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LOW COST PROSTHETIC HAND BASED ON 3-LEAD MUSCLE/ELECTROMYOGRAPHY SENSOR AND 1 CHANNEL EEG

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Abstract. *Prosthetic hand is an example of assistive technology and has advanced to a remarkable degree in the past two decades. Measuring muscle activation via electric potential, referred to as electromyography (EMG) and electroenchepalography (EEG) can be applied to prosthetics systems. This paper presents development of low cost prosthetic hand using 3-lead muscle sensor and combined with 1 channel EEG. The signals from the muscle and combined with mediation and attention from the brain are used to control the hand and for grasping purpose. The average of thinking/control using attention signal from EEG is about 3.5 seconds and the average of moving a wrist using MyoWare muscle sensor about 1 second.*
Keywords: Prosthetic hand, Brainwave, EMG, EEG, Muscle sensor

1. **Introduction.** There are millions of amputees in the world, and about 10% amputees need prosthetic hand. Recently, many developments of science and technology have led assistive technology such as prosthetic hand or arm developed based on muscle sensors or EEG in favor of commercialization. The human body as a whole is electrically neutral; it has the same number of positive and negative charges. However, in the resting state, the nerve cell membrane is polarized due to differences in the concentrations and ionic composition across the plasma membrane. A potential difference exists between the intra-cellular and extra-cellular fluids of the cell. In response to a stimulus from the neuron, a muscle fiber depolarizes as the signal propagates along its surface and the fiber twitches [1].

Electrical signals due to muscle activation have been evolving since Francesco Redi found electrical generation in the muscles of the electric ray fish in 1666 [2], then Dubois discovered electrical activation in voluntary muscles in 1849 [3], and Mari coined the term electromyography in 1922 [1]. Evolving over the following decades, electromyography has found widespread use in clinical settings as well as extensive use in ergonomic assessment and biomechanics research laboratories. One of the state of the art of this area is a research conducted by Otto Bock that provides a variety of EMG based prosthetic hands to the commercial market including high speed (300mm/s) and high force (160N compression) options. i-Limb provides a hand with five independently powered digits but is controlled by only two EMG electrodes [4-6]. Besides, EEG sensor now can be used to control assistive devices such as electric wheelchair [7].

A large range of various prostheses have been 3D-printed, of which the majority are used by children. Evidence with respect to the user acceptance, functionality and durability of the 3D-printed hands is lacking. Contrary to what is often claimed, 3D-printing is not necessarily cheap, e.g., injection molding can be cheaper. Another method is using servo

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actuators that have the good durability and power. Unfortunately, simple implementation that focuses on the control of low cost prosthetic hand has not yet presented. This paper presents the development of low cost prosthetic hand combined with 1 channel EEG to be used for disabling person. The organization of this paper consists of introduction, related works, proposed methods, experimental results and discussion.

2. Related Works.

2.1. **Human brain.** Previous work on robotics arm/manipulator [8] based on computer vision has limitation only for the robot, not for human. The human brain weighs about 3 pounds, which is 2% of a person's weight, but consumes as much as 25 percent of our body's oxygen, burns 20% of our total calories each day, with glucose being the main energy source for the brain that runs on around 12 watts of power, which is a fifth of the power required by a standard 60 watt light bulb [14]. Human brain is considered as the most delicate organ in human body which receives interference under omnipresence of radio frequency (RF) signals and systems. Many commercial EEG devices are successfully able to detect brain activity and used to control electronic devices such as Emotiv [15].

There is growing recognition that neural oscillations (brain waves) are important in a wide range of perceptual and cognitive functions such as information transfer, motor control and memory. Neural oscillations are electrical activities of the brain measurable at different frequencies. Many complex and functional areas in our brain are such as working memory, sensory and visual processing. Figure 1 shows our brain functional lobes and regions.

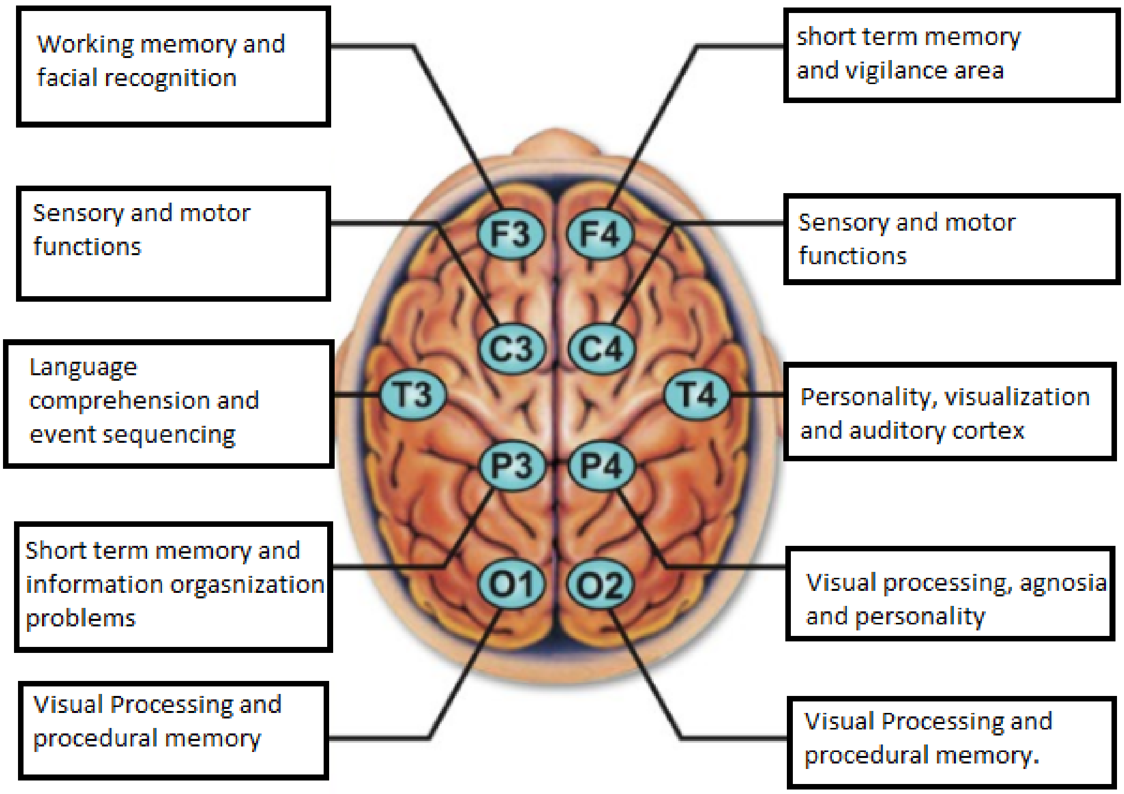

Figure 1. Functional lobes and regions of brain

2.2. **Muscle sensor.** EMG signal acquisition systems are traditionally composed of analog filters and gain stages for each channel. In order to meet our goal of using fewer components than a traditional EMG acquisition system, our team explored a newer approach to the problem. A high-resolution analog to digital converter can be used to capture the signal with a resolution of only a couple hundred Nano Volts. This level of resolution allows all of the filtering to be done in the digital domain. Myoelectrodes pick up electrical signal on the surface of the skin generated by muscle contractions, whereas Touch Pads, Servo Transducers, and Switches are all actuated by movement. The choice of input device depends not only on the user's abilities, but also on the device being controlled, and the type of control circuit [13].

Muscle cells are surrounded by a selectively permeable membrane with a resting electrical potential of 70 to 90 millivolts. The outside of the cell is positive relative to the inside. Motoneurons carry impulses from the central nervous system to the muscle cells called the nerve action potential (NAP). Each muscle is comprised of many muscle motor units, which are comprised of many cells, and are connected to many motoneurons; thus, a seemingly simple muscle contraction will correspond to a complex overall MAP waveform. An electrode properly positioned with respect to the muscle can record these MAP waveforms. The sensing and recording of these electrical waveforms are called electromyography (EMG) [12]. Properly recorded and processed EMG signal is known to correlate to muscle activation level, and in some cases can be used to determine muscle tension [9]. EMG sensors have found their way into prosthetics, robotics and other control systems.

Prosthetic input sensors are like translators that communicate the user's wishes to the motors of an externally-powered prosthesis. The muscle sensor using MyoWare muscle sensors to measure the muscle activation via electric potential designed to be used directly with a microcontroller and the output is an amplified, rectified and integrated signal (EMG's envelope) as shown in Figure 2. The sensor consists of embedded electrode connector and an RAW EMG Output and Rectified and Integrated EMG output.

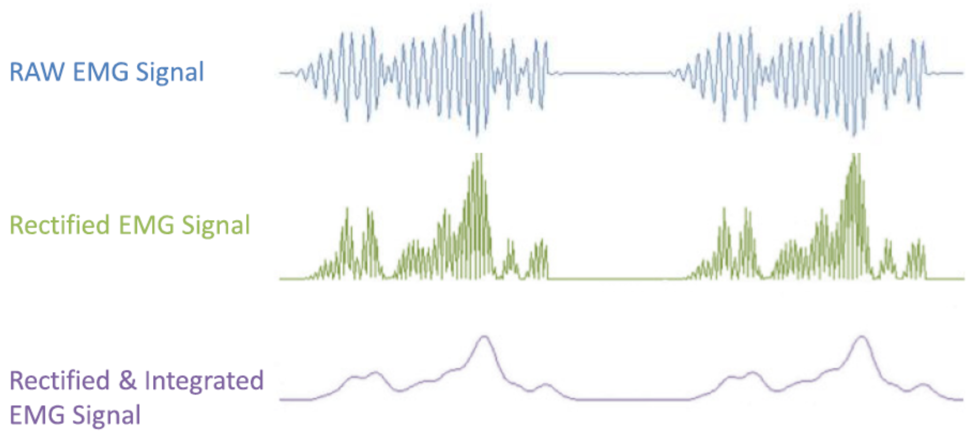

FIGURE 2. Example signal of EMG using MyoWare muscle sensor [10]

This sensor is able to sense the electrical activity of your muscles. It then converts that into a varying voltage that can be read on the analog input pin of any microcontroller with the position of the snesor shown in Figure 3.

2.3. **Mindwave EEG.** The MindWave Mobile Brain-Computer Interface (BCI) device turns your brainwaves into actions and safely measures and outputs the EEG power spectrums (alpha waves, beta waves, etc.), NeuroSky eSense meters (attention and meditation) and eye blinks. 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

FIGURE 3. Setup position of the sensor

is on the sensor arm, resting on the forehead above the eye (FP1 position). Output NeuroSky proprietary eSense meter such as Attention, Meditation, and other future meters. The table below gives a general synopsis of some of the commonly-recognized frequencies that tend to be generated by different types of activity in the brain. Generally, Attention can be controlled through a visual focus. For Meditation, it typically helps to try to relax yourself. Connect to a sense of peace and calm by clearing your mind of thoughts and distractions. If you are having difficulty engaging Meditation, close your eyes, wait several seconds, and then open your eyes to see how the meter has responded [9]. They are typically described as low frequency bands at delta ($<$ 4Hz), theta (4-7Hz), alpha (8-12Hz), and beta (12-30Hz) as shown in Table 1.

TABLE 1. Brainwave type and the description

Brainwave type	**Frequency range**	**Mental states and conditions**
Delta	0.1Hz to 3Hz	Deep, dreamless sleep and unconscious
Theta	4Hz to 7 Hz	Intuitive, recall, fantasy, imaginary and dream
Alpha	8Hz to 12Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	12Hz to 15Hz	Formerly SMR, relaxed yet focused
Midrange Beta	16Hz to 20Hz	Thinking, aware of self and surroundings
High Beta	21Hz to 30Hz	Alertness and agitation

3. Proposed Method.

3.1. Architecture of the system.

Measuring activity based on the muscle sensor and brain is challenging task. So, we design an efficient architecture of the system as shown in Figure 4 using Arduino UNO as main controller to controller 5 degree of freedom (DoF) prosthetic hand and 1 servo for wrist. 5 DoF prosthetic hand from MechaX Robot is the lowest cost for this project. The connection with Mindwave EEG and the controller is using Bluetooth. The data from Mindwave EEG send in serial form using bluetooth and

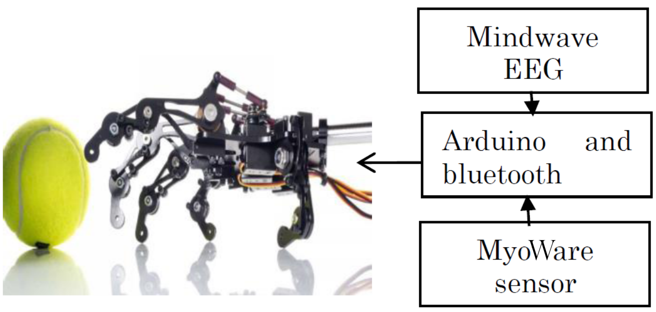

FIGURE 4. Architecture of prosthetic hand and the devices

processed by the Arduino. The related action based on the command from muscle and EEG signal is sent to servos.

3.2. **Algorithm.** The algorithm for prosthetic hand controller by EMG and 1 channel EEG shown in Algorithm 1.

Algorithm 1: controlling prosthetic hand

```
Initialize variables
Set the actuators to original position
Do
Read muscle sensor
Read EEG
If muscle active then
    Move wrist
If EEG active and attention signal is active then
    Grasp object
      if EEG active and attention signal is not active then
          Release an object
      endif
Endif
Endif
```

4. **Experimental Result.** We use MechaX Robot Right Hand having 5 DoFs (degrees of freedom), one per finger/thumb for prosthetic hand, and 1 servo motor. This prosthetic hand can be controlled by 1 MyoWare muscle sensor and Mindwave EEG device. Distractions, wandering thoughts, lack of focus or anxiety may lower the attention signal. Note that Meditation is a measure of a person's mental states, not physical levels, so simply relaxing all the muscles of the body may not immediately result in a heightened Meditation signal. Closing the eyes is general method for increasing the Meditation meter signal. We advise users to adjust the gain such that the output signal will not saturate the amplifier. Common mode rejection ratio (CMRR) of MyoWare sensor is 110.

We conduct 10x experiments to control the prosthetic hand and the result is shown in Table 2. The average of thinking/control using attention signal from EEG is about 3.5 seconds and the average of moving a wrist using MyoWare muscle sensor about 1 second. In the experiment, due to acquisition, physiological reasons, the delay between command from muscle sensor and prosthetic hand action is 4 seconds.

Table 2. Results of activities

No	Results		
	Activities	**Success**	**Accuracy**
1	Grasp an object	8	80%
2	Release an object	8	80%
3	Move wrist	9	90%

The prototype of prosthetic hand is shown in Figure 5.

5. **Conclusion.** EMG signal carries valuable information regarding the nerve system. Our research has a good initial result for prosthetic hand using EMG and EEG. The signal from the muscle, mediation and attention signal from EEG is able to control the hand for grasping purpose. Controlling devices using EEG still needs improvement. Future work is likely to propose the development of more powerful prosthetic hand and leg for human.

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Figure 5. Prototype of the system

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