Prosthetic arm Controller Based on Brainwaves Spectrum EEG Sensor

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Abstract. The purpose of this study is to discuss the brain wave system that can move the prosthetic arm based on brain wave activity. The sensor used to detect EEG brainwave activity uses a mobile mind wave sensor. Movement and detection of brainwave signals is carried out in the Lab VIEW application program. Plan this robot to make movements based on brain wave activity, utilizing blinks and attention. This research method through a process carried out to control the prosthetic arm. Where there are 2 modes, the first mode for the selection of movements with a blink of an eye, and the second mode of attention to move the fake arm. Based on research results Prosthetic arms can make movements that are designed for extension, flexion, supination or pronation and increase or depression. The prosthetic arm can make movements based on the subject's commands by utilizing brain wave activity. With a speed response time of 9.54 seconds to do all the moves. In addition to the advantages of this artificial arm, it can accommodate objects with a diameter of 2.2 cm to 6 cm. With an average percentage success of 6 experiments conducted by 86.67%.

1. Introduction
EEG signal analysis and feature extraction from these signals is a very difficult problem. This is because the EEG signals that is applied to the prosthetic arm control must be able to answer the EEG signal or what pattern of its features can represent several prosthetic arm operations. So that it is possible to translate EEG signals into commands to control prosthetic arms [1].

A lot of research on prosthetic hands starts from making prosthetic hands to how prosthetic hands move and with what media prosthetic hands are moved, research on prosthetic hands has been done, namely the design of movable prosthetic hands where their movements can be controlled by utilizing muscle-generated EMG signals hand muscles in extension, flexion and supination or pronation movements. Prosthetic design with the use of EMG signals still has disadvantages, the movement that can be done is limited. Each movement must be represented by an EMG sensor, and in addition to carrying out each movement requires the right EMG placement point, in the EMG sensor placement and prosthetic hand movement requires the whole hand media to move [2]. However, the myoelectric prosthesis was developed, to provide more freedom than more conventional movements [3]. However, changes in signal variations are very fine, making it difficult to monitor or analyze visually with the eyes. In addition, programming algorithms are increasingly being used in the development of automated control systems through identification of variations in myoelectric signals [4]. The Brain Computer
Interface (BCI) system makes it possible to be able to utilize brain waves, to move the arms and prosthetic arms.

The purpose of this research is to design a system that can control prosthetic arms by utilizing brain wave activity. Where to control the prosthetic arm by utilizing signals produced by brain wave activity. Which is then processed to get four movements such as: extension, flexion, pronation or supination and elevation or depression. And assisted with the prosthetic system movement method of brain wave activity.

2. Method
In the design of the system four prosthetic movements are based on brain wave activity, in general there are three main parts, namely the input (input), processing (process), and output (output). Each part of the system has its own functions which will be interrelated in a system of four prosthetic movements based on brain wave activity. In Figure 1, a block diagram of a prosthetic arm controller system based on the EEG Brainwaves Spectrum Sensor.

![Figure 1. Prosthetic arm controller system](image)

In designing prosthetic arms based on brain wave activity, prosthetic arms are designed to resemble human arms, but the movement of prosthetic arm is limited to only four movements (extension, flexion, pronation or supination and elevation or depression). In Figure 2 shows, the design of the prosthetic arm made resembles an adult human arm on a scale of 1:1.
3. Results and Discussion

a. EEG Sensor analysis
The amplitude of the EEG signals ranges between 0 - 130mV with a frequency falling in the range 0.5 - 40Hz [5]. The eye blink signal is a very low frequency signal from the range 1 - 13Hz, with an amplitude range between 200-550 µV, occurring when eyes are closed and eyes open [6-8]. The threshold of peak waveform has a function to identify the signal blink. Where the amplitude value is not only detected by the program, it is also calculated to be able to identify it as a double blink, and three eye blinks. The maximum eyelid closure was analyzed by conducting an experiment and the value was higher than 400 µV[9]. The threshold value used was 400µV, in Table 1.

Table 1. EEG Sensor Testing

| Action          | Extracted Signals | Amplitude Value |
|-----------------|-------------------|-----------------|
| double blink    |                   |                 |
| eyes pulse      |                   |                 |
| triple blink    |                   |                 |
| eyes pulse      |                   |                 |

b. Testing the grip of the prosthetic arm
This test is carried out to determine the success rate of the prosthetic arm in grasping objects and knowing the diameter size of objects that can be grasped, as shown in Table 2.
Table 2. Testing Results of Prosthetic Arm Grasping Objects

| Held object         | Diameter size (cm) | Prosthetic results |
|---------------------|--------------------|--------------------|
| Attractor           | 2.2                | Clasped            |
| Screwdriver place   | 4                  | Clasped            |
| Canned drink        | 5                  | Clasped            |
| Drink bottle        | 6                  | Clasped            |
| Big glass           | 8                  | not clasped        |
| Big bottle          | 10                 | not clasped        |

c. Testing of the Prosthetic Arm Movement

This test aims to determine the movement of a predetermined prosthetic arm based on instructions from brain wave activity using the neurosky EEG mindwave mobile sensor. Where all processing orders on a laptop with LabVIEW application are then sent to the microcontroller to drive the actuator. The prosthetic arm will move according to the commands of brain wave activity. In this experiment to be tested are all prosthetic arm movements (extension, flexion, pronation or supination and elevation or depression) [2] in Figure 3.

![Prosthetic arm movements using detection wave activity](image)

**Figure 3.** Prosthetic arm movements using detection wave activity: (a) Flexion movement, (b) Extension movement, (c) Pronation movement, (d) Supination movement, (e) Elevation movement, and (f) Depression movement.
Table 3. Movement and Attention Value test results

| Send Data Mode | Testing | Setpoint Attention | Attention Value | Prosthetic Arm Movements | Percentage of Success (%) |
|----------------|---------|--------------------|-----------------|--------------------------|--------------------------|
|                | 1       | 70                 | 72              | Flexion                  |                          |
|                | 2       | 70                 | 68              | Not Moving               |                          |
| Flexion        | 3       | 70                 | 74              | Flexion                  | 80                       |
|                | 4       | 70                 | 80              | Flexion                  |                          |
|                | 5       | 70                 | 74              | Flexion                  |                          |
|                | 1       | 70                 | 98              | Extension                |                          |
|                | 2       | 70                 | 78              | Extension                |                          |
| Extension      | 3       | 70                 | 82              | Extension                | 80                       |
|                | 4       | 70                 | 64              | Not Moving               |                          |
|                | 5       | 70                 | 76              | Extension                |                          |
|                | 1       | 70                 | 80              | Pronation                |                          |
|                | 2       | 70                 | 90              | Pronation                |                          |
| Pronation      | 3       | 70                 | 80              | Pronation                | 80                       |
|                | 4       | 70                 | 74              | Pronation                |                          |
|                | 5       | 70                 | 60              | Not Moving               |                          |
|                | 1       | 70                 | 78              | Supination               |                          |
|                | 2       | 70                 | 84              | Supination               |                          |
| Supination     | 3       | 70                 | 82              | Supination               | 100                      |
|                | 4       | 70                 | 72              | Supination               |                          |
|                | 5       | 70                 | 78              | Supination               |                          |
|                | 1       | 70                 | 66              | Not Moving               |                          |
|                | 2       | 70                 | 82              | Elevation                |                          |
| Elevation      | 3       | 70                 | 74              | Elevation                | 80                       |
|                | 4       | 70                 | 73              | Elevation                |                          |
|                | 5       | 70                 | 78              | Elevation                |                          |
|                | 1       | 70                 | 72              | Depression               |                          |
|                | 2       | 70                 | 74              | Depression               |                          |
| Depression     | 3       | 70                 | 80              | Depression               | 100                      |
|                | 4       | 70                 | 78              | Depression               |                          |
|                | 5       | 70                 | 88              | Depression               |                          |

The "neutral" scale is at a value between 40 and 60 at a given time [7,10]. The attention of the setpoint chosen in this test is at 70, because to avoid unwanted movements, so that to control the prosthetic arm this requires attention signals that are more than the "neutral" limit. The test results in Table 3, obtained the greatest percentage of success of 100% and the smallest success of 80%. With the percentage of the overall total of 6 movements amounting to 86.67%. This is influenced by the attention value movement that does not reach the set point value.
Based on Table 4, it can be seen that all the arm movement experiments were successfully carried out, it was found that the fastest response time of the system to detect motion was flexion movement of 1.16 seconds. While the longest is the elevation movement with a response time of 32.55 seconds. This response time is influenced by the brain activity of the subject to carry out orders for the movement of the prosthetic arm. While the average response time to do all the movements obtained time response speed of 9.548 seconds.

### Table 4. Test Results Response of Prosthetic arm Movement

| Movement of the Prosthetic Arm | Testing | Response time (Sekon) |
|--------------------------------|---------|----------------------|
| Flexion                        | 1       | 2,32                 |
|                                | 2       | 8,88                 |
|                                | 3       | 2,17                 |
|                                | 4       | 1,16                 |
|                                | 5       | 1,98                 |
| Flexion average time           |         | 3,30 detik           |
|                                | 1       | 4,54                 |
|                                | 2       | 2,49                 |
| Extension                      | 3       | 5,81                 |
|                                | 4       | 1,27                 |
|                                | 5       | 3,70                 |
| Extension average time         |         | 3,56 detik           |
|                                | 1       | 3,48                 |
|                                | 2       | 10,22                |
| Pronation                      | 3       | 15,94                |
|                                | 4       | 15,03                |
|                                | 5       | 9,85                 |
| Pronation average time         |         | 10,90 detik          |
|                                | 1       | 9,67                 |
|                                | 2       | 10,90                |
| Supination                     | 3       | 14,56                |
|                                | 4       | 10,01                |
|                                | 5       | 6,81                 |
| Supination average time        |         | 10,39 detik          |
|                                | 1       | 13,62                |
|                                | 2       | 32,55                |
| Elevation                      | 3       | 21,63                |
|                                | 4       | 21,26                |
|                                | 5       | 22,61                |
| Elevation average time         |         | 22,33 detik          |
|                                | 1       | 9,30                 |
|                                | 2       | 4,55                 |
| Depression                     | 3       | 8,60                 |
|                                | 4       | 5,22                 |
|                                | 5       | 6,33                 |
| Depression average time        |         | 6,81 detik           |

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*d. User Interface Prosthetic Arm Controller using LabVIEW Programming*

The overall display test Programming in LabVIEW aims to determine whether the system has been made as expected so that it can be applied to the prosthetic arm movement system. The test starts with pairing
the EEG session with LabVIEW to find out the EEG sensor serial communication port as input initialization in LabVIEW programming. After that, test the data exchange between Arduino uno and LabVIEW data exchange link between LabVIEW and Arduino UNO. This is done to ensure communication runs well with one another using the Makerhub LINX interface [11]. The user interface for the prosthetic arm controller system can be seen in Figure 4.

![User Interface Prosthetic Arm Controller Based on Brainwaves Spectrum EEG Sensor](image)

**Figure 4.** User Interface Prosthetic arm Controller Based on Brainwaves Spectrum EEG Sensor

### 4. Conclusion

Based on the results of the system design and the results of testing and analysis that have been carried out from the "Prosthetic Arm Controller Based on Brainwaves Spectrum EEG Sensors" some conclusions were obtained: A prosthetic arm designed has been successfully created to control an prosthetic arm with the command of a subject based on brain wave activity. Prosthetic arms can grasping objects with a diameter of 2.2 cm to 6 cm. The percentage of success for the overall test results of the 6 movements tested was 86.67%. The average response time for doing all movements is a response time of 9.548 seconds.

### References

[1] Zhang, X., Li, R., & Li, Y. (2014, November). Research on brain control prosthetic hand. In *2014 11th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI)* (pp. 554-557). IEEE.

[2] Tsipouras, M. G. (2018). Uterine EMG Signals Spectral Analysis for Pre-Term Birth Prediction. *Engineering, Technology & Applied Science Research*, 8(5), 3310-3315.

[3] Bright, D., Nair, A., Salvekar, D., & Bhishikar, S. (2016, June). EEG-based brain controlled prosthetic arm. In *2016 Conference on Advances in Signal Processing (CASP)* (pp. 479-483). IEEE.

[4] R. Mahajan and D. Bansal, “Real Time EEG Based Cognitive Brain Computer Interface for Control Applications via Arduino Interfacing,” *Procedia Comput. Sci.*, vol. 115, pp. 812–820, 2017.

[5] Ang, K. K., Chua, K. S. G., Phua, K. S., Wang, C., Chin, Z. Y., Kuah, C. W. K., ... & Guan, C. (2015). A randomized controlled trial of EEG-based motor imagery brain-computer interface robotic rehabilitation for stroke. *Clinical EEG and neuroscience*, 46(4), 310-320.

[6] Abo-Zahhad, M., Ahmed, S. M., & Abbas, S. N. (2015). A new EEG acquisition protocol for biometric identification using eye blinking signals. *International Journal of Intelligent...*
[7] Utama, J., and M. D. Saputra. "Design of electric wheelchair controller based on brainwaves spectrum EEG sensor." *IOP Conference Series: Materials Science and Engineering*. Vol. 407. No. 1. 2018.

[8] Muresan, D., & Sinuraya, R. (2018, August). Relation between internet and social media to support sales in business. In *IOP Conference Series: Materials Science and Engineering* (Vol. 407, No. 1, p. 012062).

[9] Zhi-Hao, W., Yu-Fan, K., Chuan-Te, C., Shi-Hao, L., & Gwo-Jia, J. (2017). Controlling DC motor using eye blink signals based on LabVIEW. In *2017 5th International Conference on Electrical, Electronics and Information Engineering (ICEEIE)* (pp. 61-65). IEEE.

[10] Beyrouthy, T., Al Kork, S. K., Korbane, J. A., & Abdulmonem, A. (2016, August). EEG mind controlled smart prosthetic arm. In *2016 IEEE International Conference on Emerging Technologies and Innovative Business Practices for the Transformation of Societies (EmergiTech)* (pp. 404-409). IEEE.

[11] Setiawan, E. B., & Setiyadi, A. (2018, August). Web vulnerability analysis and implementation. In *IOP Conference Series: Materials Science and Engineering* (Vol. 407, No. 1, p. 012081).