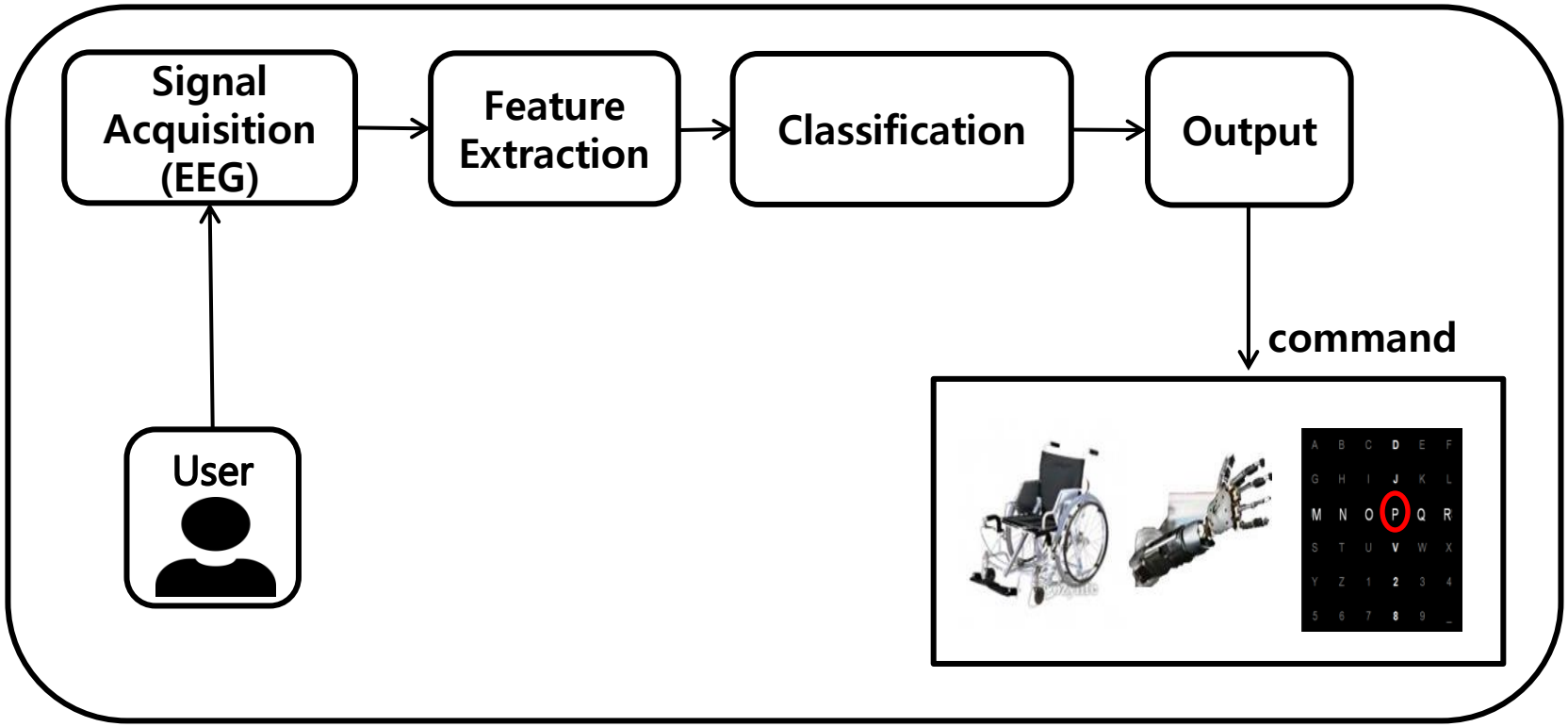
I. Introduction

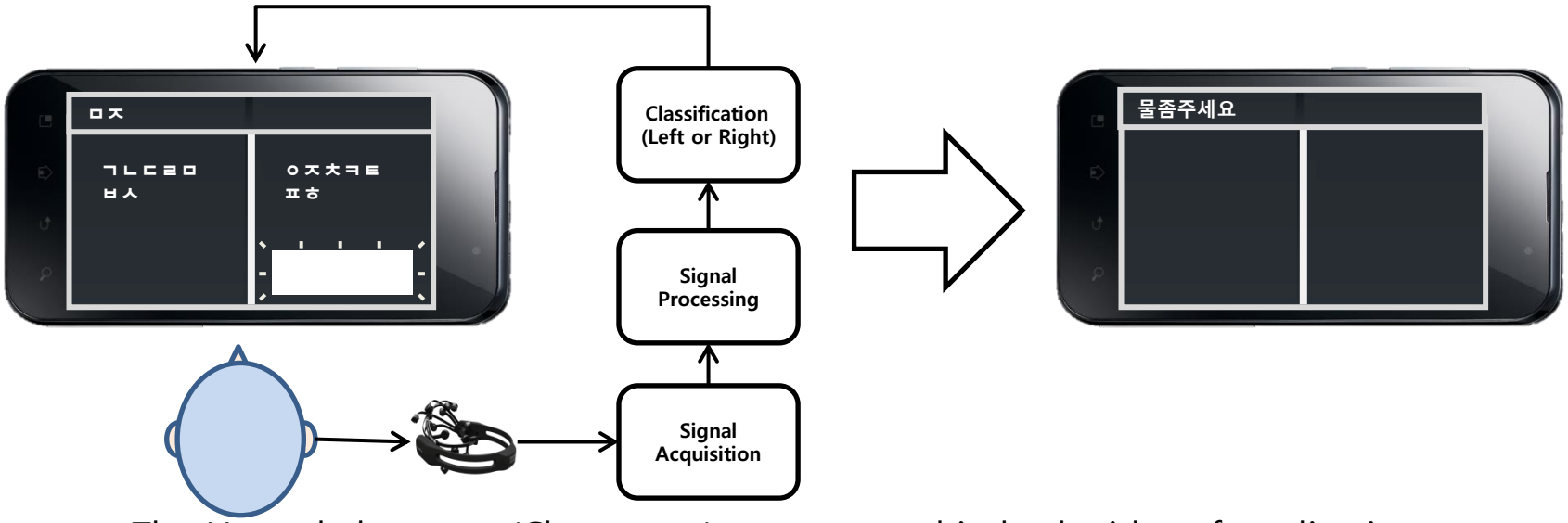
- Brain-Computer Interface (BCI) is an alternative communication and control channel between human and external devices.
- Electroencephalography (EEG) is an input source signal which is recording of the brain waves generated by electrical activity along the scalp.



II. Motivation

- Needs
  - People who have to use BCI speller uses only a few of sentence 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 want to input.
  - Conventional BCI Spellers only consist of English and Number.
  - Most of the previous BCI spellers are experimented with large display such like CRT monitor.
  - Mobile devices such like smart phone have a limited size display to adjust conventional speller paradigm.
  - Hangul is consists of 18 Choseongs, 20 Jungseongs and 27 Jongseongs.
    - Choseong : ㄱ, ㄲ, ㄴ, ㄷ, ㄹ, ㅁ, ㅂ, ㅃ, ㅅ, ㅆ, ㅇ, ㅈ, ㅉ, ㅊ, ㅋ, ㅌ, ㅍ, ㅎ
    - Jungseong : ㅏ, ㅐ, ㅑ, ㅒ, ㅓ, ㅔ, ㅕ, ㅖ, ㅗ, ㅘ, ㅙ, ㅚ, ㅛ, ㅜ, ㅝ, ㅞ, ㅟ, ㅠ, ㅡ , ㅢ, ㅣ
    - Jongseong : ㄱ, ㄲ, ㄳ, ㄴ, ㄵ, ㄶ, ㄷ, ㄹ, ㄺ, ㄻ, ㄼ, ㄽ, ㄾ, ㄿ ,ㅀ, ㅁ, ㅂ, ㅄ, ㅅ, ㅆ, ㅇ, ㅈ, ㅊ, ㅋ, ㅌ, ㅍ, ㅎ
- Purpose
  - We want to spell a full sentence just by spelling 2 Choseongs.
  - We want to help user rapidly to spell a full sentence which they want to select.
  - How? Using binary classification of Choseong and Choseong search.

III. Proposed System



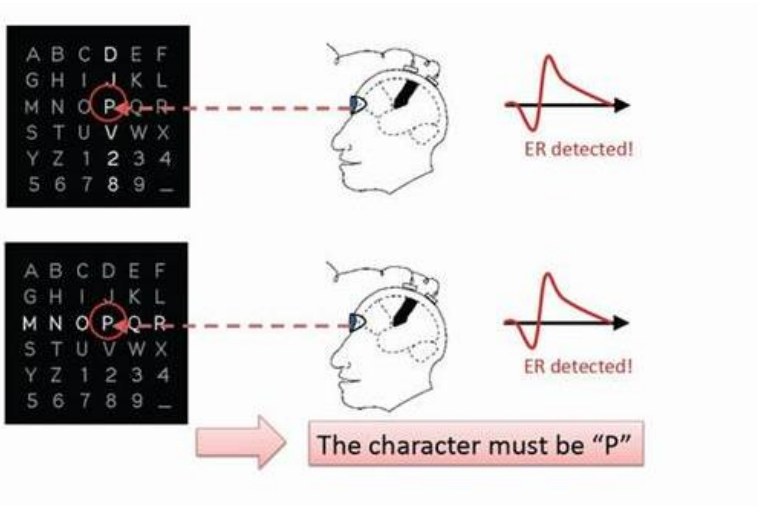
- The Hangul characters(Choseongs) are arranged in both sides of application screen.
- An quadrangle which is located in right side of the screen is flickered at 7.5 Hz frequency.
- If user wants to select right side of character, user only need to gaze right side of quadrangle to use SSVEP characteristic.
- If user wants to select left side of character, user only need to close eyes
- Classify the signal after signal processing process and repeat the above process .
- After 2 choseongs are selected, application searches full sentence based on already stored database.
- Finally, selected full sentence is typed on application display.

IV. Research Contents

- Hardware (EEG Measurement Device) selection
  - Since EEG technology has become more accessible and robust over the past few years, a variety of EEG measurement devices already released.
  - We have to decide the type of signal which is used in our system because there are many kinds of brain signal.
  - We have to select a proper product among the released EEG measurement devices.
- Software Development
  - To transfer raw EEG signal from the measurement device to the mobile device, several of program are required.
  - We have to select the programming language and Integrated Development Environment (IDE) for program development.
- Speller Development
  - Development of signal processing algorithm and character search algorithm in mobile device is required.
- System Integration
  - We have to integrate each part of the above into one system.
- Demonstration (Test)

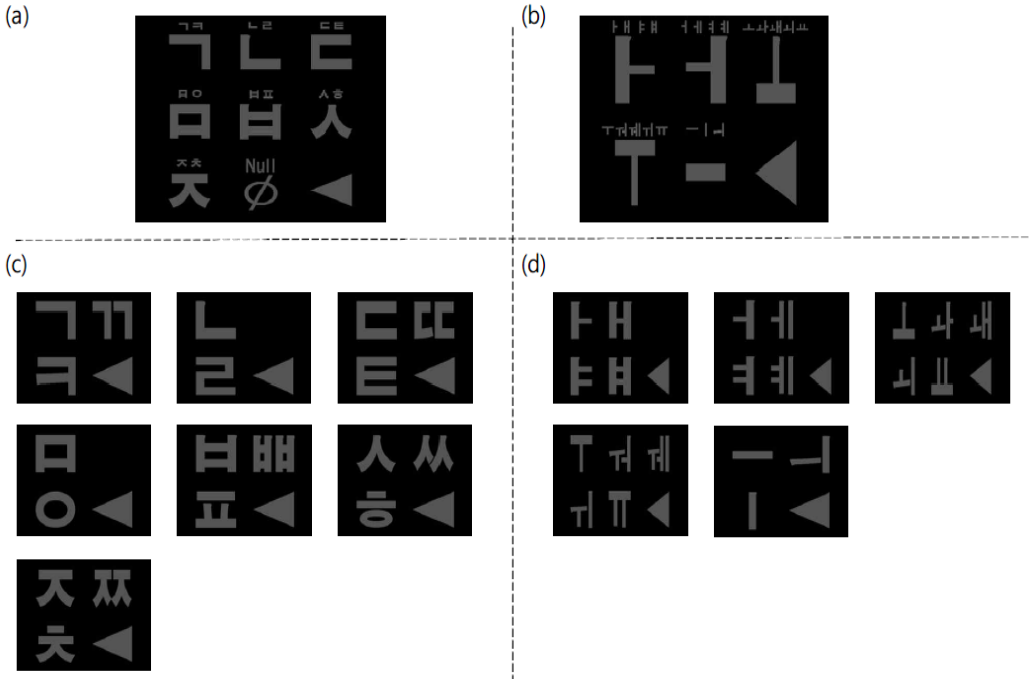
V. Related Works – Conventional Speller

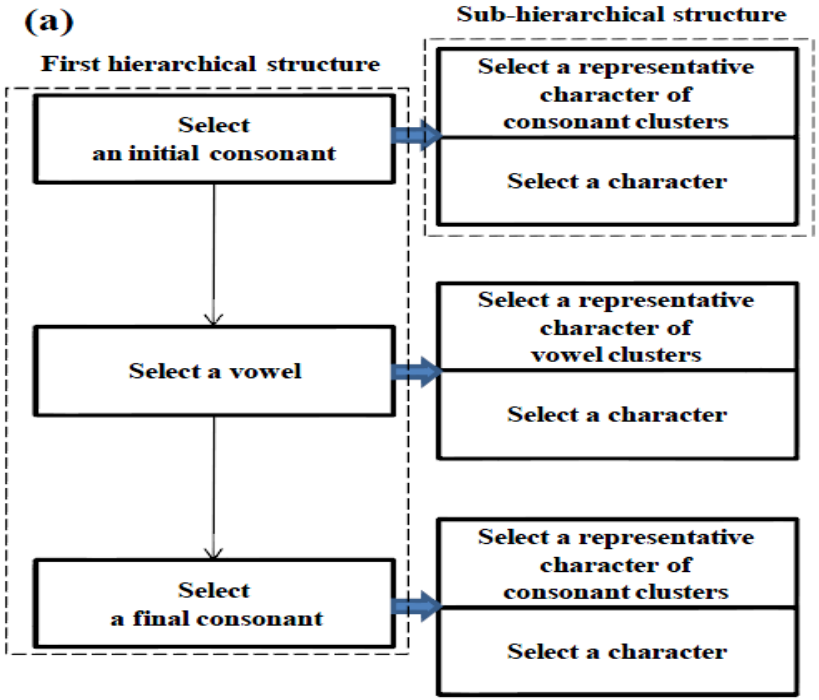
- P300 Speller [1]
  - This system is one of the most famous BCI Speller and Introduced by Farwell and Donchin in 1988.
  - P300 is positive peak in EEG after a stimulus with latency of roughly 300ms.
  - User was presented with a 6 by 6 matrix of characters.
  - All rows and columns of matrix were successively and randomly intensified.
  - Consequently, two out of 12 intensifications of rows or columns contained the desired character (i.e., one particular row and one particular column)
  - 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



V. Related Works – Developed BCI Speller

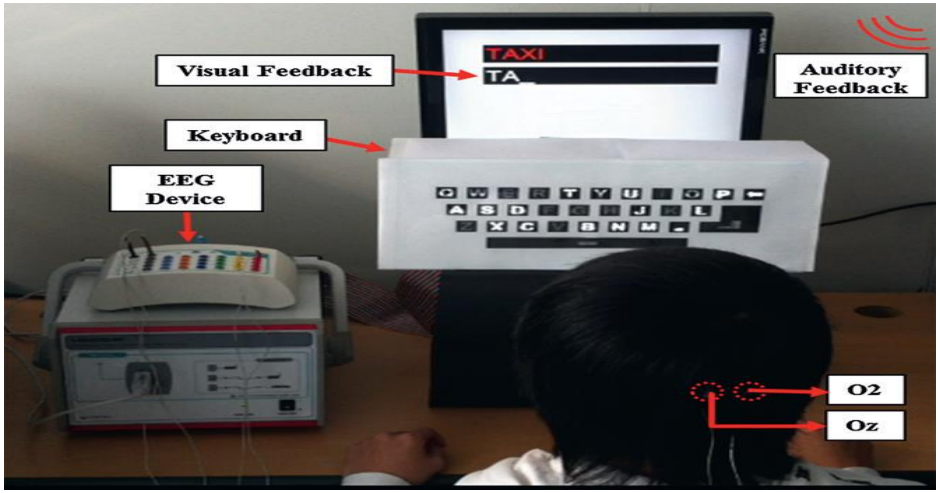
- P300-based Hangul Input System with a Hierarchical Stimulus Presentation Paradigm [2]
  - Previous row/column stimulus presentation paradigm has been well-suited to the English input, it not be optimal for a Hangul input.
  - Because Hangul has a hierarchical structure ; initial consonant, vowel, final consonant
  - Using unique hierarchical structure of Hangul, they effectively reduce of the window size of the interface.

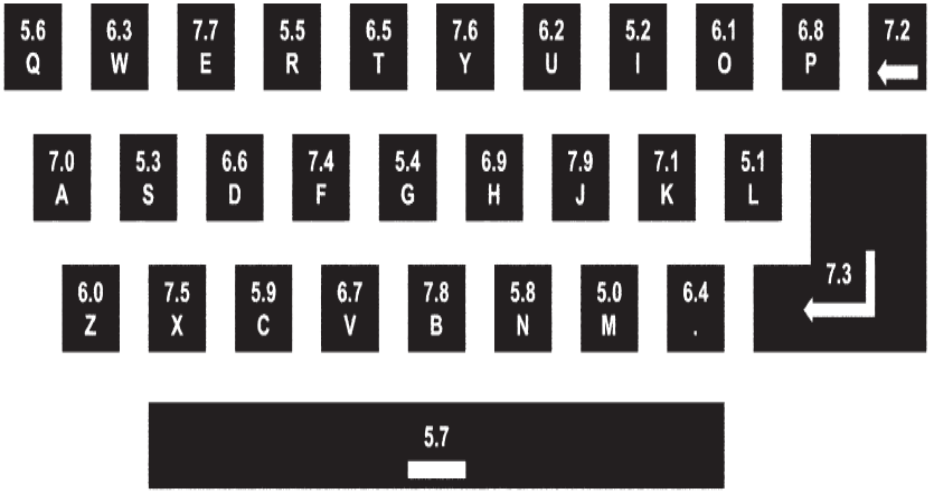




V. Related Works – Developed BCI Speller

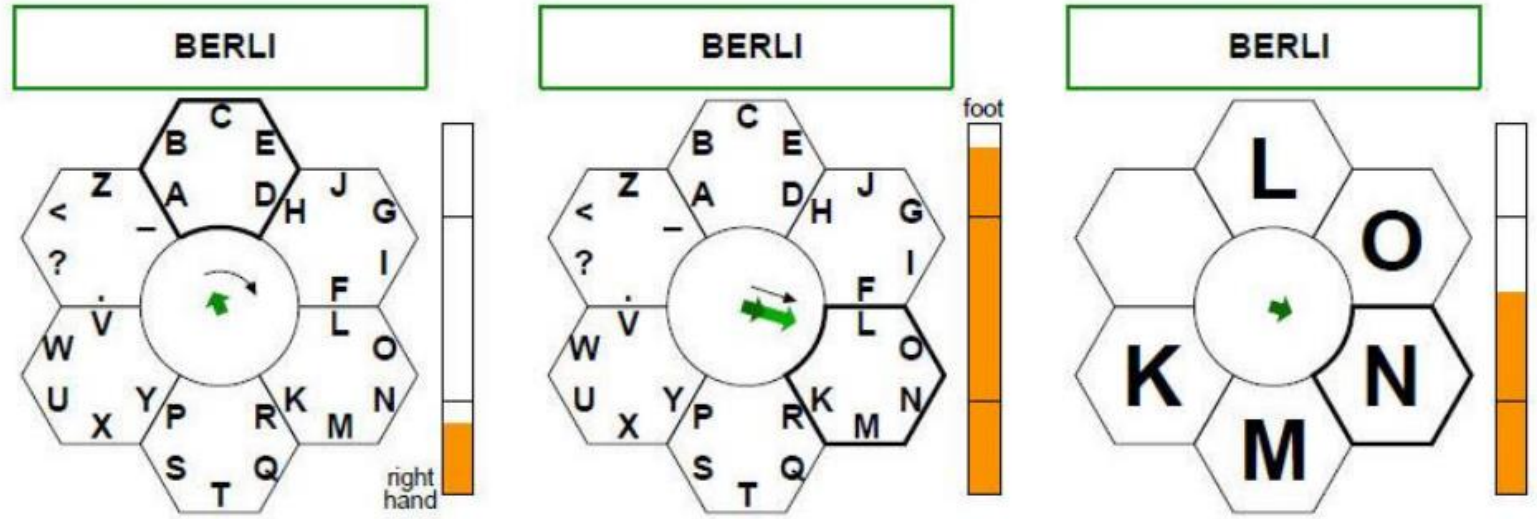
- Development of an SSVEP-based BCI Spelling system adopting a QWERTY-style LED keyboard [3]
  - In the conventional SSVEP spellers, target selection process was relatively complicated as the users had to produce sequential commands to select a target character.
  - In this study, they not require need for multiple step selections adopted by conventional SSVEP-based spelling systems.
  - They adopted a QWERTY style layout keyboard with 30 LEDs flickering with different frequencies.
  - The proposed spelling system allows the user to spell one target character per each target selection.





V. Related Works – Developed BCI Speller

- Hex-o-spell [4]
  - A BCI research group from Fraunhofer FIRST IDA, Berlin, Germany has proposed the Berlin BCI called Hex-o-spell based on motor imagery in 2009.
  - This is controlled by two mental states: imagined right hand movement and imagined foot movement.
  - When the user imagines a right hand movement, the arrow turns to the right.
  - When the user imagines a foot movement, the rotation stops and the arrow starts extending to the desired field.



VI. Contribution

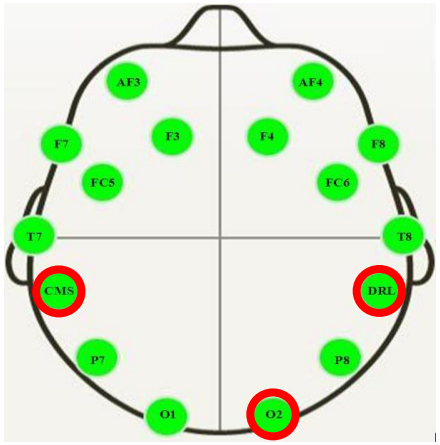
- Previous developed speller was mainly experimented in large display monitor with laptop or desktop.
- The speller system which we propose enables user to spell a full sentence rapidly without inputting full character.
- The speller system which we propose is aimed at android mobile devices including smartphone, tablet.
- People who have to use BCI speller uses only a few of sentence in several situation such like emergency room, patient's room and their home.
- This system includes 10 ~ 15 full sentence in respect of specific situation.

VII. Research Process – H/W Selection

- In this 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. [5]
- Steady State Visually Evoked Potential (SSVEP)
  - Signal which coming from the brain in response to the visual stimuli in a particular frequency.
  - When eye is stimulated by 3.5 ~ 75 Hz frequency repeated stimuli, a signal of the same frequency in the brain is produced.
  - Mainly measured at occipital lobe.
  - Relatively robust to the noise of the outside.
- Alpha Rhythm
  - Neural oscillations in the frequency range of 8 ~ 12 Hz.
  - Mainly measured at occipital lobe.
  - During the relaxed mental state, where the subject is at rest with eyes closed, strong alpha waves were found.

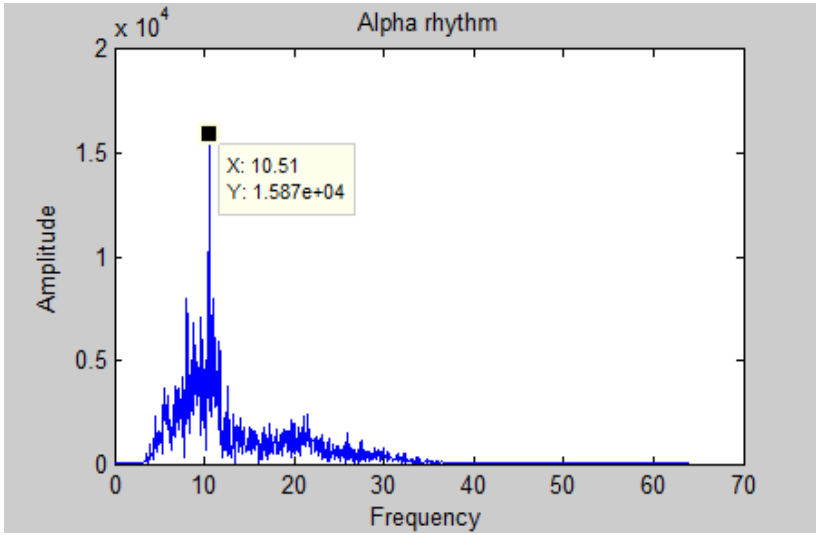
VII. Research Process – H/W Selection

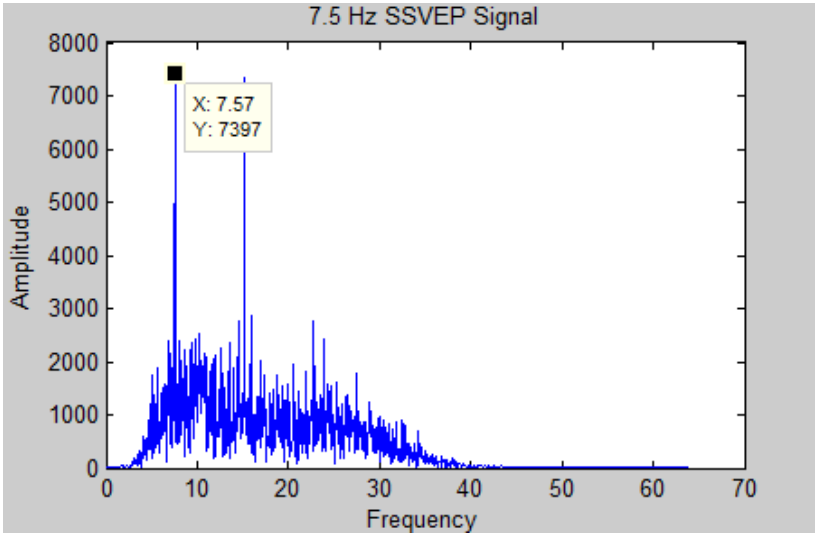
- Emotiv EPOC
  - EPOC headset is EEG-based input device, which is connected wirelessly to a PC.
  - This allows the user to move freely without any connected cables.
  - EPOC EEG sensors have to be equipped with felt pads.
  - These felt pads have to be moistened using a saline solution as a contact agent to the skin.
  - SSVEP signal and Alpha rhythm are mainly measured in occipital area.
  - EPOC has 14 channel node and 2 reference channel.
  - The channel names, based on the International 10-20 locations.
  - 128 Hz Sampling rate.



VII. Research Process – H/W Selection

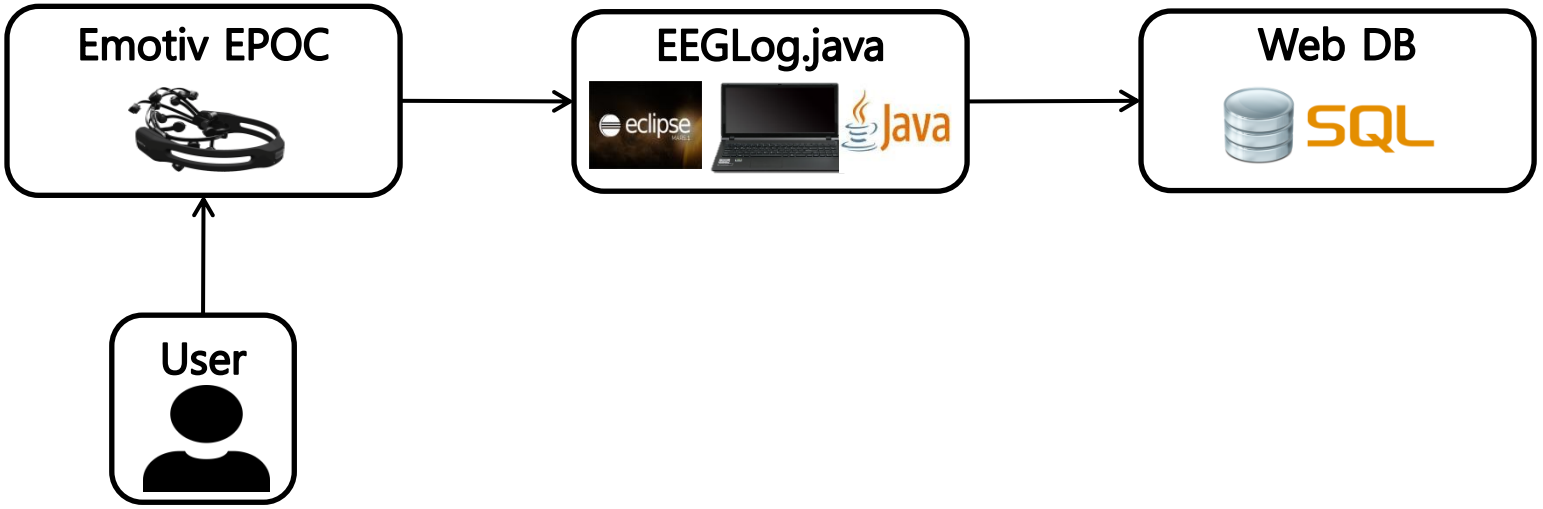
- We conducted a several of experiments to verify SSVEP signal and Alpha rhythm with Emotiv EPOC.
- Alpha Rhythm Verification
  - To verify the Alpha rhythm, subject closes the eyes for 16 seconds.
  - We can check the peak at the 10.51 Hz frequency domain through FFT.
- Application Blinking Frequency Verification
  - To verify the blinking animation of our application, subject gazes 7.5 Hz blinking animation for 16 seconds (2048 Samples).
  - We can check the peak at the 7.57 Hz frequency domain through FFT.





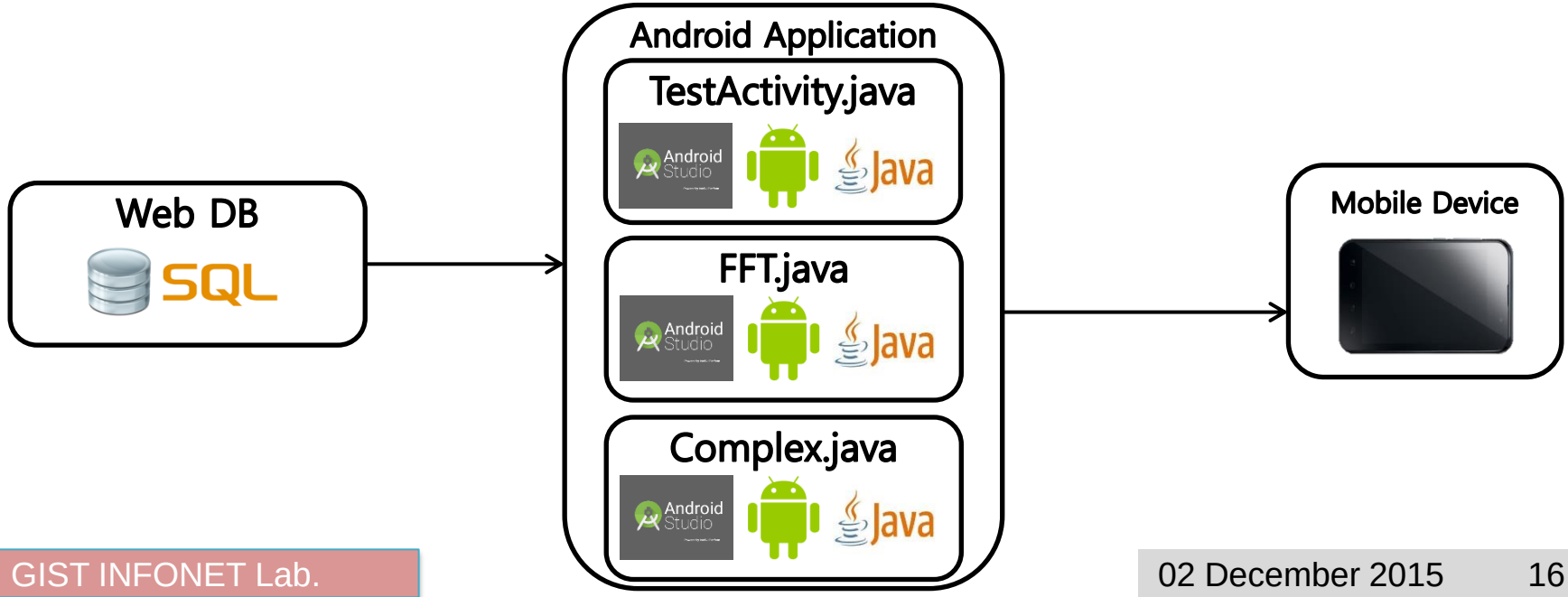
VII. Research Process – S/W Development

- In this step, we had to send raw EEG signal from the measurement device to the web database.
- We developed a Java language based program in Eclipse development tool.
- EEGLog.java
  - Interconnection between the program and Emotiv EPOC headset.
  - Receive 128 raw EEG data from Emotiv EPOC headset per 1 seconds because Emotiv EPOC has 128 sampling rate.
  - Upload 128 raw EEG data to web database.

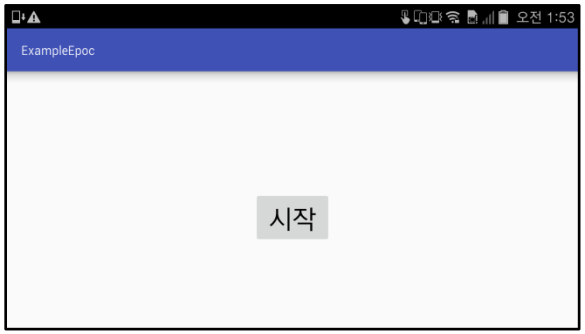


VII. Research Process – Speller Development

- In this step, we had to receive raw EEG signal from web database to the mobile device and develop a android application.
- Android application is developed in the android studio development tool.
- MainActivity.java
  - Receive the data from web database
  - Choseong search and binary classification
  - Manage all functions of the application
- FFT.java
  - Return frequency magnitude



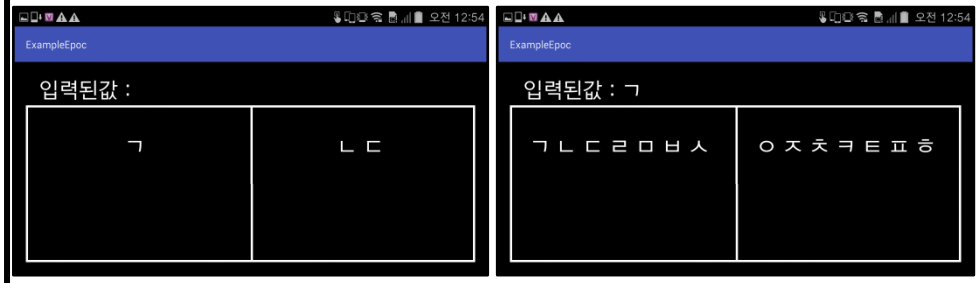
VII. Research Process – Speller Development



- Application main display
- If user pressed the start button, application will be started.
- In this explanation, user will select Choseong; ㄱㅊ.

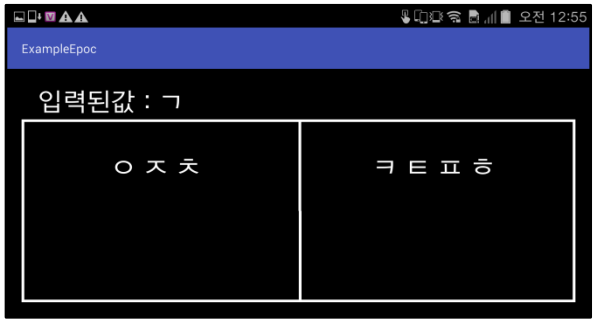
- If user pressed the start button in previous step, display will change like the above.
- Choseong characters are arranged in both side in groups of 7.

- If user closed eyes, display will change like the above.
- After the display change, user have a 5 second waiting time.

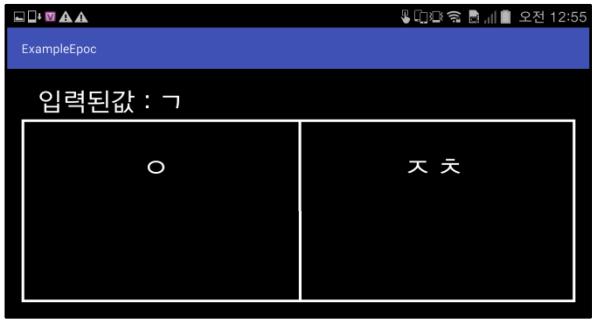


- If user closed eyes, display will change like the above.
- In this display If user closed eyes, Consequently, ㄱ is selected.
- Choseong characters are rearranged.

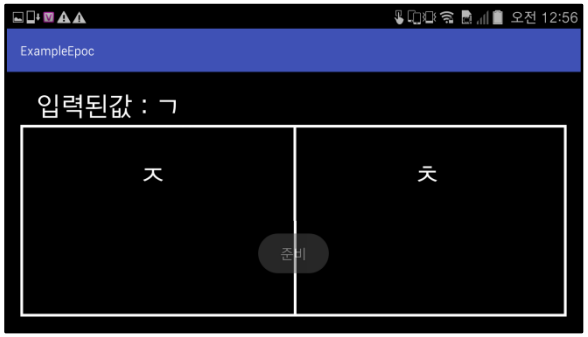
VII. Research Process – Speller Development



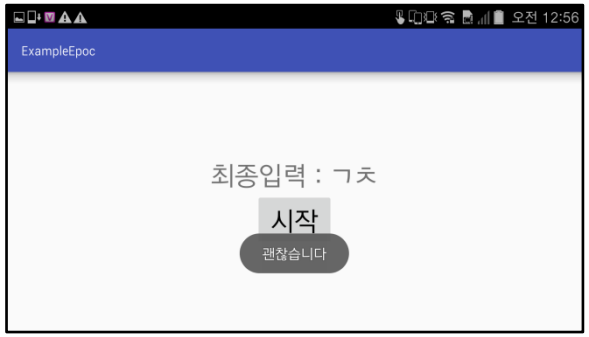
- Because next target character is ㅊ, user have to close eyes for 16 seconds.



- User have to gaze blinking animation.



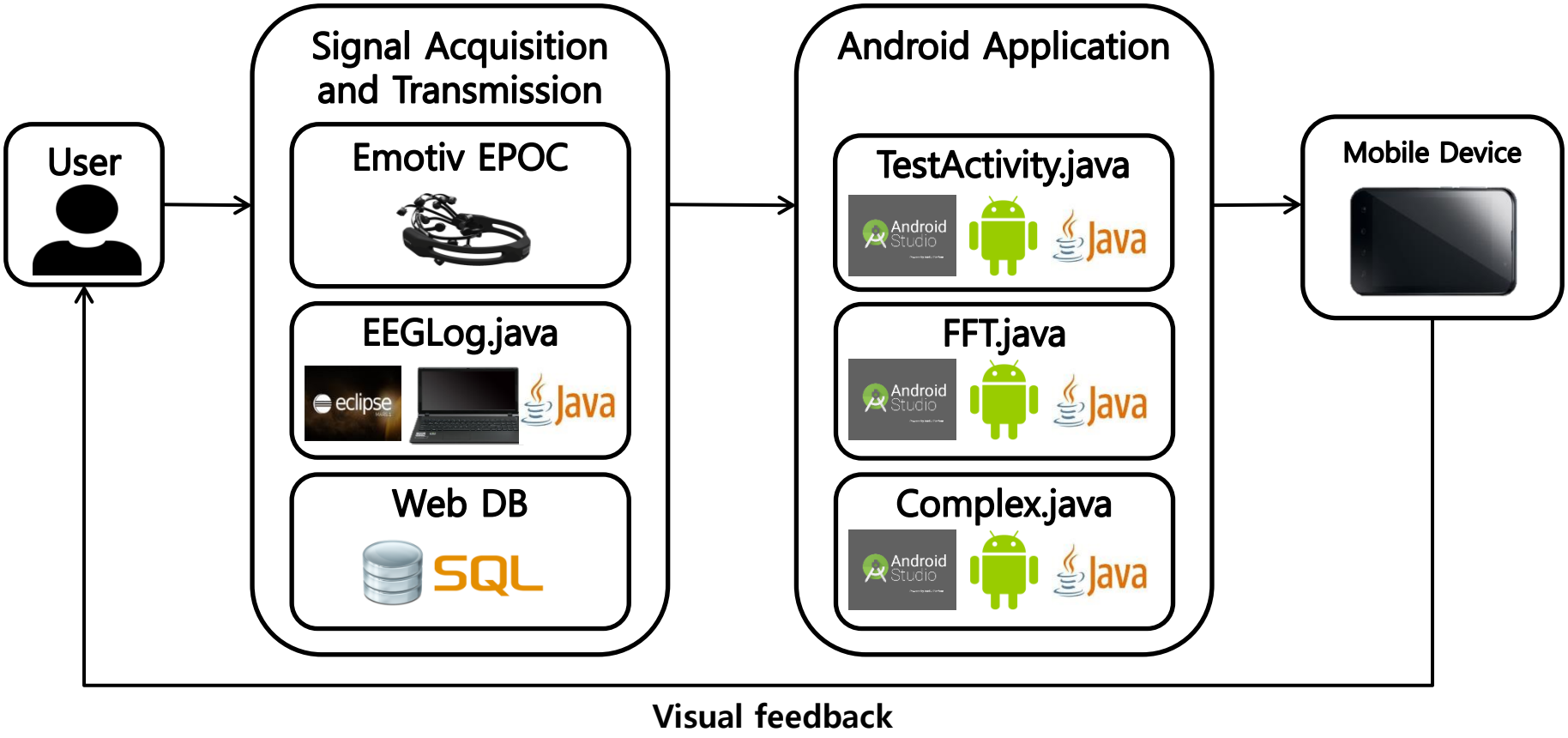
- User have to gaze blinking animation.



- Consequently ㄱ and ㅊ are selected, completed sentence ; 괜찮습니다 is displayed.

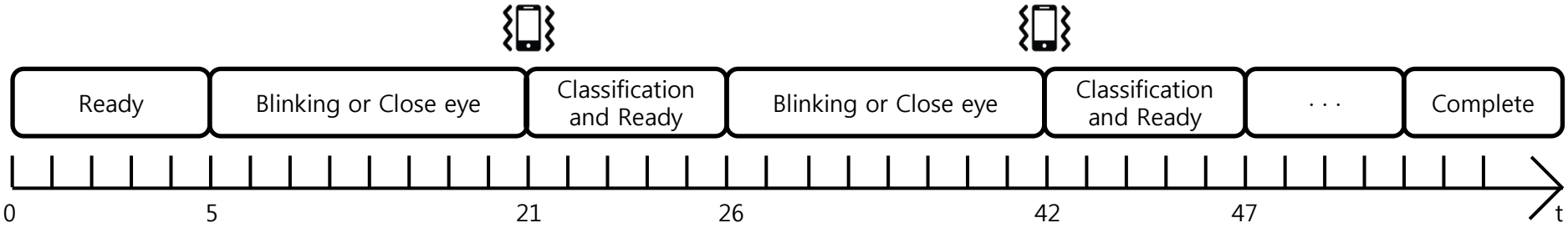
VII. Research Process – Integration

- System Block Diagram



VII. Research Process – Integration

- Application Flow



  - Ready : If user presses start button, application have a 5 seconds waiting time for preparation.
  - Blinking or Close eye : User either have a 16 seconds gazing blinking animation or closing eyes to select Choseong.
  - Vibration : After 16 seconds, mobile devices begin to vibrate for a moment.
  - After Classification process is completed, newly arranged Choseong application display is presented.
  - User have a 5 seconds waiting time for next step.
  - Until 2 Choseongs are selected, above process is repeated.

VII. Research Process – Demonstration (Test)

- In this demonstration, user wants to input ㄱ, ㅊ.
- If android mobile application is well operated, then application will select the ㄱ, ㅊ.
- Consequently, "괜찮습니다." will be displayed.
- It takes 158 seconds to complete full sentence.
- Let see the video to check how this application works.

Results

- Experiment Design
  - Mobile device : VEGA POP-UP NOTE IM-A920S – PANTECH
  - The Experiments were conducted with 5 participants of 5 men in 18 to 33 years old to verify the feasibility of the spelling system.
  - The experiments were progressed in the room with darkroom.
  - Subjects are engaged in experimentation with seated condition.
  - Before experiment, subjects were instructed how these application works.
  - subjects were asked to spell Choseong ; ㄱ, ㄴ, ㄷ, ㄹ, ㅁ, ㅂ, ㅅ, ㅇ, ㅈ, ㅊ, ㅋ, ㅌ, ㅍ, ㅎ in regular order.

Results

- Results
  - The Experiments were conducted with 5 participants of 5 men in 18 to 33 years old.
  - Among the 5 participants, only 2 participants were well aware of the BCI and the other participants were not familiar with the BCI.
  - Total accuracy is 88.89 %.

	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 %

Discussion and Conclusion

- Mobile devices have limited size of display and Hangul consists of complex structure compared to English.
- It is hard to apply previous speller paradigm to mobile devices.
- We propose speller system for android mobile devices to use easily and quickly using SSVEP-Alpha signal.
- Classification accuracy of application is 88.89 %.
- In this study, since we focused on high accuracy of classification, Information Transfer Rate (ITR) would be somewhat low.
- So, We attempt to reduce blinking time and closing eyes time for classification from 16 seconds to 10 seconds.
- If we successfully reduce blinking time and closing eyes time, it may takes about 120 seconds to spell a full sentence.

Thank you

Reference

[1] L. Farwell, E. Donchin, "Talking Off the Top of Your Head : Towar a Mental Prosthesis Utilizing Event-related Brain Potentials", Electroencephalography and Clinical Neurophysiology, vol. 70, no. 6, 1988.

[2] T. H. Lee, T. E. Kam and S. P. Kim, "A hierarchical stimulus presentation paradigm for a P300-based Hangul speller", International Journal of Imaging Systems and Technology, 21(2), 131-138, 2011.

[3] H. J. Hwang, J. H. Lim, Y. J. Jung, H. Choi, S. W. Lee, C. h. Im, "Development of an SSVEP-based BCI spelling system adopting a QWERTY-style LED keyboard", Journal of Neuroscience Methods, 208(1) : 59-65, 2012.

[4] J. Williamson, R. Murray-Smith, B. Blankertz, M. Krauledat, K. –R. Muller, "Desinging for Uncertain, Asymmetric Control : Interaction Design for Brain-Computer Interfaces", International Journal of Human-Computer Studies, vol. 67, 2009.

[5] S. Amiri, R. Fazel-Rezai, V. Asadpour, "A Review of P300, SSVEP, and Hybrid P300/SSVEP Brain- Computer Interface Systems", Advances in Human-Computer Interaction - Special issue on Using Brain Waves to Control Computers and Machines , vol. 2013, 2013

Appendix – Stored 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.