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Neuroprosthesis: A Step Towards Complete Control Over Prosthetic Limbs

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Abstract: *The paper proposes an alternative to Bionic Prosthetics, which can be advancement in the field of Neuroprosthetics, using the user's brain wave. It uses WBCI and organic opto-electronic muscle contracting sensor to interface the brain with the basic bionic arm making the mobility of amputees easier. This paper also proposes the usage and importance of "phantom limb syndrome" for replicating sensations and for creating an interface between both brain and technology.[4]*

Keywords: *BCI, WBCI,EEGs, ANNs etc.*

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I. Introduction

In this drastically changing world; robots, flying cars and travelling at speeds faster than light are the next thing[2]. However, instead of creating something smarter than ourselves or something that could possibly be the downfall to the human species, the correct invention demands evolving ourselves to become one with our creations.

Biomechanical prosthetics (Bionic Prosthetics) utilizing basic mechanisms like buttons, voice, movement or text, only barely help amputees and the disabled but with the help of Wireless Brain Computer Interfaces (invasive bci's) and Artificial Neural Networks for the completion of the original neural network, we can complete the nervous system of an amputee. Therefore, allowing the amputee to completely control the Neuroprosthetic using the user's brain.[6]

II. Description

The neurons are known as an electrically excitable cell, due to the fact that it processes and transmits signals through both electrical and chemical means.

Neurons connect to each other to form a neural network i.e the interconnections between all neurons to form a defined linear pathway.[10]

2.1 Connections in a Biological Neural Network:

The basic kinds of neural connections are:

Chemical Synapses: *Chemical synapses* are biological junctions through which neurons' signals can be exchanged to each other.[13]

Chemical synapses allow neurons to form circuits within the central nervous system.

They are crucial to the biological computations that underlie perception and thought. They allow the nervous system to connect to and control other systems of the body.

The adult human brain is estimated to contain from 10^{14} to 5×10^{14}

Electrical Synapses: An electrical synapse is a mechanical and electrical link between two neighbouring neurons that is formed at a narrow gap between the pre- and postsynaptic neurons known as a "Gap Junction"[6].

Each neuron generates a minuscule electrical signal, which can be detected by EEGs after being magnified by the large number of neurons producing this current.

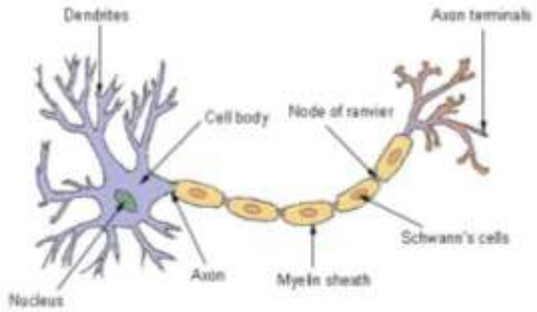

Fig1. Structure of a typical neuron

The by-product of impulses produced by our nervous system is Brainwaves; there are different brain waves for set actions and periods. The communication between neurons within our brains is the root to all our behaviors, thoughts and actions. Brain waves are produced by synchronized electrical pulses from masses of neurons communicating with each other. Brainwaves reflect different aspects when they occur in different locations in the brain.[9]

2.2 Different types of Brainwaves-

Infra-low (<.5HZ)

Infra-Low brain waves (also known as Slow Cortical Potentials), Very little is known about infra-low brainwaves. Their slow nature makes them difficult to detect and accurately measure, so few studies have been done. They appear to take a major role in brain timing and network function.

Beta (15-40Hz)

When the brain is aroused and actively engaged in mental activities, it generates beta waves. These beta waves are of relatively low amplitude. Beta waves are characteristics of a strongly engaged mind. Our Normal waking state[10].

Alpha waves (9 to 14 Hz)

Alpha brainwaves are slower and higher in amplitude. Showcases during relaxation.

Theta waves (3 to 8 Hz)

Greater amplitude and slower frequency. A Sub conscious thought or “DayDreaming” state of mind produces Theta waves.

Delta waves (.5 to 3 Hz)

Here the brainwaves are of the greatest amplitude and slowest frequency. They never go down to zero because that would mean that you were brain dead. But, deep dreamless sleep would take you down to the lowest frequency.

Gamma waves (38 to 42 Hz)

Gamma brainwaves are the fastest of brain waves and relate to simultaneous processing of information from different brain areas; eg: Multi-Tasking.

It passes information rapidly, and as the most subtle of the brainwave frequencies.

Gamma is also above the frequency of neuronal firing, so how it is generated remains a mystery[12].

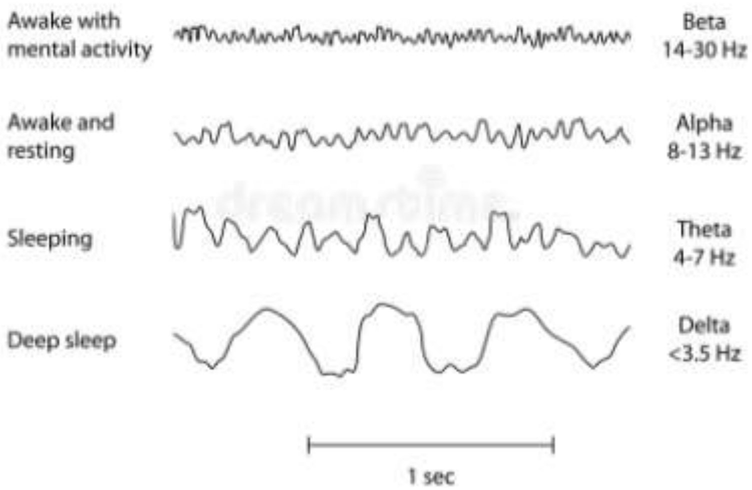

Fig2. Different Brainwaves

2.3 Brain-

The brain is responsible for all our actions, thoughts, emotions and senses. It is the hub for consciousness. The brain is separated into four different lobes:

Frontal: Responsible for speech and movement
Parietal: Responsible for stimuli response
Temporal: Responsible for stimuli related to hearing and memory
Occipital: Responsible for vision

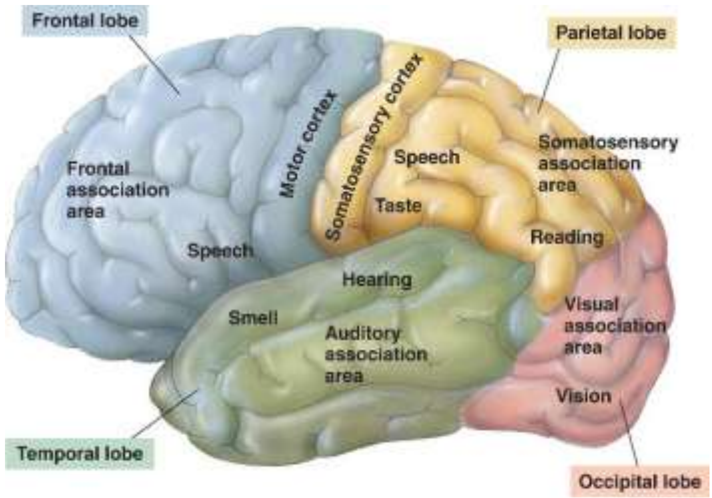

Fig3. The Brain and its sectors

Signals are usually generated within the grey matter i.e the outer layer cortex.
The Parietal and Temporal lobe fills in as the most important lobe for BCI as most stimuli responses are movements.

2.4 BCIs and neuron mapping-

Brain Computer Interface or commonly known as "BCI" is a direct communication pathway between a wired or enhanced brain to an external device.
In this research paper, we will be focusing on a particular type of BCI; "Invasive BCI", as our aim is to utilize the invasive BCI as a means of communication between the subject's brain and the neuroprosthesis[8].
There are three varieties of BCIs, invasive (neural implants), semi-invasive (ECoGs) and non-invasive (fMRI, EEG, MEG).

Invasive

-Neural implants are the least common of BCI used, due to the inherent risk of brain surgery, and long operation times. However, they can monitor the activities of very specific neurons, or single neurons. They yield a high quality signal, due to their placement in the grey matter.

Semi-Invasive

Electrocorticography, or ECoG for short, involves a matrix of platinum electrodes held inside plastic being surgically inserted below the Dura mater (fat tissue connecting brain to scalp).
Each electrode in the grid has thousands of neurons below it, and measures the current change per minute[2].

Non-Invasive

Electrodes placed on the scalp record the voltage change of the neurons below each sensor.
While this method is the most commonly used, electric noise interferes with its readings, and hence can only be used in shielded rooms.
The readings can currently be at micro volts per milliseconds. First voltage gain is calculated after which filtering and amplification takes place. Then the analog signal is converted to digital. The gain in voltage is then measured and used to calculate the signal with caution to decrease the noise.[5] After this, the signal gets processed and split over time periods to then be finally broken into samples.
MEGs measure the magnetic field released by each neuron's current. This method involves using SQUIDS, or Superconducting Quantum Interference Devices (A very sensitive magnetometer which can detect the smallest of magnetic fluxs), which are cooled to extremely low temperatures, as the magnetic field of each neuron is immensely smaller than that of the earth.[5]
fMRIs calculate the ratio of oxygenated to deoxygenated blood in the blood vessels near neurons, and then use this data to infer brain activity.

A neural network is a complex network, therefore has complex algorithms to produce a desirable outcome after being given the vaguest of data.
This research paper considers neuroprosthesis to be a neuroprosthetic artificial limb.
Therefore, algorithm mainly focuses to produce the product of motion/movement.

Table1. Accepted and Rejected input signals

Associated value	1	0
waves	α	Δ
waves	β	Θ

There are two classifications of input signals “1”; the accepted input signals and “0”; the rejected input signals. We classify “Alpha” and “Beta” waves as “1”, “Delta” and “Theta” as “0”.
As, Alpha and Beta are brain waves in charge of conscious thought; reflex and motor functions while Delta and Theta are that of subconscious thought; dream and deep thought/sleep.

III. Matlab

Table2. Brain waves description

α	□	**Output**	**Description**
0	0	0	No brains are present
0	1	1	Only Beta waves present
1	0	1	Only Alpha waves present
1	1	0	α , β both present, this is an impossible condition hence output is zero

CODE:

```
clc;
clear all;
close all;
x=input('Enter 1st stream of bits: ');
y=input('Enter 2nd stream of bits: ');
z=xor(x,y);
subplot(3,1,1);
stem(x);
subplot(3,1,2);
stem(y);
subplot(3,1,3);
stem(z);
```

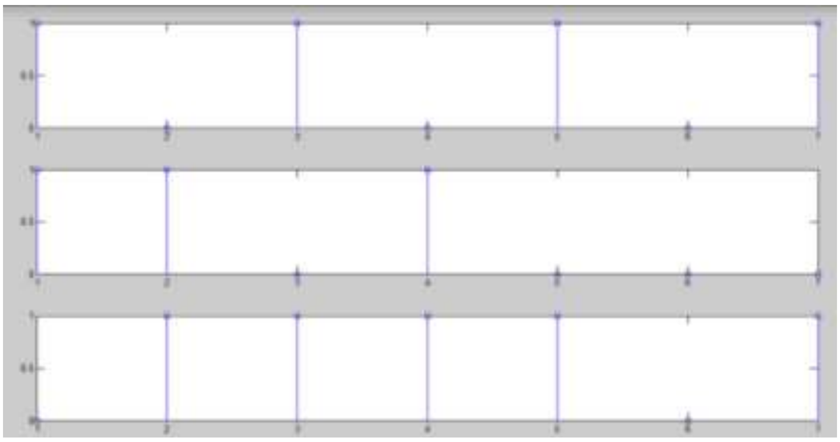

Fig4. Waveforms showing output of Alpha and Beta waves

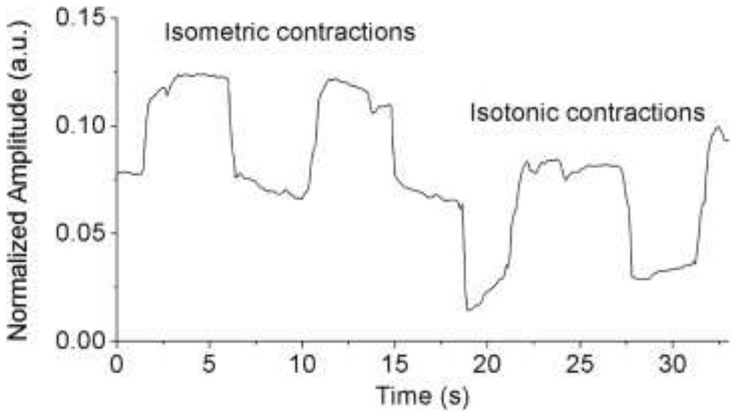

Fig5. Graphical representation of Isometric and Isotonic contractions

```
clc;
clear all;
close all;
alpha = input('Enter the alpha bit stream: ');
beta = input('Enter the beta bit stream: ');
voltage = input('Enter the voltage valules: ');
z=and(voltage,(xor(alpha,beta)));
subplot(4,1,1);
stem(alpha);
subplot(4,1,2);
stem(beta);
subplot(4,1,3);
stem(voltage);
subplot(4,1,4);
stem(z);
```

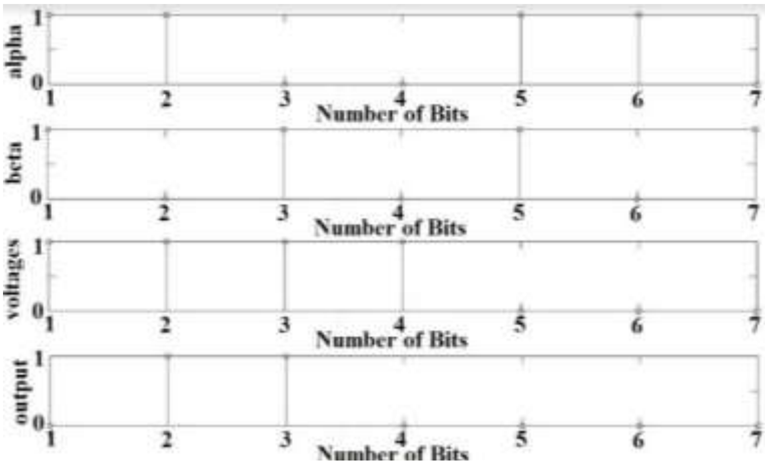

Fig6. Waveforms showing output of Alpha and Beta waves with voltages

The organic opto-electronic muscle contraction sensor:
A flexible, non-invasive organic optoelectronic device can be worn on the body to measure signals from muscles and control artificial limbs.

Working:

Once the sensor senses the contraction of the muscle it then submits the signal to the bionic arm, the arm is also connected to an invasive BCI (WBCI) the wbci's senses the brain waves produced by the ganglia (neuron cluster) near the amputated part of the arm. If brain waves produced are giving an output of 1 and the contraction occurring is within the range of the code the bionic arm will contract.

Both isotonic contraction (joint angle and muscle length change during contraction) and isometric contraction (joint angle and muscle length do not change during contraction) movement are possible.

Therefore, movement which causes both 180 degree and 90 degree movements on either axises are possible.
PHANTOM LIMB SYNDROME:
When an arm or leg is amputated, many patients continue to experience the vivid presence of the limb; hence the evocative term ‘phantom limb’, thus, when placed in a situation where the visual cortex confuses the brain of the presence of the amputated limb the patients feel extreme surges (the neurotransmissions from the dormant neurons). Therefore utilizing Phantom limb syndrome we can activate the dormant neurons and use them to gain data via WBCI.

IV. Conclusion

This very well could be a small step towards “Neuroprosthetics” and a world where both people and technology are connected, a world where picking up your phone with one's mere thoughts wouldn't be a dream but a reality. The aim of this paper was not only to help amputated and disabled civilians by making a more efficient and effective replacement for a bionic arm but was to put across the idea of “being one with our creations” thus, instead of creating new inventions that we cannot have full manual control of, modifying either human species as a whole through ‘Artificial evolution’ or creating small implanting modification one can implement in their daily life and into themselves.

V. Future Work

Using WBCI’s and the same procedure we can replace both organic optoelectronic muscle contraction sensors and basic binary coding with ANN’s (Artificial Neural Networks). ANN’s takes into consideration more factors like movement, pressure, direction,etc using a complex algorithm. This would create even higher scope for interfacing brains with computers.

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