

# A feasibility study of BCI based FES model for differently abled people

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**Abstract.** This paper aims to present a new way of providing functional rehabilitation to paralyzed upper extremity patient using Brain Computer Interface technology. In this we use Brain wave mobile which consists of only two electrode, pre frontal electrode and reference electrode placed on ear lobe, to acquire the electroencephalography (EEG) signal. The acquired signal is transferred via Bluetooth to low end device. Recordings are read into MATLAB where signal processing algorithms are implemented. The extracted 100% accurate control signal fires the nerves by generating biphasic current impulse through functional electrical stimulator (FES) placed on the impaired limb for the motion.

## 1. Introduction

According to a review dated 2010, in Europe alone there are 330000 people are affected with spinal care damage, with 11000 new wounds happening each year [1-3]. Most frequent causes of Spinal cord injury (SCI) are due to traffic, work related, sporting accidents, nontraumatic lesions [4]. SCI leads to restriction or then again total loss of Motor, sensor or autonomic capacity underneath the level of lesion. Because of which the person is not able to perform even basic activities like Toilet Hygiene, Self-feeding, Grooming etc. The utilization of Electroencephalography (EEG) motions as vector of correspondence amongst people and machines speaks to one of the flow challenge in flag hypothesis examine. The guideline component of such a correspondence framework is known as 'Brain Computer Interface', is the translation of the EEG signals identified with the trademark parameter of mind electrical movement. This interpretation has helped the Locked in patients to communicate with the word

Many papers have provided information about using BCI signals to control the exoskeleton to make the person independent. But this setup comes with lot of disadvantages. Such as, it adds weight to the limbs, it lowers the bone density, muscle atrophy, joint contractures, mechanical complexity, less accurate, no smooth controlled, low communication rates. With time new control schemes such as shared control has evolved which helps in distributing control to shoulders, eyes, limbs, head etc., instead of centralized



control using BCI. This methods have helped the patience to overcome fatigue, stress but the problems still persisted.

In a current report directed by [5], it has been seen through factual investigation of the meetings of in excess of 500 deadened individuals that there is a solid need of such rehabilitative and assistive innovations which make utilization of BCI to control their own muscle developments as this method is non-intrusive and enable the client to control the moves autonomously. Autonomous activity and non-obtrusiveness were the most essential variables for such handicapped individuals. They presumed that most patients might want to utilize BCI based rehabilitative and assistive innovations due to previously mentioned focal points on the off chance that it is incorporated with ordinary FES frameworks. A noteworthy favorable position over other UI is that it can be worked freely from the leftover engine capacities. Moreover, MI-based BCIs have tremendous ramifications for giving restoration and achieving neuroprostheses specifically people with abnormal state SCI since they depend on volition signals recorded from the mind straightforwardly [6]. By utilizing this strategy, a patient can utilize his own particular cerebrum as the very control framework to send orders to the FES gear which is subsequently be utilized to get the attractive muscle or muscle gathering. The main motivation for this paper is most EEG recordings or experiments are done in close environment with highly sophisticated equipment. Elephantine amount of data is collected and can only be processed with very powerful processors. Dedicated systems are used to decrease computational power over a single system. So it's not even portable. All this makes it impractical for the end user application especially if a user is paralysis patient. To reduce the discomfort here we proposed readily available low cost device brain wave mobile device which is easily wearable and carry able. It has only two electrode, PF1 and reference electrode which reduces computational power required and increases the calculation speed when compared to other recordings but still able to generate the control signal required for the application. This paper also include leading research in Neuroprostheses based on functional electrical stimulator where electrodes are placed on the limb at strategic muscles activation site to generate short current impulse to depolarize efferent nerves to actuate the muscles and hence the motion.

## 2. Methodology

This section discusses the methodology for implementing a Machine interface for the motion of the limb in patient suffering with acute spinal cord injury. We obtain the above objective by using hybrid brain computer interface which describe the algorithm for process of FES Model shown below.

Step1: Identification of the problem. To meet the challenge of disabled people who cannot even perform daily activities such as Toilet hygiene, self-feeding, grooming by affording people with the greatest level of level of ability to control, sophisticated prosthetics. Hybrid Brain Computer Interface (BCI) and Functional electrical stimulator (FES) is such control scheme which allows the movement of the limb by extracting control signals recorded from the brain. Patients with conditions ranging from spinal cord injury to and locked-in syndrome could potentially greatly benefit from such control schemes.

Step2: is developing the concept. It's based on the existing design of the related works and gained knowledge from the literature survey. Few draw backs of existing designs is they are not user friendly, not easily portable, colossal data is obtained which requires huge computational power systems and problems like fatigue and stress still persisted in new designs. The optimum solution for the concept is proposed.

Step3: Next stage is to acquire the Electroencephalograph (EEG) signals from the user brain by using EEG measuring device.

Step4: Pre-processing involves the preparation of the EEG recordings prior to any form of digital signal processing and reduces the noise content.

Step5: Feature extraction stage extracting the relevant features from the EEG and reducing the complexity of the data.

Step6: Next stage, classifier algorithms is used to determine the presence or absence of a control signal in EEG recordings.

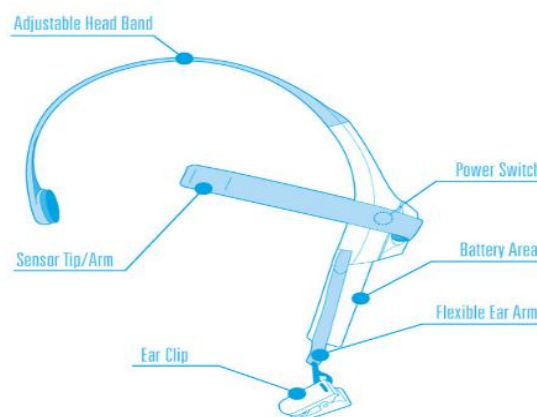
Step7: Program the Functional electrical stimulator with the corresponding control signal.

Step8: Finally, interface Signal acquisition system, MATLAB, FES device and related circuitry for the motion of the limb and test it in the real-world.

### 3. Brain Computer Interface

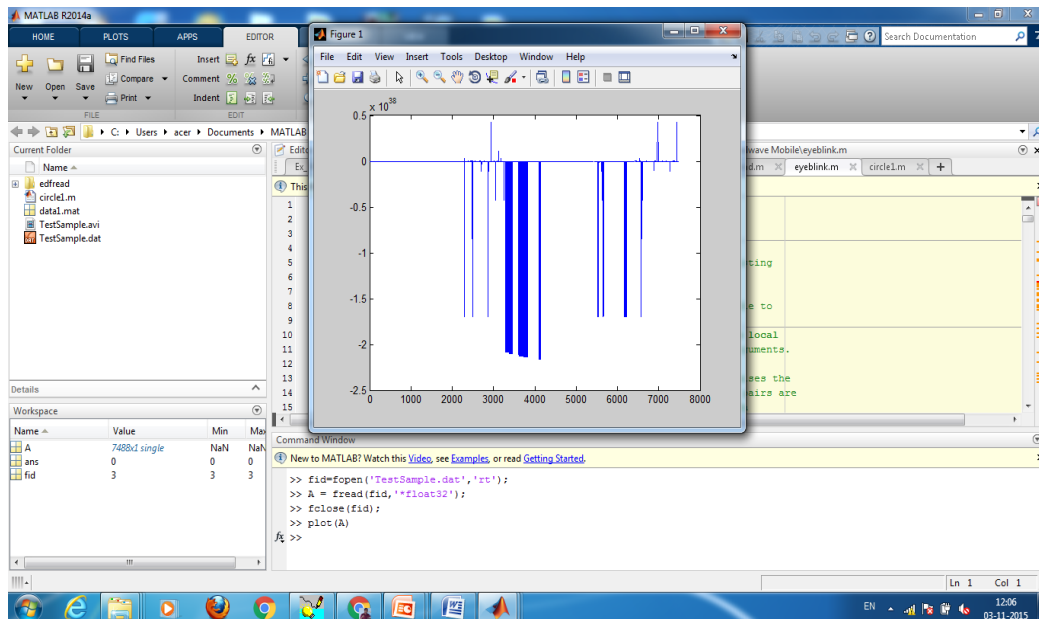
The real time Raw EEG recording carried out by using a bio-sensor head set so called NeuroSky's mind wave mobile is a device with portable EEG sensors shown in Figure 1[1]. The headset is an easy to place on head and a non-invasive dry sensor is used to read brainwave impulses. This allows to interact with Apps and digitized brainwave signals from the forehead FP1 used to transfer the control signals. NeuroSky devices have the ability to measure multiple mental states simultaneously.

Filtering protocols eliminate the known noise frequencies such as muscle, heart beat and electrical devices. Frequency ranges between 3-100Hz. Sampling rates 512 Hz is used for the interpretation of sensory information as shown in Figure 3, a notch filter is used at frequency ranges between 50-60 Hz to eliminate interference from supply lines. The acquired EEG signals are transferred wirelessly to PC by using Bluetooth interface. Raw EEG signal is allowed to pass through a 6th order Butterworth band pass filter with lower cut-off frequency 0.01Hz and higher cut-off frequency 20Hz with ripple of 1dB.



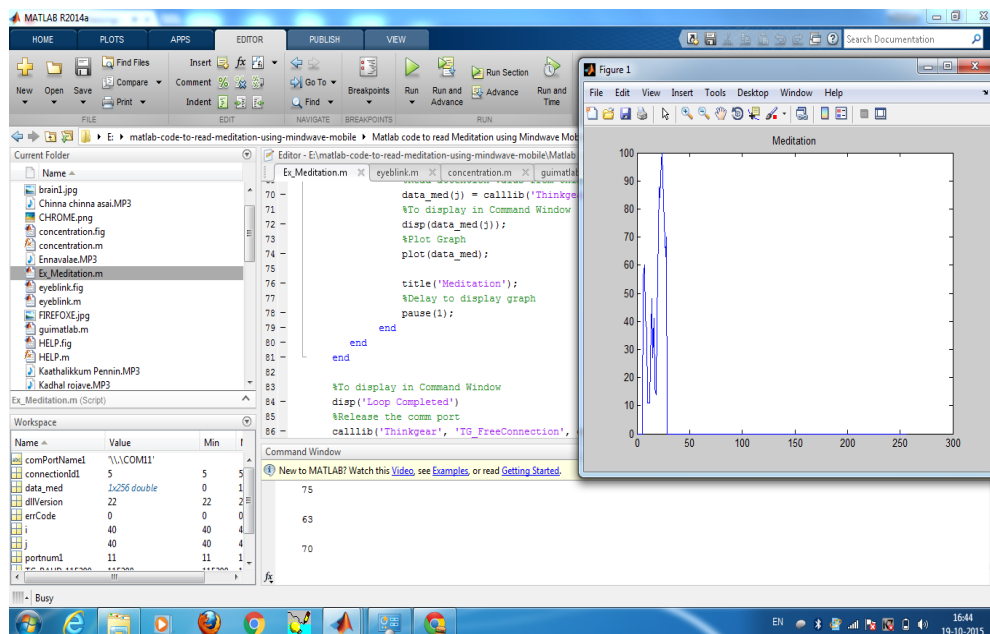
**Figure 1.** Mind wave mobile device

The power spectrum plot of EEG signals measured from the brain activity has been observed. Figure 2. shows the signal power distribution along the range of frequencies. It can be easily observed that power spectrums of the channels are closely concentrated and overlapping. On analyzing these plots, it is really difficult to comment on the power levels about different frequency bands. After filtration of raw EEG observed a commendable change in the power spectrum plot.



**Figure 2.** Time domain Plot in MATLAB by using EEG recordings

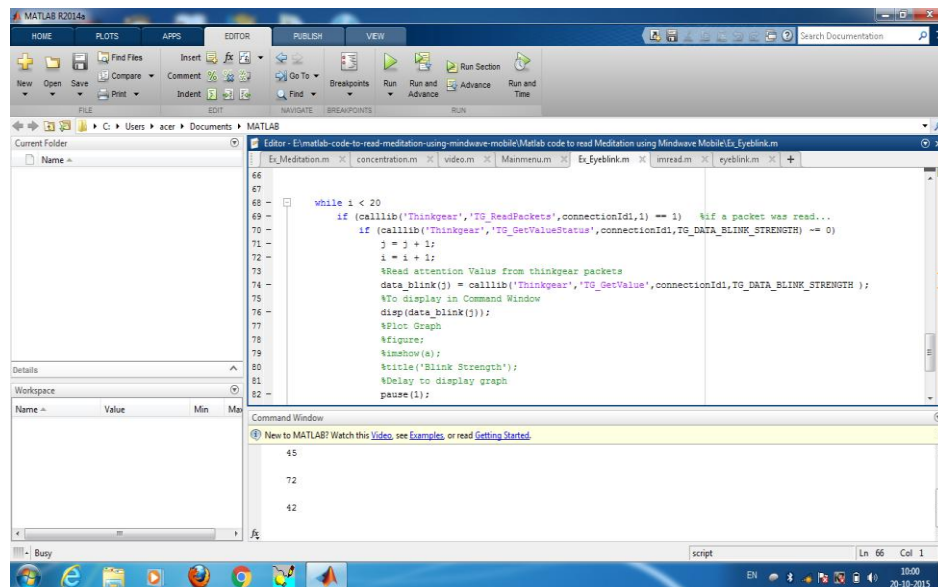
By using neurosky mind wave mobile we can communicate to MATLAB with 32 bit configuration in real-time. Signals are sent to the system with i3 processor, 4GB RAM, 2.30GHz speed, 32 bit Operating system, Windows 7 via Bluetooth serially as packets. Time plot is shown in Figure 2.



**Figure 3.** MATLAB code for detect Meditation level.

Think gear connector has provided with add-on library function for MATLAB. Thinkgear.dll and thinkgear.h should be loaded to library in MATLAB. By using the above library functions, code is

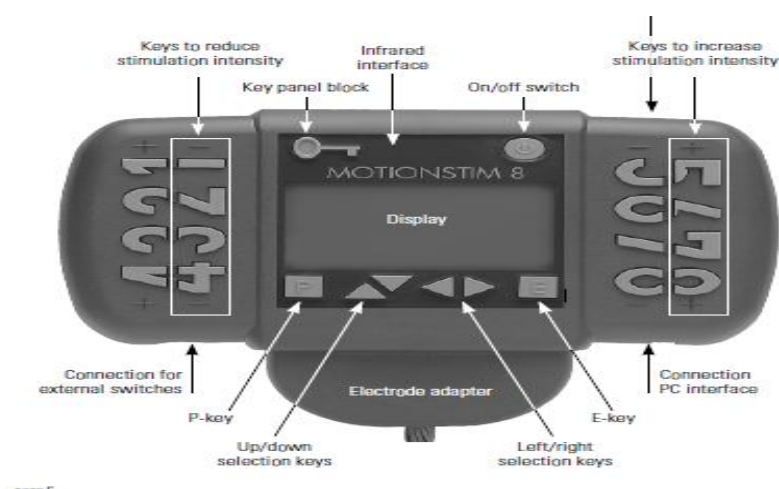
generated to plot meditation level as shown in Figure 3 and detect eye blink shown in Figure 4. Which is fed as control signal for the given application.



**Figure 4.** MATLAB code for eye blink detection

#### 4. Functional Electrical Stimulator (Fes)

Useful Electrical Stimulation was first proposed by Liberson et al in 1960s [7]. It is a technique that uses electrical currents to activate innervating extremities affected by paralysis resulting from head injury, spinal cord injury (SCI), stroke and other neurological disorders. FES is primarily used to restore function in people with disabilities is referred as neuromuscular electrical stimulation (NMES) [8].



**Figure 5.** Functional electrical stimulator- MOTIONSTIM 8

**Table 1.** Parameter and its respective values for MOTIONSTIM 8.

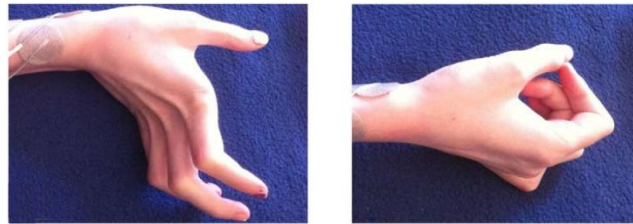
Parameters	Values
No.of channels	8
Pulse output	1-125 mA per channel
Pulse forms	Biphasic rectangular pulse
Frequency	1-99 Hz
Pulse width	10-500 $\mu$ s
Power supply	Internal battery
Switch mode	Adjustable for every switch mode(hand switch, foot contact etc)
Simulation time	0 – 59.9 sec (per phase)
Weight	Approx. 550 g

Functional electrical stimulator considered in this experiment is MOTIONSTIM 8 is shown in Figure 5. Its dimensions are 186mm×38mm×155mm and its remaining parameters and its respective values are shown in Table 1. As shown it has up to 8 channels which can be individually controlled. It works on battery and is very light weight and can be easily carry able. Maximum pulse output can be give is 1-125 mA per channel. Frequency of the pulse can be fluctuated between 1-99Hz. Even the pulse width can be varied up to 10-500  $\mu$ s. Programs can be directly fed and stored it as default in MOTIONSTIM by using programming offline mode, programming online mode. It can also be manipulated and new programs can be written in PC software MOTIONSOF and can be transferred through infrared. Certain parameters like Intensities, frequency, pulse width etc., can also be changed while the code is running in programming online mode. It has skin resistance measurement which gives level of contact between electrodes and patient skin. External switch operated through hand or foot directly connected to FES. Science mode is used for scientific application in which FES is controlled by PC.

**Figure 6.** Hand fully open (Left), full lateral pinch (Middle), and fingers closed with an extended thumb (Right).

The point of a grip neuroprosthesis is to create two handle designs, to be specific the palmar handle called control handle or barrel hold and the sidelong handle likewise called squeeze handle or key grasp. The key handle design gives the capacity to get level questions between the flexing thumb and the flexed fingers appeared in Figure 6. While in the palmar handle design, the thumb is situated resistance to the forefinger as appeared in Figure 7. licenses bigger articles to be taken care of.



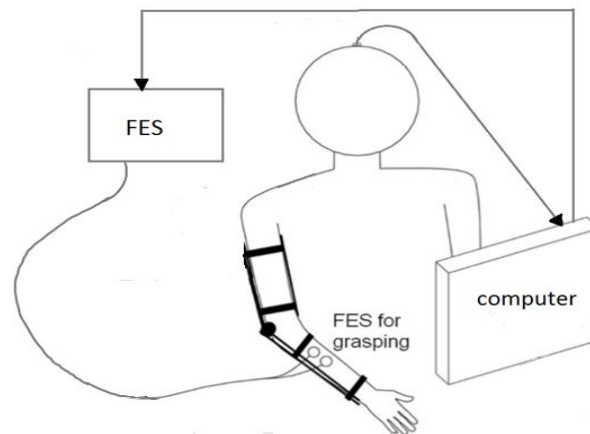


**Figure 7.** Palmar grasp pattern: hand fully open (Left) and hand fully closed (Right).

To generate these patterns, seven self-adhesive gel electrodes placed on dedicated positions on the forearm as shown in Figure 8. The pinch and power grasp patterns can be restored without the electrodes on the hand [8]. The pinch grasp can be achieved by stimulation of the fingers [ext. digitorum communis, electrode pair (EP) 1 as shown in Figure 8. and thumb [ext. pollicis longus, EP 2 as shown in Figure 8] extensor muscles for hand opening, the thumb flexor (flex. pollicis longus) for grasping and the finger flexors (flex. digitorum superficialis, flex. digitorum profundus) for hand closing. In many users it is possible to stimulate the fingers and thumb flexor muscles with a common electrode pair [EP 3 as shown in Figure 8]. By using a dedicated activation profile, it is possible to use co-contractions of the thumb flexor and extensor muscles to achieve a state, in which the fingers are sufficiently flexed and the thumb is still in an extended position. For the power grasp a branch of the median nerve innervating the opponens pollicis muscle can be selectively stimulated with an electrode pair [EP 4 in Figure 8] placed on the medial side of the forearm.



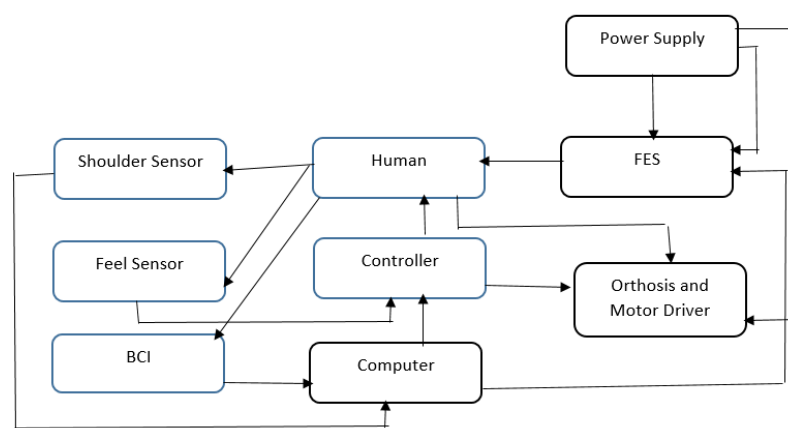
**Figure 8.** Electrode positions with the assigned channel numbers of the stimulator (Top Left); Electrodes fixed with a velcro strap for easy and quick electrode mounting (Bottom Left); Mounted forearm sleeve (Right).



**Figure 9.** BCI and FES

## 5. Conclusion

Hence a new, efficient way of functional rehabilitation to paralyzed patient is proposed as shown in Figure 9. Where EEG signals from Mind wave mobile is collected, read and plotted in MATLAB. Since we have only one electrode, data acquired is very minimal and the curse of dimensionality can be bypassed. Computational power also goes high. Eye blink detection program is generated where through mean, variance and power spectrum peaks, features are extracted and are classified to give control output. Experimental results show that when eye blink is given the code is able to detect with 100% accuracy with variation in signal strength. The control output is fed as control signal to FES device in science mode to run default program to power grasp or pinch grasp. Parameters can also be changed manually using the buttons which are on left, right, P and E of FES until functional rehabilitation is done.



**Figure 10.** Future BCI based FES Model



## 6. Future Work

Apart from what is already proposed more research can be done in graphical user interface and give the patient with more options such as what to control. Figure 10, shows the block diagram for future model. Where it consists of input from other devices such as shoulder sensor, external switch to FES, touch sensor for force calculation. All this can be given to FES directly or to a motor placed on limb and actuated directly and can be implemented in PID controller for smooth motion.

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