TARGET SELECTION USING SINGLE ELECTROENCEPHALOGRAM ELECTRODE BASED ON MENTAL TASK

HUSNAINI BINTI AZMY

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MARCH 2014

To my beloved

Azmy Abdul Aziz, Wan Hindon Wan Sulong,

Ahmad Sazali Senawi together with my 3 children

and

Norlaili Mat Safri (Dr.)

ACKNOWLEDGEMENT

Thank you Allah for giving me chance and good health experienced these precious moments doing my master study.

The greatest appreciation and specialthanks, to my supervisor Dr Norlaili binti Mat Safri for guiding and supervising me with patient to complete this Master study successfully. My sincere appreciation to Ministry of Science, Technology & Innovation, Malaysia (MOSTI) for National Science Fellowship (NSF) scholarship and Universiti Teknologi Malaysia (UTM) for helping in terms of fundingand assisting my Master study.

My sincere gratitude goes to the wonderful person in my life, Ahmad Sazali Senawi for being my helping hands and providing lots of assistance along this study completion. Also to Dr. Fauzan khairi bin Che Harun,Dr.Ahmad Zuri Sha'ameri, Dr. Yusmeeraz, Dr. Rubita Sudirman, Dr. Suhaila, Mr. Mohd Afzan bin Othman, Ms. Nurul Ashikin Abdul Kadir, Mrs. Siti Zuraimi Salleh and others who provide assistance along the completion of this study. Special thanks to technicians from Medical Electronics Lab, Ms. Wan Nor Afiza and Mrs. Rohanifor the support inside the lab.

My great husband along with my beloved 3 children, mother, father, sister, brother and friends who always support me along my way, thank you very much for the prayers, support, kind, love, care and patience.

ABSTRACT

Electroencephalogram (EEG)-based BCI studies have been done since early 21st century. The main focus is to improve in areas of neuroscience. It has lead to the use of electrical activity on brain into controlling devices such as wheelchair, cursor movement on computer screen, etc. The purpose of this study is to detect the brain activation on scalp by EEG task-based Brain Computer Interface (BCI) using wireless control robotto determine one scalp location which will give signals that can be used to control the wireless robot without subject training. EEG was measured in 8 normal subjects for control and two tasks conditions. In control condition, subjects were asked to relax but in Task 1 condition, subjects were asked to imagine a star rotating clockwise at position of 45 degree direction pointed by the wireless robot where at this angle the target is located. Same conditions applied for Task 2 but subjects were asked to solve multiplication number 13 without saying or moving, just solve in their mind. At position 0 and 90 degrees angle for both tasks, subjects were asked to relax since there is no target on these directions. Using EEG spectral power (analysis I) and normalization (analysis II), the optimum location for these two tasks were detected and compared. For Task 1, the significant brain activation occurred at position $F_{8,}$ which is atthe frontal cortex area and the significant rhythm was alpha frequency band with $P < 0.001$ and $F_{(10,70)}= 5.31$. However, Task 2 which is mental task of solving multiplication number did not give significant results as Task 1($P > 0.05$).In conclusion, it is possible to direct wireless robot towards direction of target location using an imaginary star rotation movement without prior training given to subject and with only single electrode.

ABSTRAK

Kajian Electroencephalogram (EEG) berasaskan *Brain Computer Interface* (BCI) telah dilakukan sejak abad ke-21. Focus utama adalah untuk meningkatkan bidang neurosains. Ia telah mengembangkan ilmu aktiviti elektrik pada otak untuk mengawal peralatan seperti kerusi roda, pergerakan kursor pada skrin komputer dan lain-lain. Tujuannya adalah untuk menentukan satu lokasi di kulit kepala yang memberikan isyarat yang boleh digunakan bagi mengawal robot tanpa wayar menggunakan EEG dan BCI tanpa perlu melatih subjek. EEG diuji kepada 8 orang biasa untuk mengawal minda dalam keadaan rehat dan tugas. Terdapat dua keadaan tugas iaitu Tugasan 1 dan Tugasan 2. Subjek telah diminta untuk berehat pada keadaan rehat. Dalam ujikaji Tugasan 1, subjek diminta untuk membayangkan bintang berputar mengikut arah jam apabila robot tanpa wayar berada dalam kedudukan 45 darjah di mana sasaran terletak pada arah ini. Begitu jugaTugasan 2 tetapi subjek diminta untuk menyelesaikan beberapa sifir 13 tanpa mengatakan atau bergerak, hanya menyelesaikan dalam fikiran mereka. Pada kedudukan 0 dan 90 darjah untuk kedua-dua tugas, subjek diminta untuk berehat tanpa memikirkan apa-apa kerana tiada sasaran pada arah ini. Menggunakan kuasa spektrum EEG (analisis I) dan normalisasi (analisis II), lokasi yang optimum bagi kedua-dua tugas dikesan dan dibandingkan. Sebagai keputusannya, analisis II telah menunjukkan bahawa padaTugasan 1, pengaktifan otak yang ketara berlaku di F_8 yang berada dalam kawasan korteks hadapan dan berlaku di frekuensi alfa dengan $P < 0.001$ dan $F_{(10,70)} = 5.31$. Pada kedudukan ini, isyarat dari otak dapat mengawal robot ke arah yang diperlukan dengan memberi isyarat yang betul dan tepat bagi robot bergerak ke arah sasaran. Walau bagaimanapun Tugasan 2 tidak memberikan hasil yang ketara seperti Tugasan 1 untuk kedua-dua analisis dengan nilai $P > 0.05$. Sebagai rumusan, adalah tidak mustahil untuk mengarahkan robot tanpa wayar ke arah lokasi sasaran menggunakan imaginasi gerakan bintang berputar tanpa perlu melatih subjek dan hanya menggunakan satu elektrod.

TABLE OF CONTENTS

CHAPTER	TITLE		PAGE
	DECLARATION		ii
	DEDICATION		iii
	ACKNOWLEDGEMENT		iv
	ABSTRACT		v
	ABSTRAK		vi
	TABLE OF CONTENTS		vii
	LIST OF TABLES		x
	LIST OF FIGURES		xi
	LIST OF APPENDICES	xiii	
1	**INTRODUCTION**		
	1.1 Introduction		1
	1.2 Overview of EEG and BCI Research History		1
	1.3 Problem Statement		3
	1.4 Objective		4
	1.5 Scope of Study		5
	1.6 Significance of the Study		6
	1.7 Organization of Thesis		7
2	**LITERATURE REVIEW**		
	2.1 Introduction		8
	2.2 Methods Use In Analyzing Brain Condition and Neuroimaging Techniques		10
	2.3 EEG		10
	2.3.1 EEG Frequency classification		12

2.3.2 Electrodes Positioning and Areas around the Cerebral Cortex 13
2.4 BCI system 15
2.5 EEG-based BCI 16
2.6 Subject training 17
2.7 Motor Imagery for Task-dependent EEG-based BCI 18
2.7.1 Task-based Condition 19
2.7.2 Multiplication Task and Geometric Rotation Task 21
2.8 Summary 23

3 EXPERIMENTAL PLATFORM AND PROCEDURE
3.1 Introduction 24
3.2 Experimental Set Up 24
3.2.1 Hardware Development and Devices 25
3.2.1.1 Wireless Robot Communication Circuit andConfiguration 25
3.2.1.2 Equipments and Supplies 27
3.2.2 Software Development and Programming 28
3.2.2.1 LabVIEW Program 28
3.2.2.2 Mikroelektronika and PIC Kit Software 31
3.2.2.3 Linux C Program 31
3.2.3 Data Acquisition and Recording Process 32
3.2.3.1 Participant 32
3.2.3.2 Experimental Procedure 32
3.2.3.3 Data Recording 33
3.2.3.4 Task 34
3.2.4 Feature Extraction 36
3.2.5 Statistical Analysis 36
3.2.6 Parameter Determination 37
3.2.7 Performance Test 38
3.3 Summary 39

4 RESULT AND DISCUSSION

4.1 Introduction 41

4.2 Feature Extraction and Analysis 41

4.2.1 Analysis I: Difference in Power 42

4.2.2 Analysis II: Normalization 46

4.3 Feature Translation and Statistical Analysis 48

4.4 Performance Test Results 53

4.5 Summary 55

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion 57

5.2 Recommendations and Future Works 58

REFERENCES 59

Appendices A-E 64-99

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Frequency band and its ranges	12
2.2	Comparison of W-K and Burg methods, average percent classification accuracy over five subjects, 20 data records, eyes open cases only	22
3.1	List of equipments and supplies	28
3.2	Multiplication numbers for each trial in Task 2	35
4.1	Values of t-test for all 19 channels at each frequency band and ANOVA p-value for 0-45 degree angle for Task 1	49
4.2	Values of t-test for all 19 channels at each frequency band and ANOVA p-value for 0-90 degree angle for Task 1	50
4.3	Values of t-test for all 19 channels at each frequency band and ANOVA p-value for 0-45 degree angle for Task 2	51
4.4	Values of t-test for all 19 channels at each frequency band and ANOVA p-value for 0-90 degree angle for Task 2	52
4.5	Percentage values of each trial in Task 1, F_8 location, alpha frequency band for non-target (before target), target, and non-target (after target) signals	53
4.6	Summarize of condition-related power performance of the non-target and target data	55

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Scope of study flow	5
2.1	Example of EEG signal recorded during a voluntary finger movement	11
2.2	Electrode placement	14
2.3	Network output vaues and desired values of EEG for one test Trial for Subject 1	21
3.1	Experimental set up	25
3.2	USB to UART breakout board for Xbee set up	26
3.3	Transmit communication circuit connections from computer to robot	27
3.4	Receiver circuit connections from computer to robot PIC	27
3.5	EEG waveforms data sheet from EEG machine	29
3.6	Graphical User Interface of LabVIEW program	30
3.7	Block diagram of LabVIEW program	30
3.8	Description of main shell script together with its sub program in C language	31
3.9	Flow chart of recording process	34
3.10	Starting angle and direction angles of the wireless robot	35
3.11	Flow chart of parameter determination	38
4.1	Results of Task 1 maximum difference in power (DP) for each angle; (a) 0 degree, (b) 45 degree and (c) 90 degree	43
4.2	Results of Task 2 maximum difference in power (DP) for each angle; (a) 0 degree, (b) 45 degree and (c) 90 degree	44
4.3	Topographic map for condition related power changes for Task 1 geometric star rotation imaginary. A: changes between	

	angle 0 and 45 degrees (non-target and target conditions).	
	B: changesbetween 0 and 90 degrees angle (both are non-target)	47
4.4	Topographic map for condition related power changes for Task 2 multiplication of number 13. A: changes between angle 0 and 45 degrees (non-target and target conditions).	
	B: changes between 0 and 90 degrees angle (both are non-target)	47
4.5	Performance chart of condition related power values for Task 1 frontal area F_8 at alpha frequency band at every angles and trials	54

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Xbee Configuration	64
B	LabVIEW programme	73
C	Program to control PIC	76
D	Linux C programme	89
E	Publications	99

CHAPTER 1

INTRODUCTION

1.1 Introduction

Electroencephalogram (EEG) and Brain-computer Interface (BCI) are well known in areas related to medical such as biomedical, neurosciences, cardiology and etc. The researches in this area is becoming more crucial and important especially to people with motor disabilities such as people with amyotrophic lateral sclerosis (ALS), people who has brainstem stroke and people who are paralyzed. Therefore the purpose of this study is to develop a system that can read and record EEG signal from a patient or subject, then translate the signal into a command that can control tools or devices such as wheelchair, robot arm, mobile robot, cursor movement and others. This chapter tells about the history of EGG and BCI together with problem statement of the study. Then the objectives, scope of study, significance of study and the organization of this study thesis are also explained here.

1.2 Overview of EEG and BCI Research History

Electroencephalogram (EEG) is a test to measure brain electrical activity or a procedure to measure electrical signals from scalp produced by monitoring neurons activities in brain, captured non-invasively which is rather safe, doable and low risk procedure where the electrodes are placed on the scalp without the need of surgery.

This test has been done since 1842 by Richard Caton who was the first to record the spontaneous electrical activity on brain [1]. However Hippocrates in the century of 430-350 BC has been able to espouse many in his writings about the brain function which is responsible for the behaviours and functions ascribed to the heart [2]. Therefore it can be seen here that research in brain areas has been started since many years ago. Then a German psychiatrist Hans Berger was known as the first person to report human EEG in 1929 where he recorded the electrical activity from the skull and reported brain activity changes according to the functional state of the brain such as sleep, hypnotize or during epilepsy [3]. Afterwards in 1957, an American named William Grey Walter used cutting edge electronic to built the first brain topography machine that was able to build maps of cerebral activity and it has revealed as a useful tool in the diagnosis of mental diseases (e.g. epilepsy). These examples of studies and researches from these people show the importance of this topic to be developed and explored. Up until now the research on EEG is still ongoing and developing along with the new technologies advancement [4]. The discovery of electroencephalography has lead to the advancement of neuroscience and of neurologic and neurosurgical everyday practice, especially patient with seizures, brain tumors and degenerative brain changes.

On the other hand, Brain-computer Interface (BCI) or also known as neural interface or brain-machine interface (BMI) is a direct communication link between brain and external electronic devices. BCI has been introduced in 1970s.Earliest paper describing a BCI system was published in 1973 by J. J. Vidal where he started to evaluate the feasibility and practicality of utilizing the brain computer communication [5]. BCI2000 was introduced in the era of millennium where it shows the communication between the brain signal to control robot such as a wheelchair. The BCI2000 is used to create BCI systems for a variety of brain signals, processing methods, and applications. Later after year of 2003, BCI research has grown substantially [6]. People with motor disabilities, people who are totally paralyzed or people who lost control over every motor output can still have chance to communicate with outside world by controlling external devices using their brain signals providing that they do not have any mental issues. As a result, nowadays the research has lead to applications with more advanced and useful features to these targeted group of people.

There are several ongoing research regarding to this topic, however current system has limitations and previous researchers encounter certain problems such as location of the probe that can affect the quality of signal recording. If the probe was not placed at the correct and exact location, the desired signal from the brain will be difficult to read [7]. Too many electrodes may carry strong disadvantages since they are of difficult placement, resulting in time-consuming and complex attachment procedures.

During the experiment the patient may have difficulties of feeling fatigue for the experiment that requires training beforehand. The procedure of setting up and connecting the electrodes on human scalp has led to longer time taken before starting the procedure. Feeling fatigue can cause inaccurate signal produced during the experiment as reported on paper from [8]. Too many electrodes attached on the scalp also cause problem to the system. The signals are interfering with each other causing noise and irrelevant data. Time taken to put on the electrodes on scalp is longer and leads the subject to feel exhausted.

Some of the procedure requires training protocol before taking the real data. It is because the subject has to focus better on the experiment. Therefore it requires longer time of training for the experiment[9]. The training may require to be done at many times until the desired signal is ideal. Without the training, subject can also produce good signal to control output devices [10]. Therefore subject can save a lot of time during the experiment and allows faster set up which consist less time taken and also create a robust system by eliminating training process.

These reasons causes this study to give solutions in order to meet the objectives. Next section highlighted the problem statement of this study.

1.3 Problem Statement

Identified limitations of current systemfromprevious researchers on the effect of probe location to the quality of signal recording, has lead to this study mission

which isselecting target using minimal or single EEG electrode. Too many electrodes attached on the scalp also cause problem to the system. Subject will feel exhausted, heavy load on the head because of the configuration set up. The signals are interfering with each other causes noise and interference signal. The displacement of the electrode can be reduced as the electrode needed is less. With less probe involved and placed at the correct and exact location, the desired signal from the brain may have better performance.

Difficulties of feeling fatigue during the experiment can cause inaccurate signal produced during the experiment. With the simple, easy and less set up time, the subject or disable person will be more relax and less nervous during the execution on using the system.

Longer time of training for the experiment has concern this study to approach on a system without the need of training. As mentioned in section 1.2, subject still can produce good signal to control output devices. Therefore a lot of time can be saved during the experiment and allows faster set up by starting the experiment without the training.

Therefore this study identified and considered these disadvantages of EEG-based BCI and pursued towards sustainable, efficient and ergonomic BCI systems which is not only reliable at research laboratory but also reliable in practical and daily real life.

1.4 Objective

The main objective of this research is to define the best location on scalp position where the control of the device such as robot points towards target location successfully.Several key points that contribute to the main objective of this research work are to use brain wave to control robot movements for target detection, develop classification algorithm to control robot using EEG signals and BCI and to develop a faster and more convenient method for disable people by using only 1

electrode/channel, non-invasive and without subject training. In other words EEG-based BCI technology reduces number of electrode used, increase the speed to recognize the direction of target and increase its accuracy and efficiency.

1.5 Scope of Study

As this study persist, the procedure used is using EEG signalwhich is a non-invasive method, without subject training and the control of wireless robot by human by EEG signal. The collection of EEG signals were from healthy adult human subjects aged between 23 to 33 years old which is a group of adults. During the experiment, there are no training involved and subject has to do task-dependent brain imagery as a method and tool to control output devices for example, wireless mobile robot.

The acquisition system contains EEG signals where it is a non-invasive BCI.The EEG signal was recorded from the scalp through 19 electrode channels and digitized using acquisition system from the EEG machine.

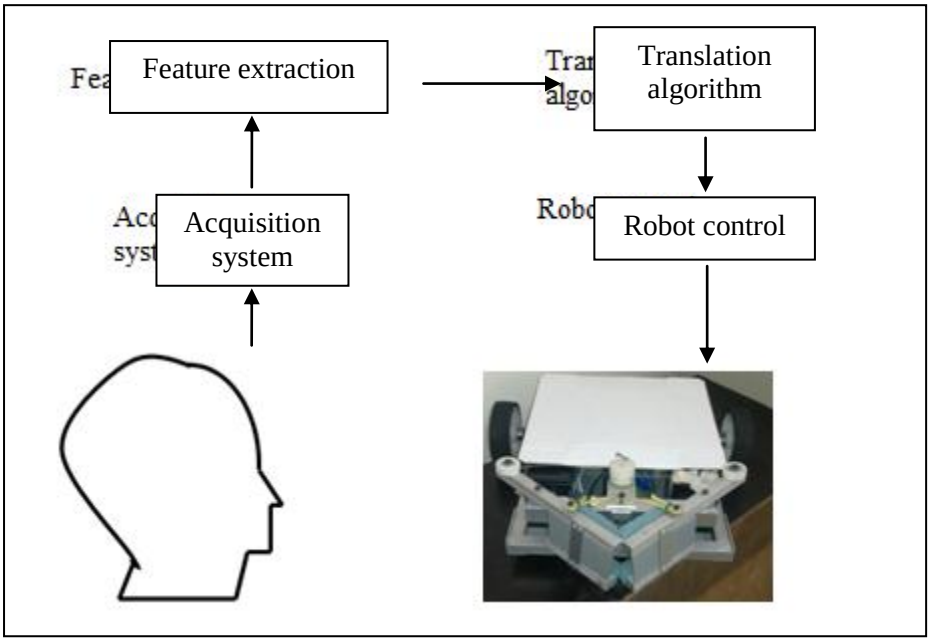

Figure 1.1 Scope of study flow

After the collecting and recording data from subject, data then go through FFT (Fast Fourier Transform) analysis which also known as feature or parameter extraction. The digitized signals were manipulated to feature extraction procedures, such as power spectral analysis. After such feature extraction, the system has to go through translation algorithm where C language has been used in programming the program to analyze signals and LabVIEW program was used to control robot. The PIC on the robot was programmed and has enough information to know the directionof desired target location.

1.6 Significance of the Study

This study aims to help people with motor disabilities to communicate with outside world rather than just being lock inside their own body since their body parts are malfunction. This study can also be as a platform as new paradigm for assistive medical services, helping to improve people's quality of life in their daily activities and even in gaming. Other researches can have more input and data that can be comparared or study further about the location on scalp that helps getting the best EEG signals during specific task or task dependent experiment in BCI system. At the same time it supports previous researchers on their findings and help other researches on doing further and advanced studies in this area.

In developing country like Malaysia, more research is needed in this area since it can help to improve the rehab facilities for disable people to be more advance and with better infrastructure according their needs. Local people will be aware on how to treat or communicate with people with motor disabilities and vice versa for people with motor disabilities who will communicate back using their devices controlled by their brain waves.

1.7 Organization of Thesis

This thesis is divided into five chapters. Following this first chapter of introduction chapter is Chapter 2, which presents some background information of the study and literature reviews of related research of EEG, BCI, types of neuro analysis techniques and motor imagery with visual imagery task of geometric rotation and multiplication numbers.

In Chapter 3, we described briefly about methodology used in this study. Overall system design and implementation are described from software and hardware perspective.

Chapter 4 discusses the findings during experiments and result of electrode position on scalp. This chapter shows every steps of feature extraction and translation algorithm and also the statistical analysis involved.

Chapter 5 concludes research findings from this study supported with previous research findings and recommendations of some ideas for future work.

REFERENCES

[1] Finger, S.*Origins of Neuroscience: A History of Explorations Into Brain Function*. New York: Oxford University Press. 1994

[2] Martin, G. N. Human *Neuropsychology*.Europe: Prentice Hall. 1998

[3] Brazier, M.A.B.*A history of the electrical activity of the brain; the first half-century*. New York: Masmillan. 1961

[4] Ron-Angevin, R., Angel Lopez, M., and Pelayo, F. The Training Issue in Brain-Computer Interface: A Multi-disciplinary Field. *In proceeding of: Bio-Inspired Systems: Computational and Ambient Intelligence, 10th International Work-Conference on Artificial Neural Networks, IWANN 2009*.June 10-12, 2009.Salamanca, Spain: Springer-Verlag Berlin Heidelberg 2009. 666–673.

[5] Jacques J. Vidal. Toward Direct Brain-Computer Communication. *Annual Review of Biophysics and Bioengineering.* 1973. Vol 2: 157-180.

[6] Brahim, H. BCI literature-a bibliometric study.*International Conference on Information Sciences, Signal Processing and their Applications ISSPA 2010*.May 10-13, 2010. Singapore: IEEE. 2010.626-629.

[7] Fernandes, M., et al.Wearable Brain Cap with Contactless Electroencephalogram Measurement for Brain-Computer Interface Applications. *Proceedings of the 4th International IEEE EMBS Conference on Neural Engineering*. April 29 - May 2, 2009. Antalya, Turkey: IEEE. 2009. pg:387-390.

[8]Raphaëlle,N.Roy et al.Mental fatigue and working memory load estimation: Interaction and Implications for EEG-based Passive BCI. *35th Annual International Conference of the IEEE EMBS*. 3 - 7 July, 2013. Osaka, Japan : IEEE. 2013. pg: 6607-6610.

[9] Bryan, M. et al. Automatic Extraction of Command Hierarchies for Adaptive Brain-Robot Interfacing. *2012 IEEE International Conference on Robotics and Automation (ICRA).* May 14-18, 2012. Minnesota, USA: IEEE. 2012. pg: 3691-3697.

[10] Benjamin Blankertz et al.The Berlin Brain–Computer Interface: EEG-BasedCommunication Without Subject Training. *IEEE Transactions on Neural Systems and Rehabilitation Engineering.* 2006.Vol. 14(2): 147-152.

[11] Kennedy, P.R., Bakay, R.A.E. et al. Direct Control of a Computer from the Human Central Nervous System. *IEEE Transactions on Rehabilitation Engineering.*2000. Vol 8(2):198-202.

[12]McFarland, D.J. and Wolpaw, J.R. Brain-Computer Interface Operation of Robotic and Prosthetic Devices. *Journals & magazines NewYork State Department of Health, IEEE Computer Society.* 2008. Vol 41(10): 52-56.

[13] Neumann, N. and Kuber, A. Training Locked-in Patients: A Challenge for the Use of Brain–Computer Interfaces. *IEEE Transactions on Neural Systems and Rehabilitation Engineering.*2003.Vol 11(2): 169-172.

[14] Barbosa, A.O.G., Achanccaray, David R. and Marco, A. Meggiolaro. Activation of a Mobile Robot through a Brain Computer Interface. *IEEE International Conference on Robotics and Automation.* May 3-7,2010. Anchorage, Alaska: IEEE. pg: 4815-4821.

[15] Salleh, Siti Zuraimi.,Mat Safri, Norlaili andAli, Siti Hajar Aminah. Moving One Dimensional Cursor Using Extracted Parameter from Brain Signals. *Signal Processing: An International Journal (SPIJ).* 2009. vol. 3 (5):110-119

[16] Obermaier, B., Müller, G.R.,and Pfurtscheller, G. Virtual Keyboard controlled by spontaneous EEG activity. *IEEE Transactions on Neural Systems and Rehabilitation Engineering.* 2003. Vol 11(4): 422-426

[17] Iturrate, I.; Antelis, J., Minguez, J. Synchronous EEG brain-actuated wheelchair with automated navigation. *Robotics and Auto-mation. IEEE International Conference ICRA.*May 12-17,2009. Kobe, Japan: IEEE. pp 2318-2325

[18] A. Curran, Eleanor and J. Stokes, Maria. Learning to control brain activity: A review of the production and control of EEG components for driving brain-computer interface (BCI) systems. *Brain and Cognition.* 2003. 51 :326-336

[19] J. R., Wolpaw, et al. Brain-Computer Interface Technology: A Review of The First International Meeting. *IEEE Trans. Rehab. Eng*. 2000. 8:164-173.

[20] Li-Wei Wu, Hsien-Cheng Liao, Jwu-Sheng Hu and Pei-Chen Lo.Brain-controlled robot agent: an EEG-based e-Robot agent. *Industrial Robot: An International Journal*. 2008. Vol. 35 (6): 507–519.

[21] Georg E. Fabiani, Dennis J. McFarland, Jonathan R. Wolpaw, and Gert Pfurtscheller. Conversion of EEG Activity Into Cursor Movement by a Brain–

Computer Interface (BCI). *IEEE Transactions On Neural Systems And Rehabilitation Engineering.* 2004.Vol 12(3): 331-338.

[22] Hema C.R., Paulraj M.P., S. Yaacob, A. H. Adom, and R Nagarajan.Motor Imagery Signal Classification for a Four State Brain Machine Interface. *International Journal of Biological and Life Sciences.* 2007. 3(1): 76-81

[23] Kawada, M. and R.M., Leahy. Electrical Brain Mapping of Motor Imagination Using the Minimum Norm Solution. *International Symposium on Communications and Information Technologies (ISCIT)* .Oct 18- Sept 20,2006 . Bangkok, Thailand: IEEE.2006. 595-598.

[24] C.L, Johnny and S.T., Desney. Using a Low-Cost Electroencephalograph for Task Classification in HCI Research. *UIST'06*, October 15–18, 2006. Montreux, Switzerland: ACM.2006. 81-90.

[25] Andre Ferreira et al. Human-machine interface based on EMG and EEG applied to robotic systems. *Journal of NeuroEngineering and Rehabilitation*. 2008. 5(10):1-15

[26] Schalk, G. and Leuthardt, E.C. Brain-Computer Interfaces Using Electrocorticographic Signals. *IEEE Reviews In Biomedical Engineering*. 2011. 4:140-154

[27] Sitaram, R.,Wiskopf, N., Caria, A. et al. fMRI Brain-Computer Interfaces. *Signal Processing Magazine, IEEE*. 2008. 25(1):95-106

[28] Barlow, David H. and Durand, Vincent Mark. *Abnormal Psychology: An Integrative Approach*. 6th Edition. Wadsworth: Cengange Learning. 2012.

[29] M. C. Park et al. The Future of Neural Interface Technology. In: M. Lozano,Andres. *Textbook of Stereotactic and Functional Neurosurg*ery. Berlin: Springer-Verlag. 3185-3200; 2009

[30] Durka, P.J. and Blinowska, K.J. A Unified Time- Frequency Parametrization of EEGs. *Engineering in Medicine and Biology Magazine, IEEE.* 2001. 20(5): 47-53.

[31] R. Kandel, Eric, H.S., James and Jessell, Thomas M. *Principles of Neural Science.* Forth Edition. United States: McGraw-Hill. 2000

[32] Jian Le et al. A rapid method for determining standard 10/10 electrode positions for high resolution EEG studies. *Electroencephalography and clinical Neurophysiology.* 1998. 106 (1998): 554–558.

[33] O.O., Jorma, et al. Effects of electrode properties on EEG measurements and a related inverse problem. *Medical Engineering & Physics.* 2000. 22 (2000) 535–545.

[34] Sharbrough, F., Chatrian, G.E., Lesser, R.P., Lüders, H., Nuwer, M., and Picton, T.W. American Electroencephalographic Society Guidelines for Standard Electrode Position Nomenclature. *J. Clin. Neurophysiol*. 1991. 8: 200-202.

[35] Park, Jangwoo, Woo, Il and Park, Shinsuk. Application of EEG for Multimodal Human-Machine Interface. *12th International Conference on Control, Automation and Systems.* Oct. 17-21, 2012 . Jeju Island, Korea: IEEE. 2012. 1869-1873

[36] K.K, Hyun, Park, Shinsuk and A. Srinivasan, Mandayam. Developments in brain–machine interfaces from the perspective of robotics. *Human Movement Science*. 2009. 28 (2009):191–203

[37] Schalk, G.,McFarland, D.J. , Hinterberger, T.et al. BCI2000: A General-Purpose Brain-Computer Interface (BCI) System. *IEEE Transactions on Biomedical Engineering*. 2004. Vol.51(6):1034-1043.

[38] Millán, Jd.R., Renkens, F., Mourino, J. et al. Noninvasive Brain-Actuated Control of a Mobile Robot by Human EEG. *IEEE Transactions on Biomedical Engineering*. 2004. Vol. 51(6):1026-1033.

[39] Zhu, Xiaoyuan, Guan, Cuntai, Wu, Jiankang et al. Expectation-Maximization Method for EEG-Based Continuous Cursor Control. *EURASIP Journal on Advances in Signal Processing.* 2006. Vol. 2007:1-10.

[40] Mat Safri, N., Murayama, N., Hayashida Y., Igasaki T., Effects of Concurrent Visual Tasks On Cortico-Muscular Synchronization In Humans. *Brain Research.* 2007. Vol.1155(2007): 81 – 92.

[41] C.C., Byung and Seo, B.H. Development of new brain computer interface based on EEG and EMG. *IEEE International Conference onRobotics and Biomimetics, ROBIO 2008*. Feb 22-25, 2009.Bangkok, Thailand: IEEE. 2009. 1665-1670.

[42] Neumann, N. and Kubler, Andrea. Training Locked-in Patients: A Challenge for the Use of Brain–Computer Interfaces.*IEEE Transactions on Neural Systems and Rehabilitation Engineering*. 2003. Vol. 11(2): 169-172.

[43] B., Benjamin et al. The Berlin Brain–Computer Interface: EEG-Based Communication without Subject Training. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*. 2006. Vol. 14(2):147-152.

[44] Kawada, M. and Leahy, R.M. Electrical Brain Mapping of Motor Imagination Using the Minimum Norm Solution. *IEEE ISCIT*. Oct 18- Sept 20, 2006. Bangkok, Thailand: IEEE. 2006. 595-598.

[45] Iáñez, Eduardo et al. Mental Tasks-based Brainrobot Interface. *Robotics and Autonomous System*. 2010. Vol. 58(12):1238-1245.

[46] W.A., Charles. Identifying Mental Tasks from Spontaneous EEG: Signal Representation and Spatial Analysis. In: Jose Mira and Juan V. Sanchez-Andres. ed. *Engineering Applications of Bio-Inspired Artificial Neural Network*. New York: Springer Berlin Heidelberg. 228-237; 1999

[47] Keirn, A. and Aunon, J.I. A new mode of communication between man and his surroundings.*IEEE Transactions onBiomedical Engineering*. 1990. Vol 37(12): 1209 – 1214.

[48] Manzoor, R.S., Gani, R. and Jeoti, V.et al. Dwpt based FFT and its application to SNR estimation in FDM Systems. *Signal Processing: An International Journal*. 2009. 3(2):1-6

[49] Siti Zuraimi bt Salleh. *Control Of One-Dimensional Cursor Movement By Noninvasive Brain-Computer Interface In Humans.* Master thesis. Universiti Teknologi Malaysia; 2011.

[50] Cre´mers,J., Dessoullie`res,A. and Garraux, G.. Hemispheric Specialization during Mental Imagery of Brisk Walking. *Human Brain Mapping*. 2012. 33(4): 873-882.

[51] Romero, D.H., Lacourse, M. G., Lawrence, K. E. et al. Event-related Potentials as a Function Of Movement Parameter Variations During Motor Imagery and Isometric Action. *Behavioural Brain Research*. 2000. 117(1-2): 83-96.

[52] Crivello, F. et al. Functional Anatomy of Visuo-Spatial Mental Imagery: Correlation Maps Between Baseline NrCBF and Psychometric Data. *NeuroImage*. 1996. 3(3): S206.

[53] Slotnick, S.D., Thompson, W. L. and Kosslyn, S. M. Visual memory and visual mental imagery recruit common control and sensory regions of the brain. *Cognitive Neuroscience*. 2012. 3(1): 14-20

[54] De Borst, A.W., Sack, A.T., Jansma, B.M., et al. Integration of "what" and "where" in frontal cortex during visual imagery of scenes. *NeuroImage.* 2012.60(1): 47-58.

[55] Ramli, S.N., Safri, N.M., Sudirman, R.,et al. Cortical Connectivity during Isometric Contraction with Concurrent Visual Processing by Partial Directed Coherence. *IFMBE Proceedings.* 2011.35: 496–499.