Prosthetic hand with 2-dimensional motion based EOG signal control

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Abstract. A prosthetic hand is an artificial device that resembles a human hand which can help the human with a physical disability. Previously, the development of a prosthetic hand is designed in various method, from passive to bionic. Electrooculography (EOG) is a technique for measuring potential differences between the front (positive pole formed by the cornea) and the back (negative pole formed by the retina) of the eyeball which can be used to detect eye movements. The purpose of this study is to design a prosthetic hand with two degrees (2D) of freedom using EOG based control. This system consists of electrodes, EOG amplifier, Bluetooth transmitter-receiver, servo motors, and hand prosthetics. In this study, the system will recognize the eye movements, namely front, right, left, up, and down. The system will recognize the motion based on a threshold value. In the hardware implementation, the system was composed of five electrode sensors which installed around the eye, instrumentation amplifier, high pass filter, low pass filter, noninverting amplifier, summing amplifier, a notch filter circuit, and Arduino UNO microcontroller. In EOG data acquisition, this study involved ten healthy subjects. After the evaluation with five trial for each motion, the error for each eye movement is 0%, 0%, 36%, 4% and 16% for right, left, top, bottom, and front, respectively. This study provided an alternative method to control a prosthetics hand with good performance.

1. Introduction
Electrooculography is a technique for measuring the resting potential of the retina. The resulting signal is called an electrooculogram. An electrooculography is a device that measures the voltage between two electrodes placed on the face of the subject so that it can detect eye movements [1]. Electrooculography (EOG) is a method for measuring potential differences between the front (positive pole formed by the cornea) and the back (negative pole formed by the retina) of the eyeball and thus can be used to detect eye movements and blink, when the eyes are fixed in the future, a stable base line potential is measured by electrodes placed around the eyes [2]. Electrodes must be placed as close as possible to the eye to maximize measured potential. Potential changes are detected when the pole approaches or moves away from the electrode when moving the eyes. The sign of change depends on the direction of movement. EOG measurements can be influenced by artifacts arising from muscle potential and small electromagnetic disturbances due to wires or disturbances in the surrounding power lines [3].

Some studies related to EOG signals, Chacko, et al. conducted a study on "Microcontroller Based EOG Guided Wheelchair" on the results of the EOG signal successfully applied and shown for microcontroller-based wheelchair control [4]. Similar research is also conducted by Naga Rajesh, et al. has carried out research on "EOG Controlled Motorized Wheelchair for Disabled Persons" in the results
of the study that EOG motorized wheelchair control for persons with disabilities was successfully implemented, but in this study the wireless EOG acquisition system has not been implemented [5]. In studies related to the implementation of control systems and wireless EOG acquisition, Sanjaya, et al. has conducted a research on "Design and Experiment of Electrooculogram (EOG) System and Its Application to Control Mobile Robot" on the results of the research navigation control system for robot cars using a microcontroller with serial data communication via Bluetooth HC-05 successfully applied [6].

Based on the identification of the above problems, EOG signal detection has been successfully made and implemented for the control system using wireless serial data communication, the authors will develop the use of EOG 2 channel signals (horizontal and vertical), for left, right, up and down to control the movement of the open cap of the robot claws and the movement of the pronation robot arm using the Arduino microcontroller, sending and receiving serial data via Bluetooth [7]. Therefore, the author wants to make the module with the title of the thesis "2 Dimensional Motion Prosthetic Hands with EOG Signal Control" [8].

2. Materials and methods

2.1. Experimental setup

In this study, researchers looked at results in 5 respondents with normal eye conditions over the age of 18 years. Respondents were taken randomly and data collection for each respondent was repeated 5 times.

2.1.1. Materials and tool. This study uses disposable ECG electrodes. The placement of the electrodes as shown in Figure 1. Using the Arduino UNO Board as a microcontroller for EOG signal data processing, uses Bluetooth HC-05 as the sending and receiving of data and using a MG995 servo motor as a prosthetic hand drive.

![Figure 1. Electrode placement.](image)

In figure 1, is the point of mounting electrodes around the face, black marks are placement of vertical channel electrodes, red marks are placement of horizontal channel electrodes, and yellow marks are placement of reference electrodes or ground [9,10].

2.1.2. Experiment. In this study, the modules that have been made will be applied to 5 respondents and will be tested for success rates and error rates in controlling prosthetic hand movements 5 times in each respondent. Tests carried out consist of upward eye movement signals to control pronation motion, downward eye movement signals to control supination motion, right eye movement signals to control close motion, left eye movement signals to control open motion and forward eye movement signals.

3. Diagram block and flowchart

In this study, the researcher made 2 modules consisting of a transmitter module and a receiver module [1]. The block diagram and flowchart from the transmitter module and receiver module are shown in figure 2 and figure 3.
Figure 2. Diagram block, (a) Transmitter module, (b) Receiver module.

Figure 3. Flowchart, (a) Transmitter module, (b) Receiver module.
In figure 2 and figure 3 can be explained from the diagram block and flowchart the transmitter module is input through five electrodes that will be installed around the eyes to measure potential differences from the front eye view, right eye view, left eye view, eye view up and down eyes. Input from the five electrodes will enter the instrumentation amplifier circuit, so that the voltage obtained will be more maximal and can know the range of changes in eye movement. A filter circuit is needed for processing the desired signal using a 0.1 Hz High Pass Filter and a 30 Hz Low Pass Filter. The output of the vertical channel EOG circuit will enter the ADC1 pin and the horizontal channel instrumentation output will enter the ADC2 pin on the Arduino Uno for processing. The results of decisions of the right, left, up and down eye movements will be processed using the Arduino software design. In the processed output, a command will be sent via the Tx Bluetooth HC-05 module through the control of the Arduino UNO Board.

3.1. Analog circuit

3.1.1. Instrumentation amplifier. The instrumentation amplifier circuit based on figure 4 serves as an initial gain from the Horizontal Channel Electrode and Vertical Channel inputs to get the shape of the EOG signal. The shape of the EOG signal requires amplitude amplification [11-13].

![Instrumentation amplifier](image)

Figure 4. Instrumentation amplifier.

The R3 resistance is a resistor gain (Rg) which is used to regulate its gain. By setting the resistor value on R3, gain can be adjusted to adjust the output voltage of the EOG signal. In this EOG signal an initial gain of 9.8 times will be set. To calculate the magnitude of reinforcement can be determined in the following equation, Eq. (1):

$$G = \frac{49.4K}{R_3} + 1$$

4. Results and analysis

4.1. The design of prosthetic hand with 2-dimention motion based EOG signal control

The photograph of the analogue and digital part of the Prosthetic Hand with 2-Dimention Motion Based EOG Signal Control was shown in figure 5 and figure 6, respectively. The analogue part consisted of AD620 and three of CA3240 (OP-AMP). The digital part consisted of the Uno Arduino microcontroller which is the main board of Prosthetic Hand with 2-Dimention Motion Based EOG Signal Control device,
Bluetooth module which used to communicate the data between the microcontroller and The Design Hand Prosthetic Robotic.

Figure 5. The analogue design module.  

Figure 6. The digital design module.

4.2. The result and measured of respondent
In this study, the authors measured the Horizontal and Vertical EOG Channel signals to the respondents and tested the respondent's eye movements if there was an order to move the 2-dimensional prosthetic hand simulation [14,15].

Figure 7. Placement of Disposable EOG Electrodes.  

Figure 8. Placement of Disposable EOG Electrodes.

Table 1. Test results on subject 1.

| Eye Movement | Command | Test result | The Error |
|--------------|---------|-------------|-----------|
|              |         | 1 2 3 4 5   |           |
| Right        | Supination | ✓ ✓ ✓ ✓ ✓ | 0%        |
| Left         | Pronation  | ✓ ✓ ✓ ✓ ✓ | 0%        |
| Up           | Open      | × ✓ ✓ ✓ × | 40%       |
| Down         | Close     | ✓ ✓ ✓ ✓ ✓ | 0%        |
| Front        | No Movement | ✓ ✓ ✓ ✓ | 20%       |

Table 2. Average results of testing errors 5 respondent.

| Eye Movement | Command | Test Result (%) | Average Error |
|--------------|---------|-----------------|---------------|
|              |         | S1 S2 S3 S4 S5 |               |
| Right        | Supination | 0 0 0 0 0 0 | 0%            |
| Left         | Pronation  | 0 0 0 0 0 0 | 0%            |
| Up           | Open      | 40 60 40 20 20 | 36%          |
| Down         | Close     | 0 20 0 0 0 0 | 4%            |
| Front        | No Movement | 20 40 20 0 0 | 16%           |
5. Conclusion

This study shows that the prosthetic wireless Bluetooth hand control technology can facilitate users with hand disability with eye movements from the EOG signal. Electrooculography (EOG) is a technique for measuring potential differences between the front (positive pole formed by the cornea) and the back (negative pole formed by the retina) of the eyeball which can be used to detect eye movements. The EOG signal is tapped by attaching 5 disposable electrodes which are placed around the eyes. The results of the study show that the EOG signal has a cut off frequency of 0.1-30 Hz.

Based on the results of measurements and testing of 5 respondents, the average error in each movement is: Supination 0%, Pronation 0%, Open 36%, Close 4% and no move 16% by testing 5 times.

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