CLASSIFICATION OF ELECTROENCEPHALOGRAM (EEG) FOR LOWER LIMB MOVEMENT OF POST STROKE PATIENTS USING ARTIFICIAL NEURAL NETWORK (ANN)

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Thank You Allah.

For my beloved mother and father,

My wife and son,

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ABSTRACT

Nowadays, many neurological conditions happen suddenly, such as stroke or spinal cord injury. This can cause chronic gait function impairment due to functional deficits in motor control. Current physiotherapy techniques such as functional electrical stimulation (FES) can be used to reconstruct some skills needed for movements of daily life. However, FES system provides only a limited degree of motor function recovery and has no mechanism for reflecting a patient's motor intentions, hence requires novel therapies. Brain-Computer Interfaces (BCI) provides the means to decode mental states and activate devices according to user intentions. However, conventional BCI cannot be used fully, due to the lack of accuracy, and need some improvement. In addition to that, the integration of BCI with lower extremity FES systems has received less attention compared to the BCI-FES systems with upper extremity. The discussion of this thesis was divided into two parts, which were the BCI part as input and the functional electrical stimulator (FES) controller part as the output for this system. For BCI part, the main processes involved are brainwave signals classification and mapping process. Here the signal has been classed will be applied to match the appropriate rehabilitation exercise. Whereas for the FES part, the signal from the mapping system will be controlled by the controller to ensure that the target knee angle is achieved to make the rehabilitation process more effective. As a conclusion, patients can be classified into two classes based on their alpha and beta signals status and these must undergone rehabilitation sessions according to their post-stroke level. So the results proved that the ANN model developed was able to classify the post-stroke severity. Also, the result had proven that the BCI fuzzy-based mapping system in this study was able to work perfectly into mapping the post-stroke patient with a suitable exercise according to their post-stroke level.

ABSTRAK

Pada masa kini, banyak keadaan neurologi berlaku secara tiba-tiba, seperti strok atau kecederaan saraf tunjang. Ini boleh menyebabkan kerosakan yang kronik pada fungsi pergerakan anggota badan disebabkan oleh penurunan fungsi kawalan motor. Pada masa kini teknik fisioterapi seperti stimulasil elektrik fungsional (FES) boleh digunakan untuk membina semula beberapa fungsi anggota badan yang terjejas. Walau bagaimanapun, sistem FES hanya memberikan tahap pemulihan fungsi motor yang terhad, oleh itu proses pemulihan memerlukan terapi yang baru atau novel. Antaramuka otak dan computer (BCI) menyediakan cara untuk menyahkodkan keadaan mental pesakit dan berupaya mengaktifkan peralatan hanya berpandukan keinginan pengguna. Walau bagaimanapun, BCI konvensional tidak boleh digunakan sepenuhnya, kerana tahap ketepatan, yang kurang dan memerlukan peningkatan . Di samping itu, integrasi BCI dengan sistem FES pada bahagian bawah tubuh manusia adalah kurang mendapat perhatian berbanding dengan bahagian atas tubuh. Perbincangan thesis ini dibahagikan kepada dua bahagian, iaitu bahagian BCI sebagai input dan bahagian stimulasil elektrik fungsi (FES) berfungsi sebagai output untuk sistem ini. Bagi bahagian BCI, proses utama yang terlibat adalah proses klasifikasi dan pemetaan isyarat otak. Di sini isyarat yang telah dikelaskan akan digunakan untuk menyesuaikan dengan latihan pemulihan yang sesuai. Sedangkan untuk bahagian FES, isyarat dari sistem pemetaan akan dikendalikan oleh pengawal untuk memastikan bahawa sudut yang dikehendaki oleh gerakan lutut dicapai untuk membuat proses pemulihan lebih berkesan. Sebagai kesimpulan, pesakit boleh diklasifikasikan ke dalam dua kelas berdasarkan status isyarat alfa dan beta mereka dan ini mesti menjalani sesi pemulihan mengikut tahap pasca-strok mereka. Jadi hasilnya membuktikan bahawa sistem yang dibangunkan dapat mengklasifikasikan keparahan pasca-strok. Juga membuktikan bahawa sistem pemetaan berasaskan Fuzzy-BCI dalam kajian ini dapat berfungsi dengan sempurna dalam pemetaan pesakit pasca-strok dengan latihan pemulihan yang sesuai mengikut tahap pasca-strok mereka.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABI	-	Acquired Brain Injury
ABCD	-	Age, Blood Pressure, Clinical Features and Duration
ADL	-	Activities of Daily Living
AG	-	Advance Group
AL	-	Alpha Left
ANN	-	Artificial Neural Network
AR	-	Alpha Right
BL	-	Beta Left
BR	-	Beta Right
Brain	-	Biomaker Rapid Assesment in Ischemic Injury
CCS	-	Causative classification system
CI	-	Confident Interval
CISS	-	Chinese Ischemic stroke sub classification
CT	-	Computed tomography
CVA	-	Cerebrovascular accident
CVD	-	Cerebrovascular damage
df	-	Degree of freedom
DFA	-	Discriminant Function Analysis
DFT	-	Discrete Fourier transform
DL	-	Delta Left
DR	-	Delta Right
DOF	-	Degree of freedom
ECG	-	Electrocardiogram
EEG	-	Electroenceplogram
EG	-	Early Group
FES	-	Functional electrical stimulation

FFT	-	Fast Fourier Transform
FN	-	False Negative
FP	-	False Positive
FAST	-	Face Arm Speech Test
FLC	-	Fuzzy logic control
GA	-	Genetic algorithm
H	-	Hemorrhage
I	-	Infarction
IG	-	Intermediate Group
KNN	-	K Nearest Neighbors
LAC	-	Lacunar Stroke
LM	-	Levenberg-Marquardt
MLP	-	Multilayer Perceptron
MOU	-	Memorandum of Understanding
MRI	-	Magnetic Resonance Imaging
ms	-	Means Squares
MSE	-	Mean Square Error
NASAM	-	National Stroke Association of Malaysia
NN	-	Neural Network
OCSP	-	Oxfordshire Community Stroke Project
OE	-	Open Eye
PAC	-	Partial Anterior Circulation Stroke
PCA	-	Principal component Analysis
PET	-	Positron Emission Tomography
PID	-	Proportional-integral-derivative
PIS	-	Patient Information Sheet
PD	-	Proportional-derivative
PL	-	power left
POC	-	Posterior Circulation Stroke
PR	-	power right
PSD	-	Power spectrum density
QEEG	-	Quantitative EEG
ROC	-	Receiver Operating Characteristic

ROSIER	-	Recognition of stroke in the Emergency Room
RPR	-	Relative Power Ratio
S	-	Syndrome
SS	-	sum of square
SS	-	sum of square
SSB	-	between groups sum of squares
SST	-	total of squares
SSW	-	within groups sum of squares
TAC	-	Total Anterior Circulation Stroke
TDC	-	Transcranial Doppler (),
TL	-	Theta Left
TN	-	True Negative
TP	-	True Positive
TR	-	Theta Right
UM	-	Universiti Malaya
WHO	-	World Health Organisation

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The brain is the most complex organ in the human body and is the center of the nervous system. It produces every human thought, action, and feeling. It also controls all actions done by human body by sending some specific signal to that part of human body [1]. Therefore, if the signal transmission is interrupted, it will cause a certain disruption in that part of human body. Normally, the interruption of signal transmission process is due to the occurrence of damage to the blood vessels in the human brain. This situation will lead to a worse scenario such as stroke [2].

In some cases of stroke, the impact on the life of the survivor may be minimal, such as weakness in a hand or an arm, but in other cases the impact may be devastating, such as losing the ability to speak or to understand speech, severe behavioral or memory problems, or complete paralysis of one or more limbs [3]. Every year around the world, approximately 10,000 people are admitted to hospital following a stroke, while approximately 30,000 stroke survivors live with the lasting effects [3].

Nowadays, people with stroke, spinal cord injury (SCI) and who are paralyzed have increasingly applied electronic assistive devices to improve their ability to perform certain essential functions. Electronic equipment, which has been modified to benefit people with disabilities include communication and daily activity devices [3]. A wide range of interfaces is available between the user and the device. These interfaces can be an enlarged like computer keyboard or a complex system that allows the user to operate or control a movement using aid such as a mouth stick, an eye

imaged input system, electroencephalogram (EEG) signals and an infrared or, a functional electrical stimulation (FES), which uses short electrical pulses to generate contractions in paralyzed muscles. These contractions can be coordinated to actuate joints by stimulating one or more muscles that exert torques about the joint [4].

Recent advances in biomedical technology, however, give hope that those lasting effects following a stroke may soon be eradicated. While those lasting effects of stroke are varied, one of them - weakness and paralysis of the upper/lower limb - has a potential remedy in the use of Brain-Computer Interface (BCI) systems [5]. These BCI systems and the exploration, development, and improvement of their application as a tool for post-stroke rehabilitation are the subjects of this thesis. A BCI is a system that measures and analyses brain activity and then translates that activity into control of another system. Brain signal acquisition systems for the brain such as electroencephalography (EEG) or functional Near-Infrared Spectroscopy (fNIRS) recording data signals which may be processed by a BCI in real-time to determine control over a computer or machine [6].

Besides the weakness and paralysis of the limb, stroke also leads to susceptibility to the inactivity related diseases such as obesity, insulin resistance, and coronary heart disease [7]. Physical exercise including the use of electrical stimulation devices, in this group of patients is essential to prevent diseases associated with physical inactivity [8]. Furthermore, exercise is very beneficial to the muscle by strengthening the muscles and increasing their efficiency [9], [10]. Therefore, this thesis discussed in detail about the combination between the FES area and BCI area and its benefit, especially in stroke rehabilitation.

1.2 Background of Stroke

World Health Organization (WHO) defined stroke as a clinical syndrome characterized by rapidly developing clinical signs of focal disturbance of cerebral function, with symptoms lasting more than 24 hours or longer or leading to death, with no apparent cause other than vascular origin [11], [12]. Stroke is a challenging disease for healthcare providers, patients and the community [13]. It has been found to be a leading cause of morbidity and the third leading cause of death in developing country [14].

Every year, 15 million people worldwide suffer a stroke. Of these, five million died and another five million are left permanently disable. It is among the top four leading causes of death in ASEAN countries, with the crude death rate ranging from 0.0109% in Thailand to 0.0542% in Singapore [14]. In Malaysia, stroke was the second leading cause of death according to the Malaysian National Burden of Diseases Study and study on vital registry system in 2016. In comparison, using empirical data from vital registry systems in 2016, stroke was reported as the leading cause of death in Indonesia, Myanmar, Vietnam and Thailand. Stroke is the third leading cause of mortality for males in Malaysia, after Ischaemic heart disease and pneumonia, while it ranked second for females after Ischaemic heart disease [15]. Figure 1.1 shows the percentage of causes for total death in Malaysia for 2016.

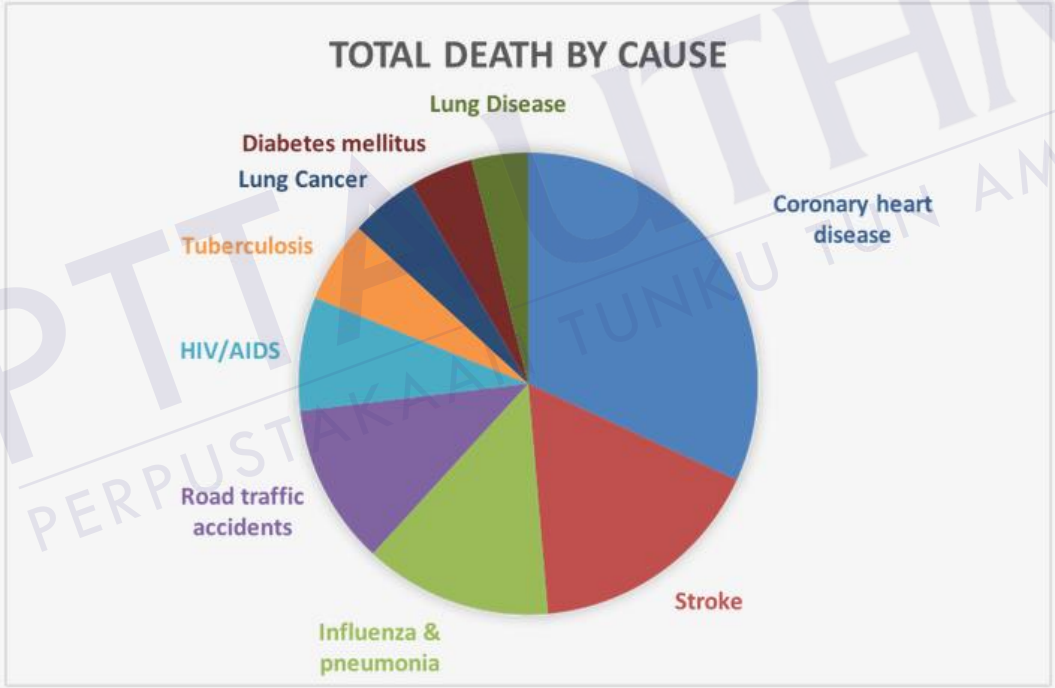

Figure 1.1: Percentage of causes for total death in Malaysia [14]

1.3 Problem Statement

Many neurological conditions, such as stroke, spinal cord injury, and traumatic brain injury, can cause chronic gait function impairment due to functional deficits in motor control. Current physiotherapy techniques such as functional electrical stimulation (FES) can be used to reconstruct some skills needed for movements of daily life, such

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