

CONTROL OF ONE-DIMENSIONAL CURSOR MOVEMENT BY NONINVASIVE
BRAIN-COMPUTER INTERFACE IN HUMANS

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*To my mother and father,
husband,
and sensei,
for their precious moments*

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ABSTRACT

Noninvasive brain-computer interface (BCI), using electroencephalogram (EEG) that records from scalp, could provide a new non-muscular channel for sending messages and command to the external world. The objectives of this study are to determine parameters that will drive cursor in BCI using noninvasive EEG signal and to control one dimensional cursor movement using the extracted parameters. This experimental-based study involved six normal subjects aged from 20 to 26 years old. Subjects were asked to perform tasks in two condition i.e. control condition and task condition. In the control condition, subjects were required to relax (resting) and fix their eyes on the centre of the screen without image displayed on the screen. In the task condition subjects were tasked to imagine a movement to move the cursor on the screen towards the target. These control and task conditions were repeated four times and each condition lasted for 10 seconds. Using Fast Fourier Transform, data in frequency domain for control and task have been obtained and analyzed in two of time interval of 1024 ms and 512 ms. Frequency is divided into six groups, i.e. delta band (0-4 Hz), theta band (4-7 Hz), alpha band (8-13 Hz), beta band (13-30 Hz), gamma band (31-50 Hz) and high gamma band (>51 Hz). Each frequency band in all frequencies of the task condition has been compared to the control condition. The present study finds optimum difference in delta frequency band between resting and active imagination at the parietal region. Furthermore, the parietal region is associated with sensory interaction and could be one of the input regions to control cursor movement. However, it is found that the delta frequency band is only applicable to a specific one-dimensional cursor movement as any imagination may produce the same results. Nevertheless, this study provides a platform for a more advance two-dimensional cursor movement study.

ABSTRAK

Pengantaramuka otak-komputer (BCI) tak invasif menggunakan elektroensefalogram (EEG) yang direkod dari kulit kepala boleh menyediakan laluan baru tanpa otot untuk menghantar isyarat dan arahan ke persekitaran. Objektif kajian ini adalah untuk mengenalpasti beberapa parameter yang akan menggerakkan kursor dalam BCI dengan menggunakan isyarat EEG tak invasif dan mengawal pergerakan kursor dalam satu dimensi menggunakan parameter yang telah diekstrak. Kajian yang berunsurkan eksperimen ini melibatkan enam orang subjek normal berusia di antara 20 hingga 26 tahun. Kesemua subjek perlu melaksanakan tugas dalam dua keadaan iaitu keadaan tugas dan keadaan kawalan. Dalam keadaan kawalan, subjek hanya perlu berehat dengan memandang ke arah tengah skrin tanpa paparan imej. Manakala dalam keadaan tugas, subjek diminta membayangkan satu pergerakan untuk menggerakkan kursor ke arah target pada skrin. Kedua-dua keadaan ini diulang sebanyak empat kali dan setiap satunya berlangsung selama 10 saat. Menggunakan jelmaan Fourier cepat, data dalam bentuk frekuensi diperolehi dan dianalisis dalam dua sela masa iaitu 1024 ms dan 512 ms. Julat frekuensi pula dibahagikan kepada enam kumpulan iaitu delta (0-4 Hz), teta (4-7 Hz), alfa (8-13 Hz), beta (13-30 Hz), gama (31-50 Hz) dan gama tinggi (> 51 Hz). Setiap frekuensi dalam keadaan tugas dan kawalan dibandingkan. Kajian ini mendapati bahawa perbezaan frekuensi dalam keadaan rehat dan imaginasi adalah optimum dalam julat delta di bahagian parietal. Dalam kajian ini, bahagian parietal berkaitan dengan interaksi deria dan menjadi salah satu input untuk mengawal gerakan kursor. Walau bagaimanapun, didapati bahawa jalur frekuensi delta hanya boleh diaplikasi ke atas gerakan kursor satu dimensi sahaja di mana sebarang imaginasi boleh memberikan hasil keputusan yang sama. Namun demikian, kajian ini juga memberi ruang yang menjurus kepada kajian gerakan kursor dua dimensi.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF ABBREVIATIONS	xvi
	LIST OF APPENDICES	xvii
1	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Problem Statement	2
	1.3 Objectives	3

1.4	Scope of Project	3
1.5	Project Contribution	4
1.6	Thesis Outline	4
2	LITERATURE REVIEW	6
2.1	Introduction	6
2.2	Electroencephalography	6
	2.2.1 EEG Waveform	7
2.3	The International 10-20 of Electrode Placement System	9
2.4	Brain-Computer Interface (BCI)	10
	2.4.1 Invasive and Noninvasive BCI	11
	2.4.2 Imagination vs. Actual Movement	12
	2.4.3 Electrophysiological Sources	12
	2.4.4 Signal Processing	15
2.5	Published Work on BCI	16
	2.5.1 Published Work on Neurofeedback	17
	2.5.2 Published Work on Cursor Control	18
	2.5.3 Published Work on Other Control	19
2.6	Discussion on Published Work in BCI	20
3	METHODOLOGY	22
3.1	Introduction	22
3.2	Experimental Set Up	22
	3.2.1 Equipment and Supplies	23

	3.2.2	Preparation of Subject	24
		3.2.2.1 Installing of Electrodes onto Electrode Board Adapter	24
	3.2.3	Clean Up	25
	3.3	Data Acquisition and Recording Process	26
		3.3.1 Participant	26
		3.3.2 Conditions	26
		3.3.3 Data Acquisition	26
		3.3.4 Data Analysis	27
	3.4	Flow Chart of Data Analysis	29
	3.5	Software Development	31
4		FREQUENCY ANALYSIS AND FINDINGS	35
	4.1	Introduction	35
	4.2	EEG Signals	35
	4.3	Feature Extraction Analysis	37
		4.3.1 1024 ms Time Interval	38
		4.3.2 512 ms Time Interval	40
		4.3.3 Mean for All Trials	43
	4.4	Feature Translation	45
5		DISCUSSION	48
	5.1	Introduction	48
	5.2	Parameters Determination	48

6	CONCLUSION	51
	6.1 Conclusion	51
	6.2 Recommendation for Future Work	52
	REFERENCES	53
	Appendices A-C	57-74

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Frequency band for EEG signals	7
2.2	Electrophysiological sources used in BCI	13
3.1	Electrodes position	25
4.1	Channels combination	45
4.2	Hit rate and mean time	46
4.3	Comparison of hit rates and movement precision	46
4.4	Size of target, cursor and workspace	47

LIST OF FIGURES

FIGURE NO.	TITLLE	PAGE
1.1	Scope of project	3
2.1	EEG waveforms	8
2.1 (a)	Delta wave	8
2.1 (b)	Theta wave	8
2.1 (c)	Alpha wave	8
2.1 (d)	Beta wave	8
2.1 (e)	Gamma wave	8
2.2	The 10-20 electrode placement system	9
2.3	Basic design and operation of a BCI system	10
2.4	Present-day human BCI system types	14
2.4(a)	Sensorimotor rhythm	14
2.4(b)	Slow cortical potentials	14

2.4(c)	P300 evoked potential	14
2.4(d)	Cortical neuronal activity	14
3.1	Equipment used in the experiment	23
3.1 (a)	Electro-cap	23
3.1 (b)	Electro board adapters	23
3.1 (c)	Body harness	23
3.1 (d)	Disposable sponge disks	23
3.1 (e)	Blunted needle/syringe kit	23
3.1 (f)	Ear electrodes	23
3.1 (g)	Electrode board adapter connector	23
3.2	Sequence of data acquisition	27
3.3	Division of data for 1024 ms and 512 ms time interval	27
3.4	Flow chart of parameter determination process	29
3.5	Flow chart of finalized parameter determination process	30
3.6(a)	Syntax of workspace	31
3.6(b)	Workspace	31
3.7(a)	Syntax of baseline	32
3.7(b)	Baseline	32
3.8(a)	Syntax of cursor	33
3.8(b)	Cursor	33

3.9(a)	Syntax of target	34
3.9(b)	Target	34
4.1	Example of 1 second of raw EEG signal from subject 1 at P _Z channel	36
4.2	Example of power spectrum of EEG signal from subject 1 at P _Z channel	36
4.3	Example of 1 second data of EEG signal from subject 1	37
4.4 (a)	The occurrences of maximum DP for trial 1 for 1024 ms time interval	38
4.4 (b)	The occurrences of maximum DP for trial 2 for 1024 ms time interval	39
4.4 (c)	The occurrences of maximum DP for trial 3 for 1024 ms time interval	39
4.4 (d)	The occurrences of maximum DP for trial 4 for 1024 ms time interval	40
4.5 (a)	The occurrences of maximum DP for trial 1 for 512 ms time interval	41
4.5 (b)	The occurrences of maximum DP for trial 2 for 1024 ms time interval	41
4.5 (c)	The occurrences of maximum DP for trial 3 for 1024 ms time interval	42

4.5 (d)	The occurrences of maximum DP for trial 4 for 1024 ms time interval	42
4.6	Average of percentage of the maximum DP for 1024 ms time interval	43
4.7	Average of percentage of the maximum DP for 1024 ms time interval	44
4.8	Translation equations in C structure	45
4.9	Location of cursor and target in workspace	47

LIST OF ABBREVIATIONS

ALS	-	Amyotrophic lateral sclerosis
BCI	-	Brain-computer interface
DP	-	Difference power
ECoG	-	Electrocorticography/electrocorticogram
EEG	-	Electroencephalography/electroencephalogram
ERP	-	Event-related potential
Hz	-	Hertz
ms	-	Milisecond
SCP	-	Slow cortical potential
SMR	-	Sensorimotor rhythm

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Coding of cursor movement	57
B	Coding to determine parameters	70
C	List of publications	74

CHAPTER 1

INTRODUCTION

1.1 Introduction

For normal people, communication is a need to undergo their daily activities. Communication is a process to transmit or transfer information, thought or by feeling by or to or between people or groups. It is a connection allowing access between persons by either verbal contact or action.

However, there are people who suffer from “locked-in syndrome” which means that they are completely unable to control any muscle that prevent them from communicating with their caregivers or environment [1]. For such users, a brain-computer interface (BCI) is the only hope for even communicating with loved ones, controlling even simple devices like televisions or lamps or otherwise expressing oneself. BCI is a novel augmentative communication system that translates human intentions into a control signal for an output device such as a computer application [2] or a mobile robot [3], in which users send information using brain activity alone without conventional peripheral nerves and muscles [3].

BCI can be divided into two general categories, i.e., invasive and noninvasive [3]. Most of noninvasive BCI systems use electroencephalogram (EEG) signals; i.e., the electrical brain activity recorded from electrodes placed on the scalp. The main source of the EEG is the synchronous activity of thousand of cortical neurons. Measuring the EEG is a simple noninvasive way to monitor electrical brain activity, but it does not provide detailed information on the activity of single neurons (a few μ Volts) and noisy environment (especially if recording outside shield rooms) [3]. In invasive BCI systems, the activity of single neurons (their spiking rate) is recorded from microelectrodes implanted in the brain. Such systems are being studied mainly in nonhuman primates, for example see [4]. These invasive BCIs face substantial technical difficulties and entail significant clinical risks as they require that recording electrodes be implanted in the cortex and function well for long periods, and they risk infection and other damage to the brain [5]. For human, therefore, noninvasive BCI systems are applied due to clinical risks and ethics [3].

1.2 Problem Statement

Among of the most important evaluation in one or two dimensional cursor movement-BCI is hit rate. It is an onset element to design a practical application of BCI that depends in speed and accuracy. If the speed and accuracy can be substantially improved, the range of applications and the number of potential users would greatly increase [1].

In one dimensional cursor movement-electrocorticogram (ECoG) study, they achieved success rates of 74-100% [6] whereas in two-dimensional cursor movement-EEG study, hit rate was accomplished until 92% [5].

1.3 Objectives

This study was conducted with the objective of:

- To determine parameters that will drive or control cursor in brain-computer interface (BCI) using noninvasive EEG signal.
- To determine parameters that can produce faster hit rate of brain-computer interface.

1.4 Scope of Project

Figure 1.1 depicts the block diagram for this study's scope of work. First, EEG is recorded from the scalp and digitalized using acquisition system. Then the digitalized signals are subjected to feature extraction procedures, such as spectral analysis or spatial filtering. Afterwards, translation algorithm converts the EEG feature into command of the cursor movement. At the monitor screen, the cursor moves and hit target.

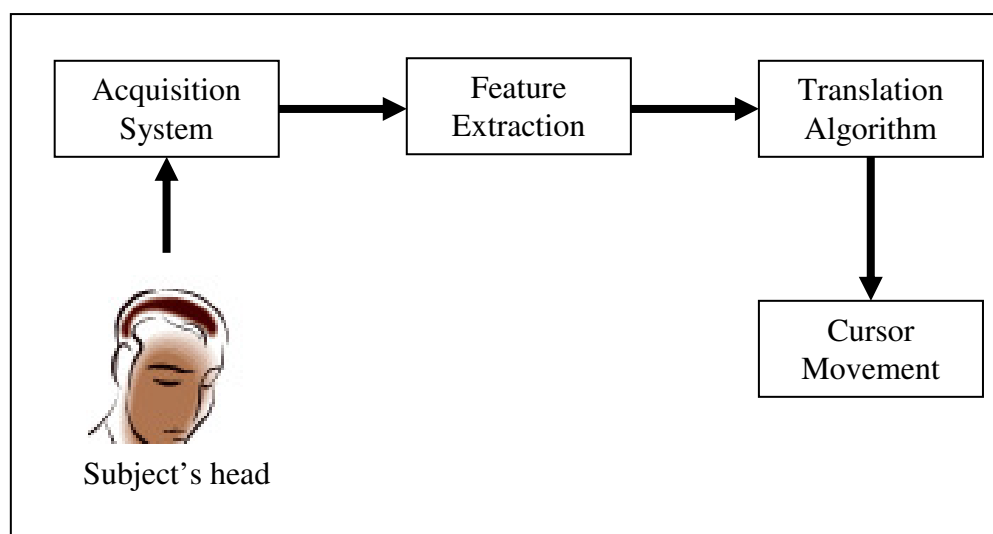


Figure 1.1 Scope of project

1.5 Project Contribution

BCI uses human brain signal to control other devices. This technology has advances significantly in the world but not many researches can be found in Malaysia. Advanced research has lead to potential use in medical field as well as in computer games industry. This research has few purposes; firstly to develop human capital in BCI for Malaysia. Secondly, is to provide platform for a more advance application such as a two-dimensional cursor movement. A study by other researchers has found that slow frequency gave highest correct response rate when presented with visual presentation of target and non-target. This research also has found slow frequency as optimum parameter to control cursor movement. However, it is noted that the methodology for the experimental set-up was weak, leading to limited application to only specific one-dimensional cursor movement as any imagination may bring about the same results. However, with proper methodology and feature extraction, there is possibility of using slow frequency for BCI application that will increase the versatility of the field.

The contribution of this research would be in the developed in-house software of BCI. The developed software is integrated with an existing hardware. The software main contribution is that it is an open source, has adjustable cursor and target size, and is panel window size-independent software. With the robust software, a more advance application can be developed and together with correct methodology, the objectives are obtainable.

1.6 Thesis Outline

This report is divided into six chapters. This initial chapter presents introduction to the project which includes the project background, problem

statement, objectives of the project, the main objectives, scope of the project and the project contribution. This chapter is referred to conclude the findings of the project in conclusion part.

Chapter 2 discussed about reviewed literatures and published works on BCI in view of applied methodologies over the years. This chapter also discussed on several types of electrophysiology sources and experimental designs including general overview of BCI study.

The project methodology is covered in Chapter 3 that include discussion on the processes and steps involve in managing the raw data from EEG, the formula that being used and the information on software and hardware utilize in this study.

Chapter 4 contains the result of feature extraction and feature translation in offline analysis. In feature extraction, EEG signals were analyzed using Fast Fourier Transform (FFT) in two time interval i.e. 1024 ms and 512 ms. Afterward, two parameters from the transformed data in frequency domain were extracted, i.e., scalp location and frequency band. Applying a value coordinated by those two parameters, translation algorithm was performed. The performance in mean time, hit rate and movement precision were observed and compared with previous studies.

Chapter 5 summarizes the results and findings from the previous chapter. The values of maximum difference in power which are pointed by the two parameters might be use to control and one-dimensional cursor movement.

The overall project is rationalized and concluded in the final chapter, Chapter 6. Some suggestion and recommendation are also discussed.