King Mongkut's Institute of Technology Ladkrabang
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Wireless Brain-Machine Interface System Based on Multi-Channel Visual Flickers

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Abstract

Brain-Computer Interface (BCI) enables peoples with disabilities communicate the outer world by using electroencephalogram (EEG) signal. Recently, steady-state visual evoked potential (SSVEP) is employed as a stimulator due to it plays an important role in the response to various visual parameters, i.e., flickering rate (F), intensity (I), and duty cycle (D). The SSVEPs are practical and useful in research because of its excellent signal-to- noise ratio and relative immunity to artifacts. However, another one of the most efficient paradigms, namely, the event-related potential (ERP) based BCI. As a result, the visual stimulation is being recognized to be a most efficient stimulus for a multiple BCI system. In this paper, therefore, we offline investigated the effectiveness of SSVEP and ERP visual flickering paradigms for BCI system in terms of optimizing the parameter of visual simulation. Different experimental conditions were compared to achieve the best performance. Subjects were instructed to fixate LED light source then record associated SSVEP waveform on O1 and O2 channels. The variation in displaying of the presentation stimuli during a task was examined thereby demonstrating the high usability, adaptability and flexibility of the visual stimulator and determine the optimal visual parameters for the subject comfort.

Acknowledgements

I would like to express (whatever feelings I have) to:

- My supervisor
- My second supervisor
- Other researchers
- My family and friends

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Chapter 1

Introduction

1.1 Motivation

Nowadays,The technology is used for the advantages in many fields, for example an ultrasound machine in medical field, a soil and crop sensor in agriculture field, a robotic arm for move the product in industry field and also the several technologies for facility in daily life. At present, one of the technology which is interesting and important is technology to improve quality of life of the disabilities. The invention of equipment which can be interacted by using non-muscular communication channel can help these kinds of people in daily life or in emergency.

For those people with physical or mobile impairment, one of the common problems in daily life is that they cannot completely control an equipment that is designed for ordinary people. Making the equipment for the disabled people to help them can be interacted or communicated by using brain signal instead of muscle that is one of choices to solve their problem. The technology that obtains the brain signal and translates the brain signal to communicate or interact with the external device is called Brain-Computer Interface (BCI). At present, there are three types of BCI, divided by the stimulation : Auditory BCI , Imaginary BCI and Visual BCI. Each type has the different advantages and disadvantages. First is the auditory BCI that is easy to analyse the brain signal but it has slow interpretation and the sound from this BCI can annoy other people. Next, imaginary BCI is the fastest way to stimulate the brain but the subject should be trained before using this BCI and it has low rate of success. The last one is visual BCI that is the easiest way to obtain the brain signal However, it cannot use in case of the epilepsy person.

Our project will use the visual type of Brain-Computer Interface to control the application for the disabled people. We use brain signal from the subject to control programs or devices. When the user was stimulated by the flicker, the brain will generate waveform and be different pattern from others.

1.2 Objective

The objective of this project is to make the user able to communicate or interact with our equipment by using brainwave. This can help the disabled people when they need some emergency or facilities.

Furthermore, our purpose is to study various techniques to record and translate the brainwave to interact with the external devices.

1.3 Scope of work

The scope of this project can be summarized as follows:

- Study the theories and techniques of recording EEG waveform.
- Make an equipment which a user can cognitively interact or use the system by brain-wave without using muscle function.

1.4 Contributions

In this project, we have developed a control module for users to interact with software by using EEG signal. Our work demonstrates a brand new alternative way to help users in a more convenient way or help immobilize-able users with limited control on their parts of body. We hope that a control module and software that we have developed will provide great advantages and only minor disadvantages to the project.

1.5 Procedure

We separate that work into 6 phases.

1. Plan the project
2. Research and study on EEG cognitive
3. Design the equipment
4. Implement the system
5. Doing an experiment
6. Testing program

Chapter 2

Problem description and related work

2.1 Problem description

Nowadays, there are many people who have been born with a disabled body from various reasons. Most of them always have a limitation of their living that be different from ordinary people. At present, one of the main problems of the disabled person is lacking help and ignore from other people. Using knowledge from the scientific and engineering field to make a brain-computer interface machine is the way to help these people to have the living like the ordinary people. For our project, we decide to assist the patient or physically disabled people that can't completely move their body part to interaction without helping from other people such as Paralysis, Spinal cord injured, Stoke and ALS.

2.2 Review of related works

2.2.1 Multitasking with BCI machine[1]

The multitasking with BCI machine experiment from EPFL Professor Jos del R. Millan. This experiment develops the BCI machine which allows the user to control the robot direction to move by using EEG signal and real-time communicate with other people via the camera that mount on the robot.

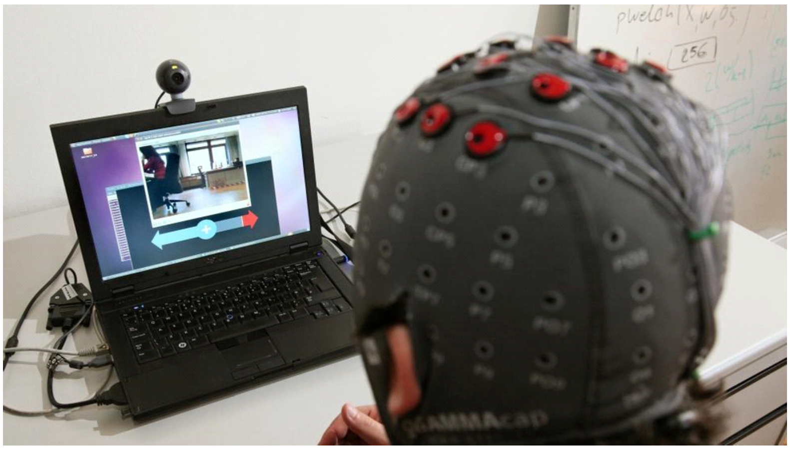

Figure 2.1: The subject control robot use brain wave and communicate via camera at same time

2.2.2 Real-time control of a robotic arm using a brain-computer interface[2]

SSVEP control of robotic arm experiment from the Applied Signal Processing in Engineering and Neuroscience Lab (ASPEN Lab) of Old Dominion University.

This Lab is used to develop an application which using EEG headset to control the robotic arm. The subject should gaze on the one of the flickers in front of him for control or command the direction of the robotic arm.

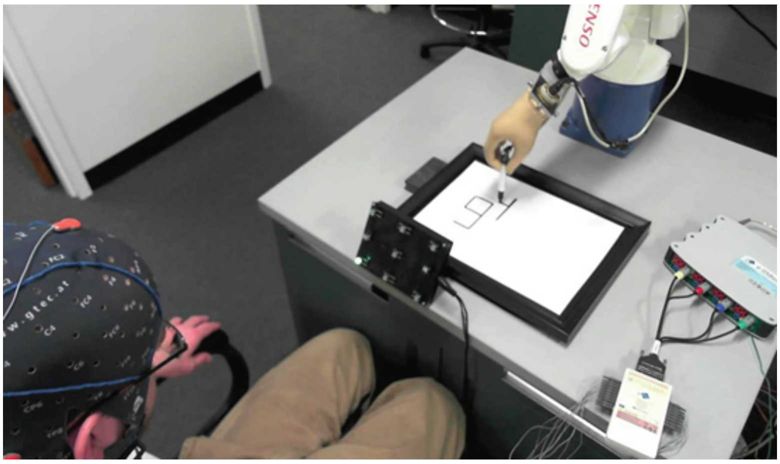

Figure 2.2: The subject control s robotic arm by fixate at stimulation ligth using SSVEP

2.2.3 Visual stimuli for the P300 brain-computer interface: A comparison of white/grey and green/blue flicker matrices[3]

P300 speller has mainly used white/grey flicker matrices as visual stimuli but they are not reducing the fatigue condition of the user. Parra and colleagues evaluated what colour is reducing the fatigue condition of the user. In their study, five single-color stimuli have been implemented. There are white, blue, red, yellow and green.

In this experiment, the green/blue chromatic flicker emerged as the safest and evoked the lowest rate of EEG spikes. The result showed that the accuracy rate was higher in response to the luminance chromatic flicker condition(LC) than in response to the luminance(L) or chromatic(C) flicker condition.

In conclusion, most users preferred green and blue make them feel less strain on the eyes. The subjects found that they could use green stimulus for longer periods as compared with red and blue in all frequency range.

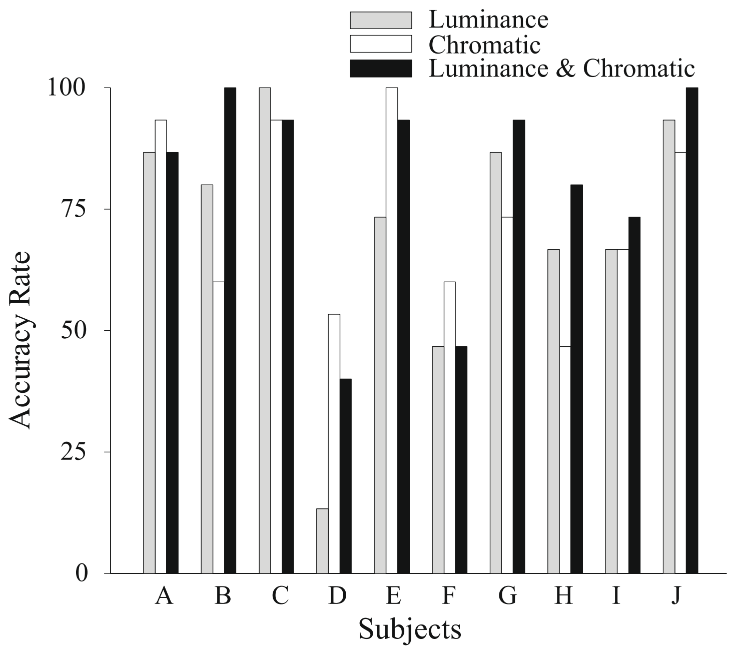

Figure 2.3: Accuracy rates for each subject. The accuracy rates in L, C, and LC conditions for each subject (AJ) are indicated by grey bars, white bars, and black bars, respectively.

2.2.4 Validation of the Emotiv EPOC EEG gaming system for measuring research quality auditory ERPs[4]

There are two kinds of equipment for obtaining a brain signal as follow: Researching headset and Gaming headset. Studying this research can be concluded that the Gaming headset can be use as well as the Research headset because of the result of an experiment showed that the characteristics of the Gaming headset's graph are very similar to the graph of Research headset.

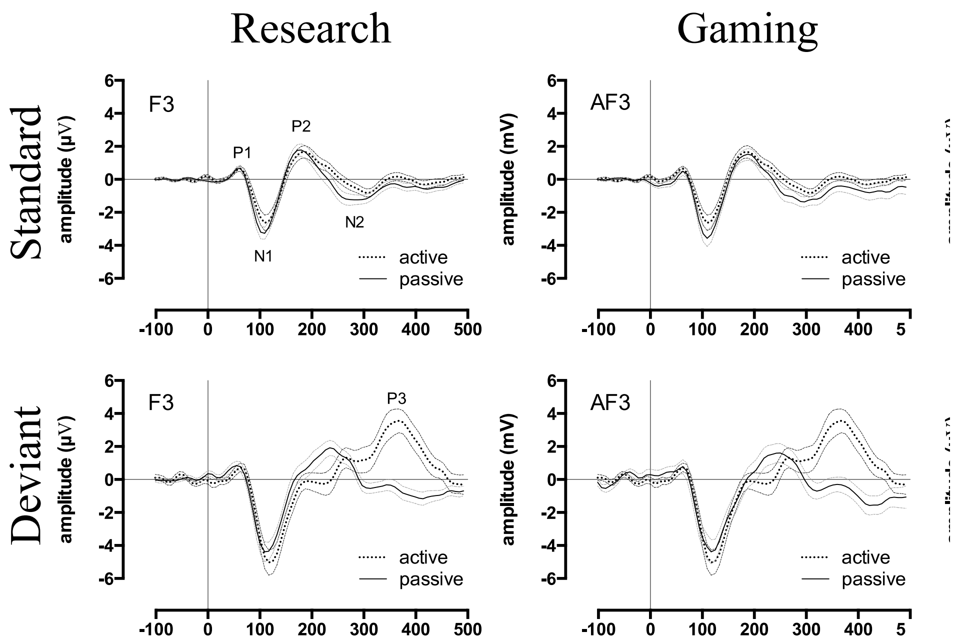

Figure 2.4: Research and gaming system ERP waveforms by condition, tone type, and hemisphere. Group ERP waveforms for research (left-side) and gaming (right-side) systems. All graphs display waveforms for the passive and active (counting deviant tones) listening conditions. The upper 4 graphs depict the left-hemisphere-activity (F3 and AF3) and the lower 4 graphs depict the right-hemisphere-activity (F4 and AF4). Rows 1 and 3 depict waveforms elicited by the standard tones, rows 2 and 4 depicts waveforms elicited by the deviant tones. Error waveforms (in grey) represent the standard error of the mean. for the passive and active (counting deviant tones) listening conditions

2.2.5 c-VEP Brain-Computer Interface (BCI)[5]

Code-modulated visual evoked potentials (c-VEP) is one of the kinds of BCI. c-VEP uses pseudorandom code to modulate different visual stimuli. The figure 2-4 A shows the configuration and modulation of the c-VEP BCI system

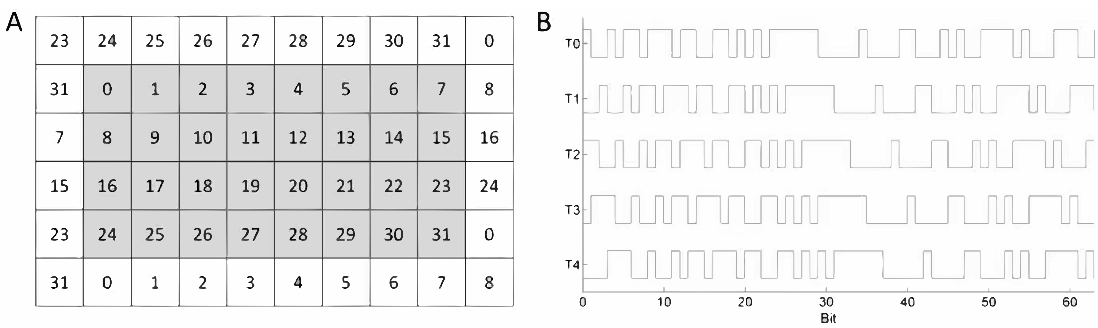

Figure 2.5: A: The gray area shows the 32 target stimuli with the number referring to number of target. The stimuli in white area are the complementary, which are synchronized to the target with same number. B: Modulation sequence for the first 5 targets. The sequence of a target is shifted by 2 bit in respect to its preceding target.

2.2.6 SSVEP-based brain computer interface using the Emotiv EPOC[6]

After the data was obtained from the headset, the two occipital channels were averaged together which help eliminated some of the noise between two channels. Because SSVEP is base on a particular frequency being present in the EEG data, the signal processing should be accomplished by using a Fourier transform to convert from the time domain into the frequency domain. After averaged the data. The result from converting is a frequency spectrum. Then, squaring the amplitude of each frequency component in this spectrum. This result was collected as active signal spectrum After that using a baseline removal method to further improve the results of signal isolation for the identification of SSVEP response. A baseline was recorded while the user was viewing a solid 50 percent gray screen without present any visual stimulation. After the data was recorded, Begin the method by using a Fourier transform with baseline spectrum and then reduce the noise by using a smoothing filter. Finally, the smoothed baseline spectrum was subtracted from the active signal spectrum. Finally, the result from this is the spectrum that can classify the observed data.

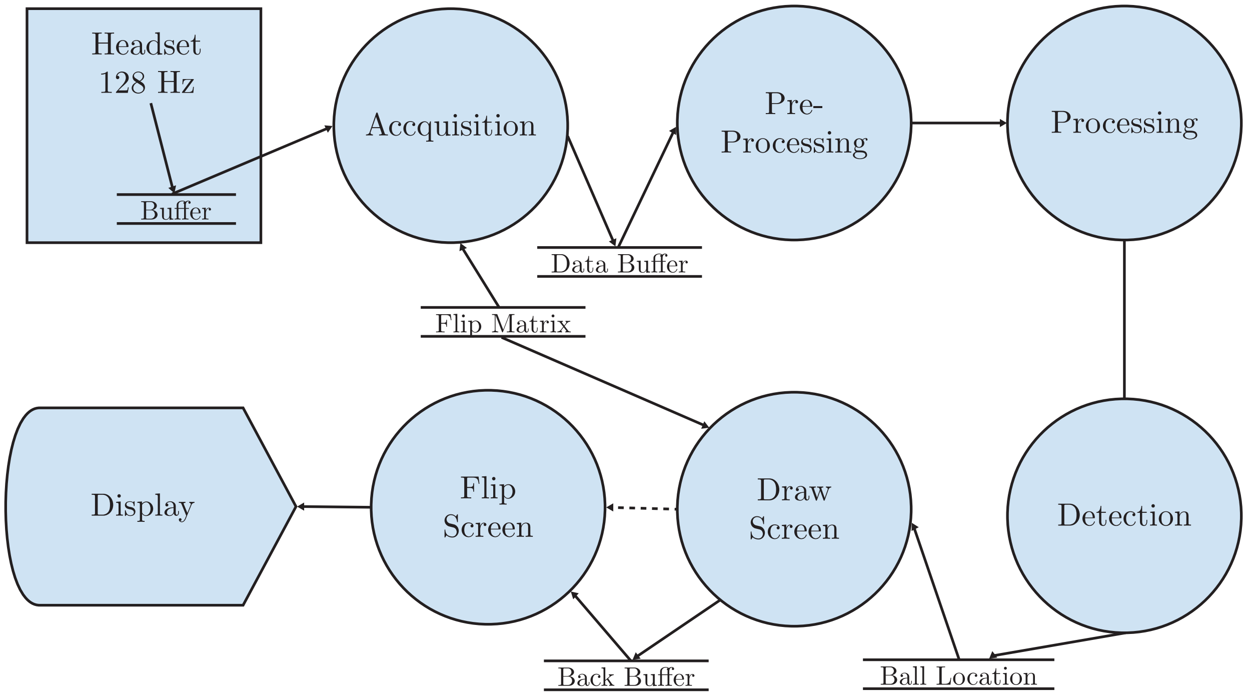

Figure 2.6: Data Processing Data Flow Diagram

2.2.7 A Survey of Stimulation Methods Used in SSVEP-Based BCIs[7]

The stimulus frequency can be divided into three bands. that is low (1-12 Hz), medium (12-30 Hz) and high (30-60 Hz). The largest SSVEP amplitudes were observed near 10 Hz followed by 16-18 Hz. Therefore, the most of the SSVEP-based BCIs use low and medium frequency bands. However, These two frequency bands have the disadvantage. First, the subjective evaluation shows that frequency between 5 and 25 Hz are more annoying than higher ones which visual fatigue would easily occur. Second, flash and pattern reversal stimuli can provoke epileptic seizures especially in the 1525 Hz range. Third, the low-frequency band covers the alpha band (813 Hz) which can cause a considerable amount of false positives. All of these disadvantages can be avoided by using the higher frequency band.

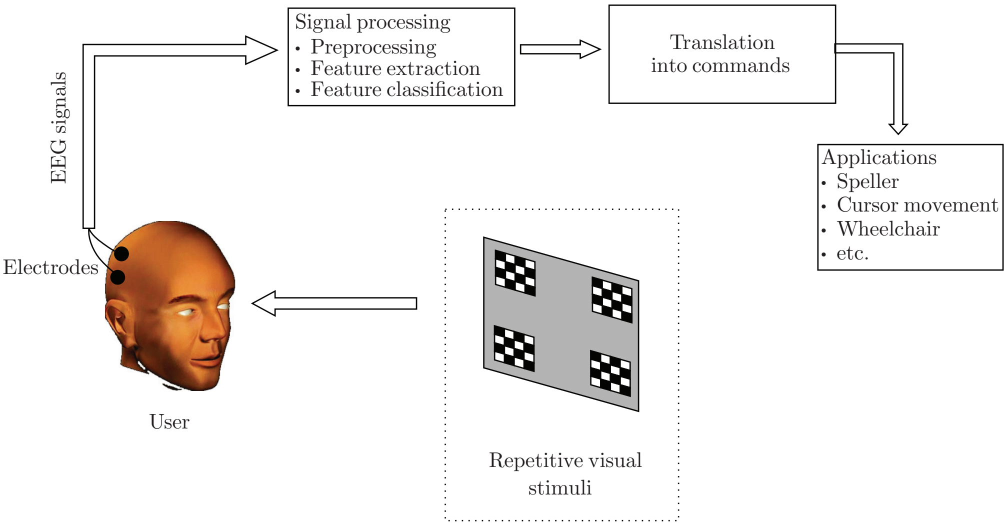

Figure 2.7: Functional model of an SSVEP-based BCI

2.2.8 Human EEG responses to 1-100 Hz flicker[8]

Human EEG responses to 1-100 Hz flicker is stimulated in visual cortex. Herrmann reported that the SSVEP responses exhibited resonance phenomena around 10,20,40 and 80 Hz

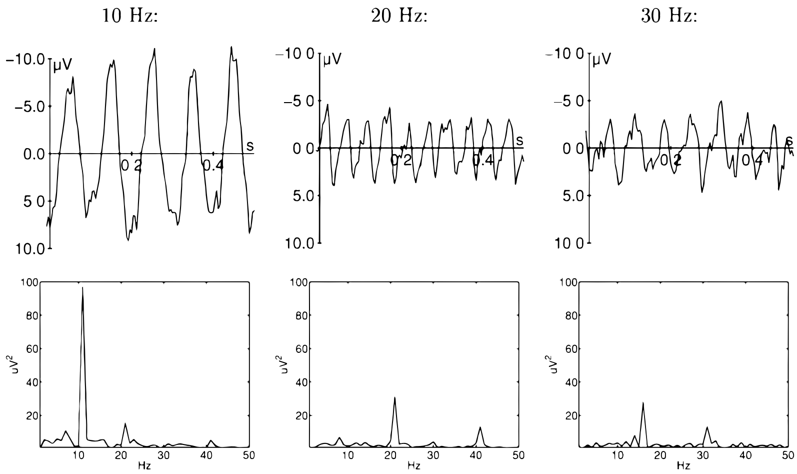

Figure 2.8: SSVEPs of a single subject in response to 10 Hz (left), 20 Hz (middle) and 30 Hz (right) stimulation (top row) and the corresponding FFT frequency spectra (bottom row)

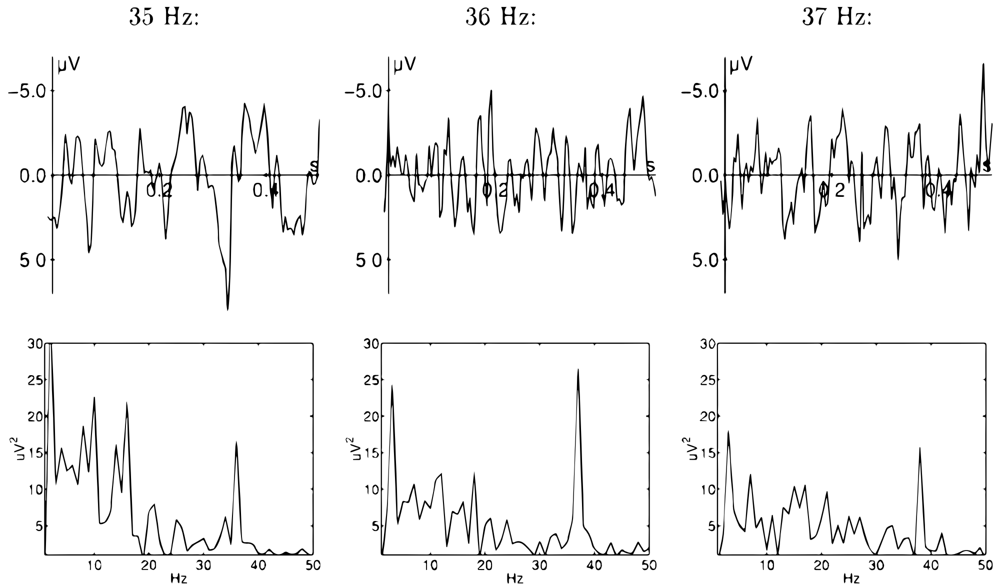

Figure 2.9: SSVEPs of a single subject in response to 35 Hz (left), 36 Hz (middle) and 37 Hz (right) stimulation (top row). The corresponding FFT frequency spectra show an increase of power at 36 Hz for 36 Hz stimulation (middle) as compared to adjacent frequencies (left and right)

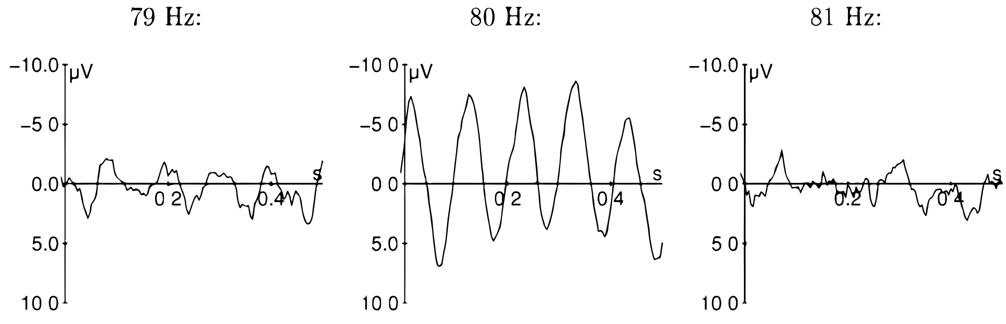

Figure 2.10: SSVEPs in response to flicker frequencies 79 (left), 80 Hz (middle) and 81 Hz (right). The VEP shows clear 10-Hz oscillations at 80 Hz which are not as prominent for the adjacent frequencies

Chapter 3

Background knowledge

3.1 Background knowledge

3.1.1 Electroencephalography (EEG)

EEG is a technique for studying the electrical activities within the brain using electrodes that attached to the surface of scalp. Wires attach these electrodes to a machine, which records the electrical impulses. The results are either printed out or displayed on a computer screen. Different pattern of electrical impulses can denote various form of epilepsy[9]. It is also used to diagnose sleep disorders, coma, encephalopathies, and brain death.

Derivatives of the EEG technique include evoked potentials (EP), which involves averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, somatosensory, or auditory). Event-related potentials (ERPs) refers to averaged EEG responses that are time-locked to more complex processing of stimuli.

Figure 3.1: EEG signal

3.1.2 Event-related potential (ERPs)

Event-related potentials (ERPs) are very small voltages generated in the brain structures in response to specific events or stimuli. They measure brain response that is directed result of a specific sensory, cognitive or motor event. To see the brain's response to a stimulus, the experimenter must conduct many trials (usually in the order of 100 or more) and average the results together, causing random brain activity to be averaged out and the relevant waveform to remain, these stimuli can be visual, auditory, tactile and even olfactory and gustatory.

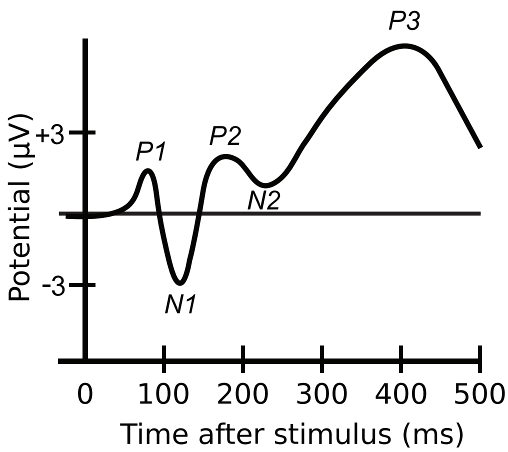

Figure 3.2: Averaged ERP waveform

3.1.3 Steady state visually evoked potential (SSVEP)

Steady State Visually Evoked Potentials or SSVEPs are signals that are natural responses to visual stimulation at specific frequencies. When the retina is stimulated by a visual stimulus ranging from 3.5 Hz to 75 Hz, the brain generates electrical activity at the same (or multiples of) frequency of the visual stimulus. SSVEP is the EEG signal but we called SSVEP because when the subject is in meditation state the brain will generate a stable EEG waveform but when the subject fixates the visual stimuli the EEG waveform is changing and become SSVEP at that time.

3.1.4 Cerebral Cortex

The human brain consists of several parts. The part that make human more intelligent than any animals are Cerebrum. Cerebrum is the largest part of human brain. The physician divides the cerebrum into four parts. There is frontal lobe, parietal lobe, temporal lobe and occipital lobe. Frontal lobe is located at the front of the brain. It controls the creative thought, thinking, problem solving and muscle movements. Parietal lobe is positioned above the occipital lobe and behind the frontal lobe. It involved in the visual functions, languages, reading and sensory controls. Temporal lobe situates beneath both frontal lobe and parietal lobe. It implicates in control memories, speech and hearing languages. Occipital lobe related with a human vision controls. Due to our project study about the human visualization, so we focus on the occipital lobe.

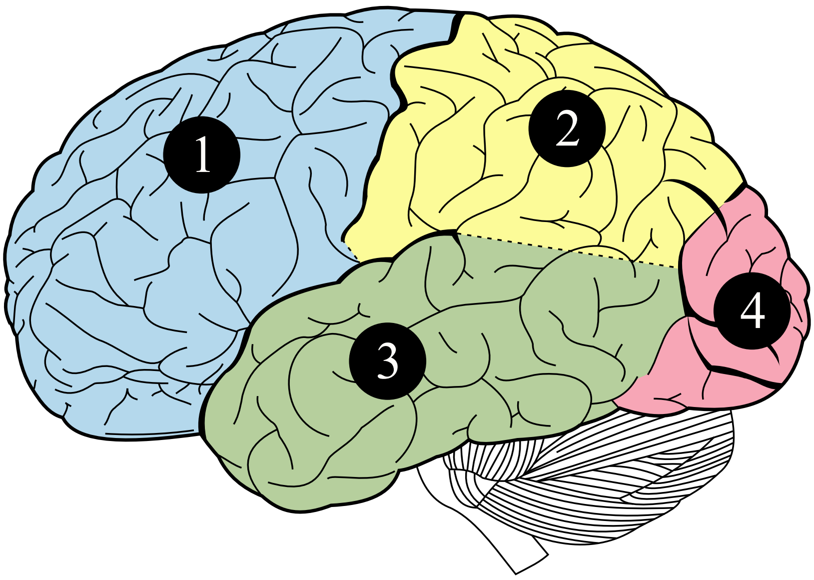

Figure 3.3: 1.Frontal lobe, 2.Parietal lobe, 3.Temporal lobe, 4.Occipital lobe

3.1.5 Feature scaling (normalization)

Feature scaling is a method that used to standardize the range of independent variables or features of data. It is known as data normalization and it is generally performed during the data pre-processing step. The calculation is determined the distribution mean and standard deviation for each feature. Next we subtract the mean from each feature. Then we divide the values (mean is already subtracted) of each feature by its standard deviation.[10]

$$x' = \frac{x - \overline{x}}{\sigma}$$

3.1.6 Uniform distribution[11]

The Uniform or Rectangular distribution has random variable restricted to a finite interval and has has constant density over the interval.

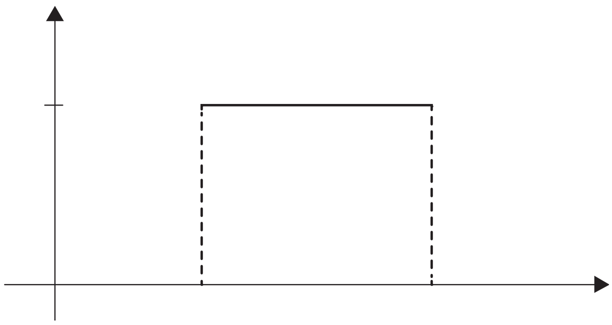

Figure 3.4: An illustrate of uniform distribution

The function f(x) is defined by:

$$f(n) = \begin{cases} \frac{1}{b-a} & \text{if } a \leq x \leq b \\ 0 & otherwise \end{cases}$$

3.1.7 10/20 international system

The 10/20 international system is a recognized method to describe and apply the location of scalp electrodes in the context of EEG test. This system is based on the relationship between the location of an electrode and the underlying area of cerebral cortex. The 10/20 international system refers to the actual distance between adjacent electrodes are either 10 % or 20 % of the total front-back or right-left distance of the skull. Each site has letters to identify the lobe and a number to identify the hemisphere location. The letters F stands for frontal lobe, T is temporal lobe, C is central lobe, P is parietal lobe, and the last one is O means occipital lobe. Even numbers refer to electrode positions on the right hemisphere and odd numbers refer to the electrode positions on the left hemisphere.

3.1.8 Standard deviation(SD)

Standard deviation is measuring a distribution of the collection of data.if the SD is high,the distribution is high.if the SD is low, the distribution is low.

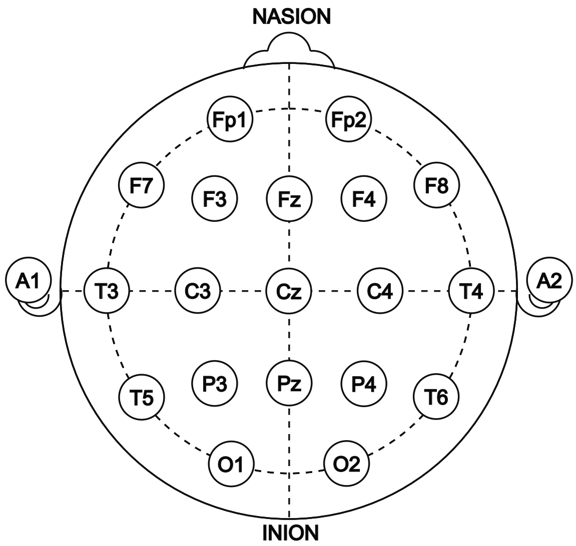

Figure 3.5: International 10-20 locations system

3.2 Material background

3.2.1 Emotiv EPOC headset[12]

The wireless headset Emotiv EPOC research edition, it records EEG data in 14 channel of International 10-20 Locations system with Sequential sampling rate at 128 per second (2048 Hz internal) with resolution 14 bit (16 bit Analog to digital converter, 2-bit instrumental noise floor discarded), the bandwidth is in range 0.2 to 45 Hz with digital notch filters at 50Hz and 60 Hz

Figure 3.6: Emotive Headset

3.2.2 Gravitech Gerora LED[13]

The full colour Light-emitting diode (LED) driver which is use for stimulate the subject has a LED light WS2812 model mounted on. It can chain connected with the same model. It can be controlled by a programmed Arduino. The luminous intensity is 550 to 700 mega candela for red, 1100-1400 mcd for green, and 200-400 mcd for blue.

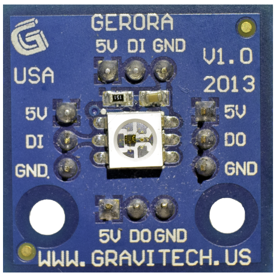

Figure 3.7: Gravitech Gerora LED base on WS2812

3.2.3 Arduino UNO[14]

The Arduino Uno is a microcontroller board based on the ATmega328 that is an open source platform. It has 14 input/output pins6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button, The USB connection for upload the software into the Arduino and VCC or supply for connecting the peripheral circuit.

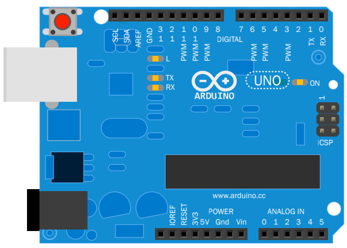

Figure 3.8: Illustrate of Arduino UNO board

Chapter 4

Requirement analysis and Software design

4.1 Requirement for application

Chapter 5

Software design

5.1 System architecture

Chapter 6

Development

6.1 Chamber for the SSVEP experiment

Chapter 7

Experiments and results

7.1 Hardware for the experiment

Chapter 8

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8.1 Summary of Thesis Achievements

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8.2 Applications

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8.3 Future Work

Future Work.

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