

# Brain Computer Interface (BCI) - Functional Electrical Stimulation (FES) Control System of Knee Joint Movement for Paraplegic

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**Abstract:** Stroke was defined as a clinical syndrome characterized by World Health Organization (WHO) which mean the clinical signs of focal disturbance of cerebral function was rapidly developing [1]. This brain injury type has two main types which were ischemic stroke and the other was hemorrhagic stroke. The Ischemic stroke can happen from occlusion of or low flow in one or more vessels by blood clots or other particles. There has four types of human brainwave which were alpha, beta, theta and delta [2]. The common used was alpha and beta signal. The electroencephalogram (EEG) is defined as electrical activity happen in human brain. This signal can be measure. There are twenty subjects were participate in this study. They were 50% male and 50% female and 70% were normal subject while the others were stroke subject in early group (EG). The Fuzzy logic based mapping mechanism system has been used in this study in order to classify the subjects into the group; Lower group (LG) or Upper group (UG). From here their brainwave, alpha and beta will be combined in the mapping mechanism system. Each group had their own range. From the range, mapping mechanism system can classify all the subjects into their new groups. All average reading was still in the correct range. So the classify process can be done. All subjects have successfully be classified into their group either upper group or lower group. The range of each group had played big role in order to make sure the mapping mechanism system can perform perfectly.

**Keywords:** BCI, FES, NeuroSky, Stroke, EEG

## 1. Introduction

Stroke was defined as a clinical syndrome characterized by World Health Organization (WHO) which mean the clinical signs of focal disturbance of cerebral function was rapidly developing, with its symptoms lasting more than 24 hours or longer or can cause the death, with no others apparent cause than vascular origin. Stroke can cause more problem and give hard challenge to the health care providers, patients and the community. More than that stroke was also has been found to be a leading cause of morbidity and the third factor of death in developing country [3]. Stroke has two main types. One was ischemic stroke and the other was hemorrhagic stroke. The Ischemic stroke can happen from

occlusion of or low flow in one or more vessels by blood clots or other particles. While the hemorrhagic stroke was caused by bleeding. The blood clot reduced the blood supply to an area of brain and the neurons in this area are affected. Disabilities occur when the neurons in these areas are killed and the functions they control are disrupted [4]. The types and degree of disability that follow a stroke vary considerably, depending upon the origin part of the brain and the size of affected area [5]. The Figure 1 was the illustration of type for stroke.

In the cerebral cortex are located many different areas of specialized brain function such as the visual centre is located in the occipital lobe, the higher brain functions occur in the frontal lobe, and the sensory area and motor area are

located on both sides of the central figure [7]. There are specific areas in the sensory and motor cortex whose elements correspond to certain parts of the body. There are several waves that can be differentiated from the EEG signal as follows in Figure 2 [8]:

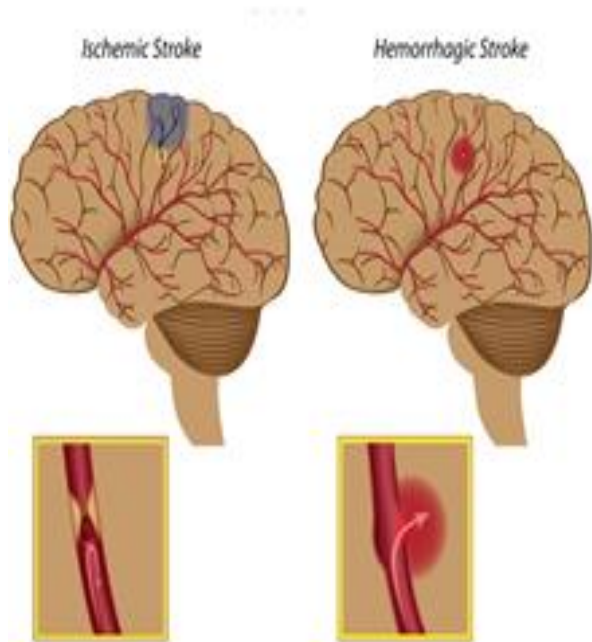


Figure 1: Two main types of stroke [6].

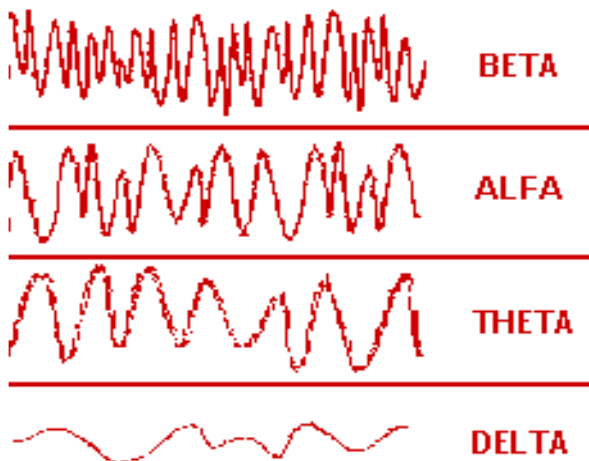


Figure 2: Brain wave samples with dominant frequencies belonging to beta, alpha, theta, and delta band [2].

In Table 1 shows the type of brainwave signal has been listed and described. There has four types of brainwave signals which were alpha, beta, delta and theta [2]. The common signal used in the research were alpha and beta signals.

Table 1: Type of brainwave signals

Waves type	Description
Alpha	Frequency spectrum of 8-13 Hz; Can be measured from the occipital region in an awake person Alpha activity disappears normally with attention (e.g., mental arithmetic, stress, opening eyes).
Beta	Frequency band of 13 -30 Hz, These are detectable over the parietal and frontal lobes Beta activity is generally regarded as a normal rhythm and is the dominant rhythm in patients who are alert or anxious or who have their eyes open.
Delta	Frequency range of 0.5-4 Hz; They are detectable in infants and sleeping adults, Can be an indicative of cerebral damage or brain disease.
Theta	Frequency range of 4-8 Hz; They are obtained from children and sleeping adults; Theta activity occurs during drowsiness and in certain stages of sleep, being abnormal in awake adults but is perfectly normal in children up to 13 years and in sleep.

Modern medicine applies variety of imaging techniques of the human body. The group of electro biological measurements comprises items as electrocardiography (ECG, heart), electromyography (EMG, muscular contractions), electroencephalography (EEG, brain), magneto encephalography (MEG, brain), electrogastrography (EGG, stomach), electrooptigraphy (EOG, eye dipole field) [9]. Imaging techniques based on different physical principles include computer tomography (CT), magnetic resonance imaging (MRI), functional MRI (fMRI), positron emission tomography (PET), and single photon emission computed tomography (SPECT). Electroencephalography is a medical imaging technique that reads scalp electrical activity generated by brain structures. The electroencephalogram (EEG) is defined as electrical activity of an alternating. Type recorded from the scalp surface after being picked up by metal electrodes and conductive media [10]. The EEG measured directly from the cortical surface is called electrocortigram while when using depth probes it is called electrogram. In this will refer only to EEG measured from the head surface. Thus electroencephalographic reading is a completely non-invasive procedure that can be applied repeatedly to patients, normal adults, and children with virtually no risk or limitation [10].

For EEG recording, the 10-20 International System electrode placement system can be used. This System standardized physical placement and designations of electrodes on the scalp [11]. The head is divided into proportional distances from prominent skull landmarks (nasion, preauricular points, and inion) to provide adequate coverage of all regions of the brain. Electrode placements are labelled according adjacent brain areas: Fp (frontopolar), F (frontal), C (central), P (parietal), O (occipital) and T (temporal), Odd numbers (left), even (right), A (ear) [12]. The 10-20 International System labelling can be seen as shown in Figure 3.

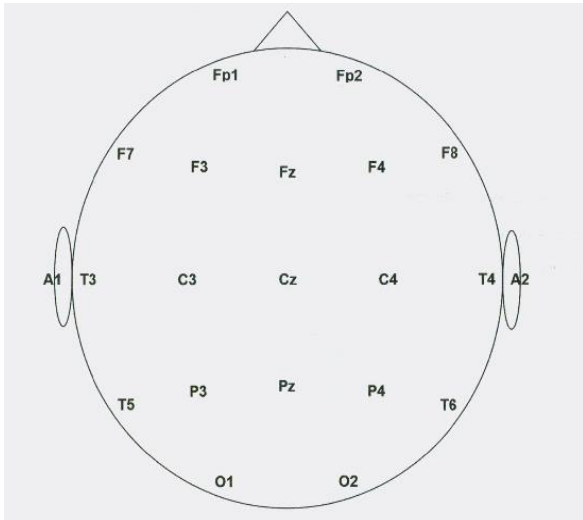


Figure 3: The 10-20 International System of Electrode Placement [13]

Thus, via this research, the combination of BCI-FES was developed as the solution to the stroke patient to get the fast recovery. This combination system between BCI and FES is one of the requirements to make sure this combination will give the effective way in stroke rehabilitation [14].

2. Method

This study was involved the EEG measurements on normal and stroke subjects. The aim for this study was to classify the subject into two groups; upper group (UG) and lower group (LG) based on their brainwave level. In this study, all subjects will do the simple activity, focus on the laptop screen to perform the attention activity in relax and open eyes condition. Relax and open eyes condition was for meditation activity. So this means subject will perform two activities in the same time. This is because at the end of this study, all subjects will be divided into two groups; UG and LG. The purpose of this classification was to minimize the range from four to two groups so the whole process becomes easier to be done and also to make the classification based on the brainwave level. Normal and stroke subjects participated in this study. Their weights average from 60 to 70 kilograms and heights from 145 to 170 centimetres. Detail subject can be seen in Table 2. Best four subjects were selected and all subjects had provided their informal written permission to join this experiment. The ethics board of the UM Medical Centre (UMMC) has approved in this event upon an assurance that all regulation involving the institution and government that are related to the intervention of human beings as volunteers are followed ethically and strictly.

Table 2: Subjects detail

Subject	Sex	Age	Height	Weight	Condition
1	m	59	170	67.7	NL
2	m	32	165	75	NL
3	f	59	170	67.7	NL
4	f	59	170	67.7	Stroke (EG)

In general, the stroke patients were grouped into three groups depending on their progression score (NASAM). There are advance group (AG), intermediate group (IG) and early group (EG). The patients will undergo several physical assessments carried out by NASAM to classify them into these three groups [15][16]. This classification of the subjects was based on their dependency on staff for carrying out their activities. Those who rely on staff to help them in 25% of their activities will be under AG. Those who require 25% to 75% of help will be under IG and those who require more than 75% will be put under EG. Usually, those subjects under EG are wheelchair users [16].

Brain-computer interface (BCI) is a relatively novel technology with a potential to restore, substitute, or augment lost motor behaviours in patients with neurological injuries [17]. Here, in this thesis will describe the successful integration of a non-invasive electroencephalogram (EEG)-based BCI with a functional electrical stimulation (FES) system that enables the direct brain classification and control of knee joint movement of stroke patient by using a fuzzy based mapping mechanism system. Figure 4 shows the schematic representation of the fuzzy based Mapping Mechanism System (MMS).

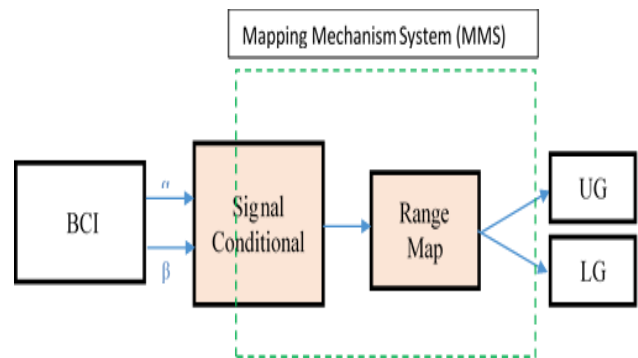


Figure 4 : Schematic representation of the fuzzy based Mapping Mechanism System (MMS)

Figure 5 shows the NeuroSky Mindwave mobile device structure. The Neurosky Mindwave Mobile safely measures and outputs the EEG power spectrums (alpha waves, beta waves, etc), NeuroSky eSense meters (attention and meditation) and eye blinks has been used [18]. The device consists of a headset, an ear-clip, and a sensor arm. The headset's reference and ground electrodes are on the ear clip and the EEG electrode is on the sensor arm, resting on the forehead above the eye (FP1 position). It uses a. It measure Outputs 12 bit Raw-Brainwaves (3 - 100Hz) with sampling rate at 512Hz [18]. Outputs EEG power spectrums (Alpha, Beta, etc.). Outputs NeuroSky proprietary eSense meter such as Attention, Meditation, and other future meters. EEG/ECG signal quality analysis (can be used to detect poor contact and whether the device is off the head).

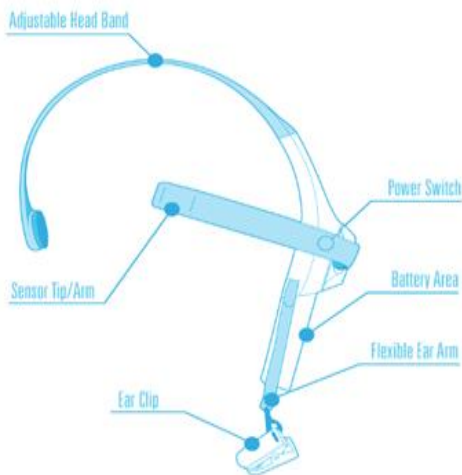


Figure 5 : NeuroSky Mindwave structure [19]

3. Results and Discussion

This section will discuss the result from this study. From the literature knowing that normal person brainwave will be reduced if the stroke happen to them. Also from the literature, also noticed that there were five group include normal and comma group. In this study only four group will be used; normal, advance, intermediate and early group. The comma group cannot be used because that group only happen after stroke stage and this study was to examine the brainwave level for normal and stroke subjects. Knowing that the aim of this study was to classify the subjects into two new groups; Upper Group (UP) or Lower Group (LG). This two new groups was determined by the subjects brainwave level which either Advance Group (AG), Intermediate Group(IG) or Early group (EG) also normal group can be assume as one group. So this will make total was four groups and from this four groups will be reduced into two groups as shown in Table 3.

Table 3 Component in new groups

Old Group	New Group
Normal	Upper
Advance	
Intermediate	Lower
Early	

Following was the result taken from the EEG test using Neurosky Mindwave device. Figure 6 was about brainwave signal taken from three normal subjects while Figure 7 was the brainwave signal taken from stroke subject in Early Group (EG). Both graph was taken in the same activity which was attention activity that involve beta signal.

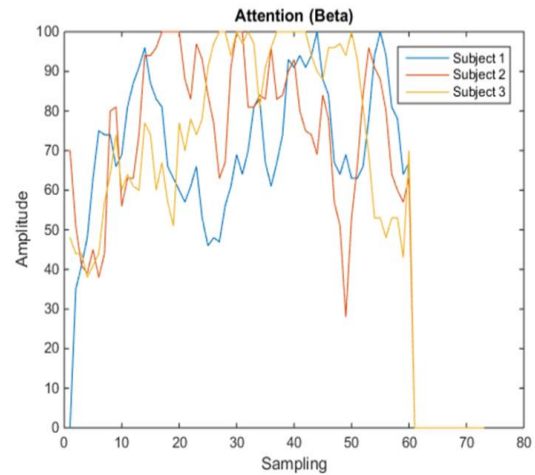


Figure: 6 : Brainwave signal taken from three normal subjects

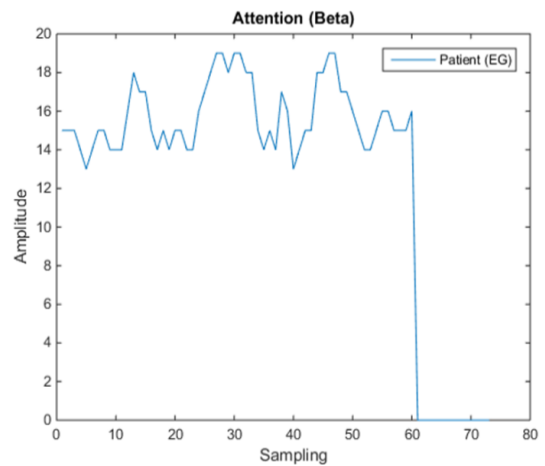


Figure:7 : Brainwave signal taken from stroke subject in Early Group (EG)

From the EEG Neurosky Mindwave test result above can be concluded that normally brainwave for normal people were in range 40 – 100 for attention activity and in range 60 – 100 for meditation activity by using eSense meter provide by Neurosky as the measurement medium.

So based on the table above, a set of fuzzy rules can be generated. Therefore fuzzy based mapping mechanism system can be developed for the purpose of this study. Following in Figure 8 and 9 were the reading for stroke patient; input and output the range map system.

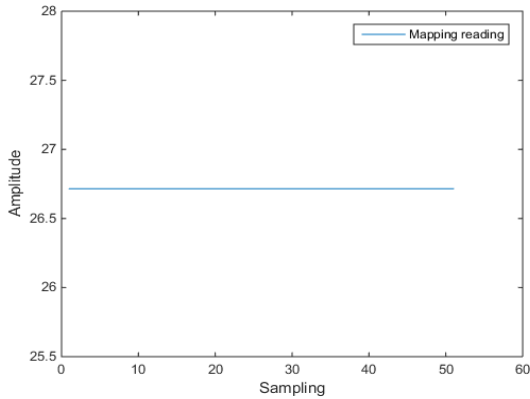


Figure 8 : The input of range mapping system taken from stroke patient (EG)

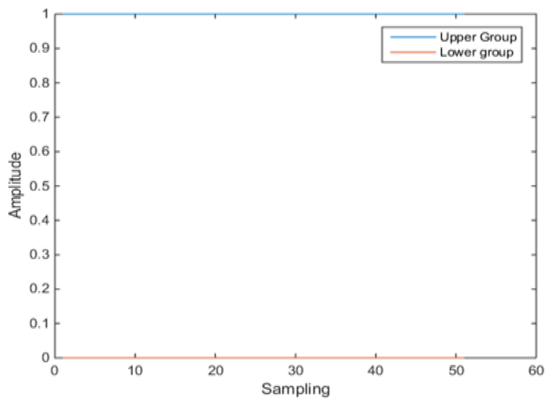


Figure 9 : The output of range mapping system taken from stroke patient (EG)

In the graph in Figure 8, the input for the range mapping system was the combination of alpha and beta signal taken from stroke subject (EG) and it was in range 26 – 27, still below 54 which the max range value for lower group (LG) while in Figure 9 was the results taken from the output of the range mapping system which also the output from fuzzy mapping. In Figure 9 can be find that the upper group was trigger to one while for the lower group still in zero. This because FES and BCI was has inverse proportional. This has been describe in figure 10 below.

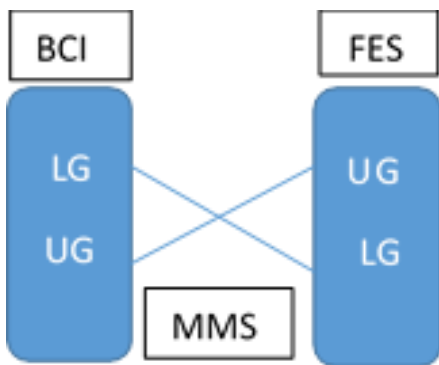


Figure 10 : FES – BCI relationship

#### 4. Conclusion

In a nutshell, the results from this study shows that the range for each group; normal, advance, intermediate and early can be divided into many category due to brainwave characteristic taken by a devices. In this study the brainwave has been divided based on its characteristic on Neurosky Mindwave device. Also the brainwave has been measured by using eSense measurement provide by the Neurosky. From this, can be concluded that the level of stroke was can be improved with in time but must through the rehabilitation process. So hopefully this finding may be useful as an indicator for stroke patient to create the fast and effectiveness of rehabilitation and also the suitable treatment or rehabilitation process for stroke patient.

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