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Hand Gesture Design Using Bionic Prosthetic Hand

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Abstract:
Brain computer interface (BCI) system empowers command over external device by retrieving brain waves and interpreting them into machine instructions. The system utilizes electroencephalogram (EEG) for receiving, processing and classifying signals to control by means of brain generated signals. The paper focuses on mental task design for BCI by acquiring the signals generated by mental activity through EEG comb electrodes, placed over three-dimensional (3D) printed headset. The experiment involved the blinking of left and right eye for the forward and backward movements of the prototype wheelchair. The experimental measurement was performed using a Cyton board where the information was transmitted through Bluetooth which were later processed and translated to the wheelchair to perform activities. The system has successfully achieved the real time control of an assistive device by using signals from the brain.

Keywords: Assistive device; Brain computer interface; Cyton; Mental activity; Mental task; Wheelchair.

1. Introduction

Nowadays, the utilization of bionic prosthetic hand has increased particularly in the field of medical rehabilitation and military. A lot of research studies and improvement are made in order to fulfill the essential human hand characteristics and to be made convenient to the users. However, the limitations in the movement and gesture of the bionic hand diminish it merchantability. In addition, the low durability and toughness of the components will cause difficulties to the users to rehearse their bionic prosthetic hand in their daily life movement.

From the World Health Organizations' data survey, the number of amputees worldwide was estimated around 650 million [1]. There is only 20 percent of people in a group of 30 million that has prosthetic or other portability gadgets to fulfill their daily requirements [2]. Despite the fact that variety types of prosthesis have been created throughout the years with the awesome advance to solve the issue of a lost limb, the progress in this technology is still limited, and the expense are restrictive on the grounds that it takes a great deal of works to produce these protheses that are fit to each of amputation need [3].

Currently, patients can just procure their bionic hands with multi-degree of freedoms i-Limb designed by Touch Bionics Co. from UK, with an official price of RM 60,000. Recently, Otto Bock Co. from Germany likewise came out with another bionic hand with five fingers called Michelangelo Hand with the price of RM120,000 which is unbearable for many users [4].

Bionic is defined as a combination of biological methods and systems found in human nature to study and design engineering system with the modern technology. Prosthetics state as the artificial replacement of human organic limbs or organs. In medical term, a prosthesis is an artificial device to replace a missing human body part, which may lose through trauma, disease or congenital conditions [5]. Bionic arm consolidates mechanical technology, biotechnology and electronics hardware to recreate an element function of the human arm [6]. Bionic prosthetic hands are the artificial devices manufactured with innovation and mechanical framework to empower amputees in performing hand part daily activities such as eating, driving, washing etc.

There are few related projects and research have been done. One of them is UiTM Prosthetic Hand. They have developed a Graphical User Interface (GUI) using LabVIEW and integrate it into the Emotiv Electroencephalography (EEG) Headset to control the prothesis hand. Patient may undertake the basic training using the GUI as a 3D Animation which acts similarly as a medium of interaction. Another is Anthropomorphic Prosthetic Hand which is made of aluminum alloy, designed with flexure hinges, and controlled by the surface electromyography (sEMG) signals which are measured from two electrodes [7]. Next, underactuated prosthetic hand which has greater degree of freedoms (DoFs) then the number of actuators. The prosthetic hand controller decides the human operator intended motion based on EMG pattern recognition and controls the fingers' movement of the prosthetic hand [8]. Then, i-LIMB Hand which is controlled by "myoelectric" signals created by the muscles in the rest part of the patient's limb, and the patient can quickly become adept at controlling his replacement hand. Last but not least, Galileo Bionic Hand that used EMG technique to detect the activity of a group muscles by measuring bio-potential acquired by surface mounted electrode [9].

The main interesting part about the bionic prosthetic hand is that anyone can print them and they can be manufactured rapidly contingent upon the size and number of parts [10]. Since the bionic prosthetic hands are easily modifiable, they can adapt to different amputations and people in constant growth [11]. Thus, this project aims to build up a basic prehensile hand gesture design with a basic model of a 3D-printed bionic prosthetic arm controlled by a micro-controller.

2. Methodology

This project is based on the combination of the hardware and software to create a functional bionic prosthetic hand that can achieve the basic robotic hand structure requirements and perform the human basic grasp task. There were four main parts in this project to construct the bionic prosthetic hand which are 3D printing of the prototype, motorized framework system, string binding connections and programming of the microcontroller. The process flow is shown in figure 1.

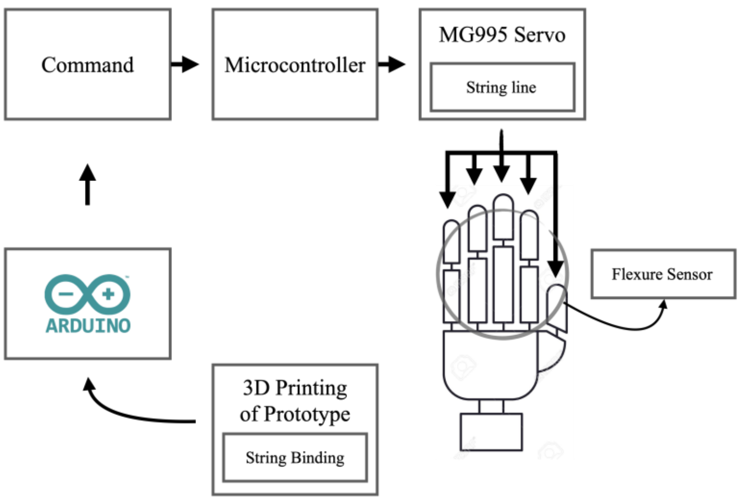


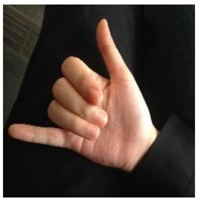
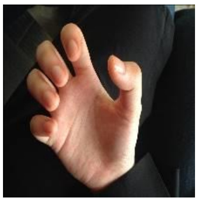
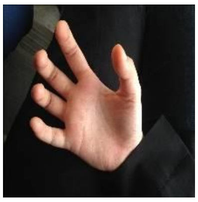
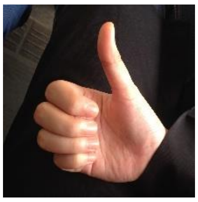
Figure 1. Process flow

2.1 Hand gesture

Hand gesture is the application of the whole part of the upper hand and the fingers to perform specific motion and pattern based on the daily human activity. Hand gesture can be categorized into static hand gestures and dynamic hand gestures [12]. Controlled prosthetic hand are used by trans-radial amputee and may likewise discover applications for the elderly and frail individuals [13].

The bionic prosthetic hand was made of Acrylonitrile Butadiene Styrene (ABS), an oiled-based plastic. ABS provided better auxiliary uprightness and was more suitable to mechanical utilize given the material that could withstand the components better than other ordinary plastics. The bionic prosthetic hand was designed with five fingers, 15 joints and five DoFs, with the similar appearance and size with actual human's right hand. From literature, there seemed to be ten hand gestures that were utilized for prosthetic hand and other similar applications. The hand gestures that were used to test the bionic prosthetic hand include call, close, cylindrical, holder, hook, neutral, pinch, point, release, rest and tripod as shown in Table 1.

Table 1. Human hand gesture

Hand Gesture	**Function**	**Hand Gesture**	**Function**
 Call	As a sign of using a telephone or in a communication.	 Neutral/Release	The hand is in normal position or steady state.
 Close	To punch, hit or strike something or to grip an object tightly	 Pinch	To squeeze small objects tightly and sharply between the finger and thumb such as pin and salt.
 Cylindrical	To grip a cylindrical item such as bottle or cup	 Point	To show a direction or pushing a button level in lift.
 Holder	To hold an item hanging on the index finger such as plastic bags.	 Rest	To raise a level surface object on which can stand such as plate and book.
 Hook	To bring and support an object using four fingers such as briefcase.	 Tripod	To grasp small item between the thumb, index finger and middle finger such as pen and eraser.

2.2 System component

The circuit diagram of bionic prosthetic hand system is shown in Figure 2 and Figure 3 respectively. The bionic prosthetic hand system was divided into four parts to achieve the project objectives. Each five fingers were individually driven by a TowerPro MG995 servo motor. The five servo motors would control each correspond finger using a string line. The string line was tied from the servo motor through the wrist, palm and end at phalanges. Consequently, the rotation degree of the servo motors would control the motion of the fingers to perform the required hand gesture.

The efficiency of the prosthetic hand relied upon the constant execution and real-time performance based on its framework design. In this project, the bending degree of each finger was used as the parameter to gauge the consistency and effectiveness in performing a hand gesture movement. Flexure sensor as shown in Figure 4, is also known as resistive bend sensor. It provides finger-joint flexion angle measurement domain that range from 0° to 100° [14]. It utilizes a carbon on a piece of plastic to act as a variable resistor with its ranges of value from 25k ohm to 125k ohm and its sizes range from 1 inch to 3 inches [15]. The flexure sensor was combined with a static resistor to build a voltage divider, that delivered a variable voltage that could be measured by analog to digital converter of the microcontroller. The 2.2" flexure sensor was set in a straight condition on each finger. At that point, the hand could perform the required hand gesture, while triggering the flexure sensor on the finger. As it bended, the resistance between the two terminals would increase with the degree of bending. The angle and resistance were measured repeatedly to characterize the consistency of each finger for each type of hand gestures.

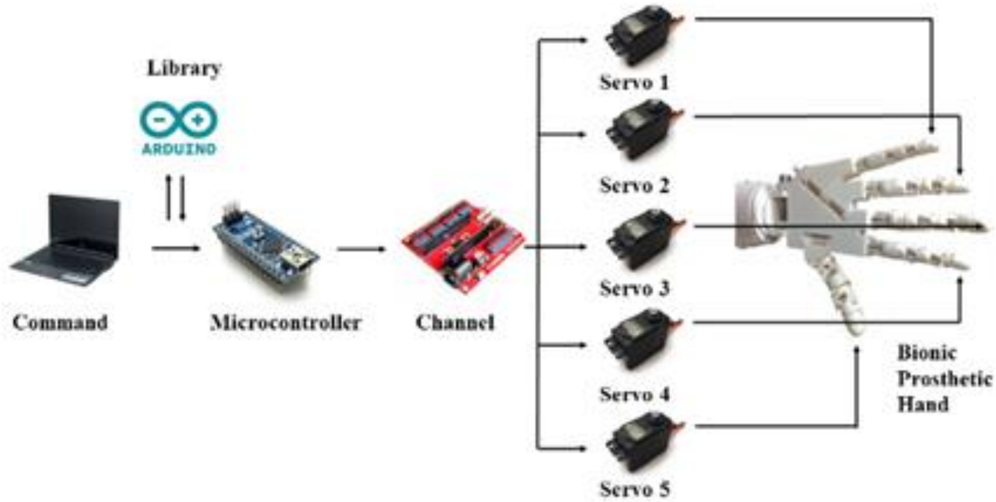


Figure 2. Block diagram of bionic prosthetic hand system

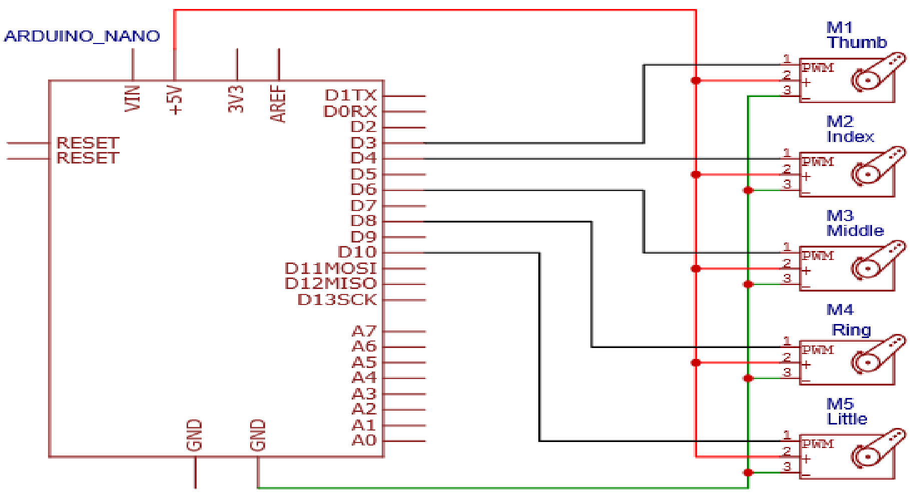


Figure 3. Circuit diagram of bionic prosthetic hand

Figure 4. Flexure sensor

3. Results and Discussion

The bionic prosthetic hand is printed based on human's right hand, consists of five fingers that can operate separately. The five fingers included the thumb, index, middle, ring and little fingers. The fingers had three phalanges which included distal, middle and proximal, that mimic the real human hand. Besides that, the distal, middle and palmar joints were allocated to the fingers as the separator between phalanges.

Figure 5. Bionic prosthetic hand.

The prototype of the bionic prosthetic hand gesture is shown in Figure 5. The prosthetic hand produced can accomplish ten types of hand gesture by controlling the motor rotation to a specific angle as shown in Figure 6. Comparing with other prosthetic hands found in the literature review, such as, anthropomorphic prosthetic hand and underactuated hand, which both of their thumb and index fingers have independent movement, while middle, ring and little fingers move at the same motion. This bionic prosthetic hand manages to control all the five fingers separately. The independent control of each finger of the bionic prosthetic hand allows more degree of freedom and smoothness to control the prosthetic hand to various types of human hand gesture.

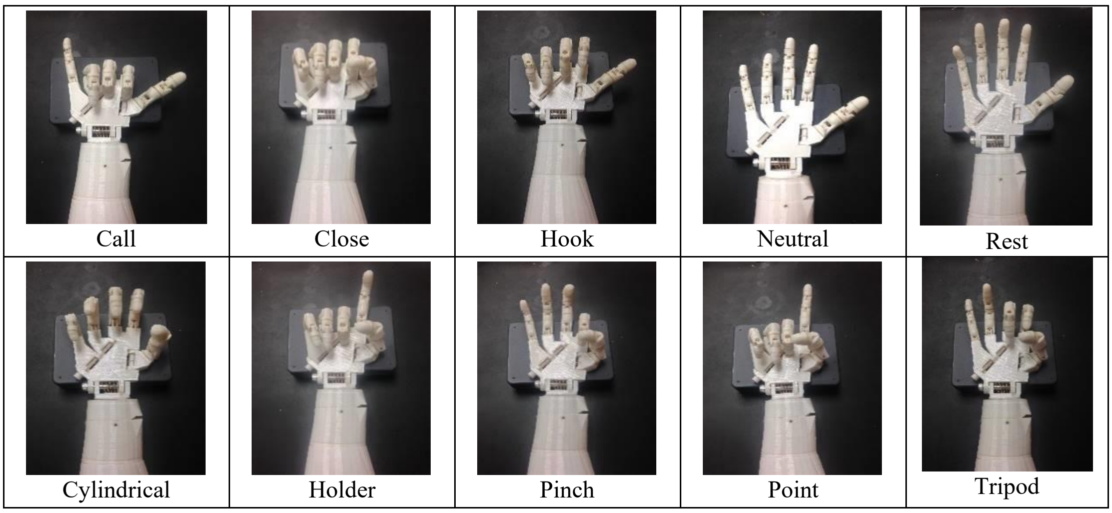


Figure 6. Bionic hand gesture control using TowerPro MG995 servo motor

From the result, the most difficult gesture to be performed by the prosthetic hand is the rest gesture. Contrast with other gestures, the angle rotation of the motor required is very small for this gesture. It is difficult for the servo motor to control the fingers to move to the required position accurately. Additionally, the stress of the fishing line that binds to the fingers and motors also contribute to the problem.

The cylindrical and close gestures are the most important gestures which mostly utilized among the ten gestures. Basically, the innovation of the bionic prosthetic hand is to perform the basic grasp tasks in daily living. Therefore, the cylindrical and close gestures can be classified as the basic dominant hand motion which is hand open and hand close.

3.1 Average level of bending of fingers

Figure 7 shows the average level of bending of each finger while performing the hand gesture. The level of bending was taken from the angle rotation that produced by the flexure sensors attached to each finger. From Figure 7, close gesture shows the highest level of bending for each finger compared to other gestures and its middle finger requires the highest level of bending, which is 28°. Meanwhile, the release gesture has the lowest level of bending where all the fingers have the same average level of bending, which is 1°. The level of the bending was influenced by the motor's angle rotation which is set in the programming. Therefore, the highest rotation angle of motor will result in highest level of bending of the flexure sensor.

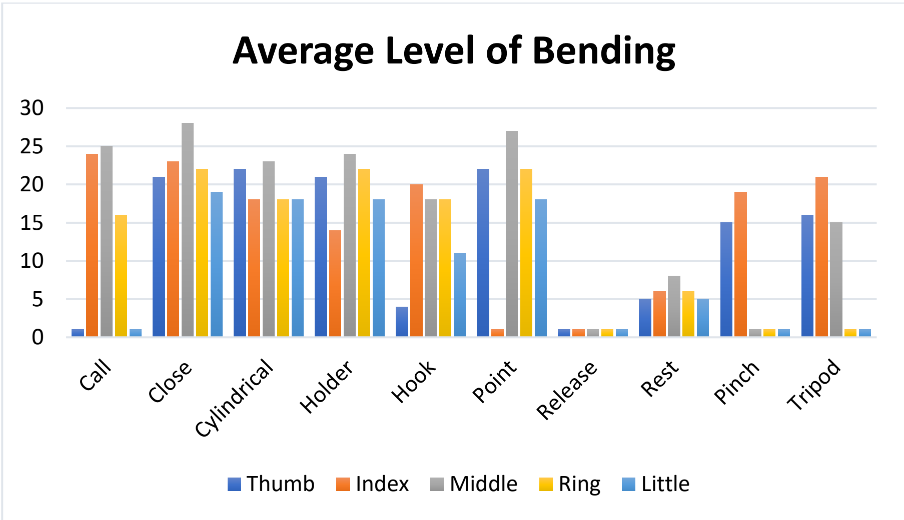


Figure 7. Average level of bending

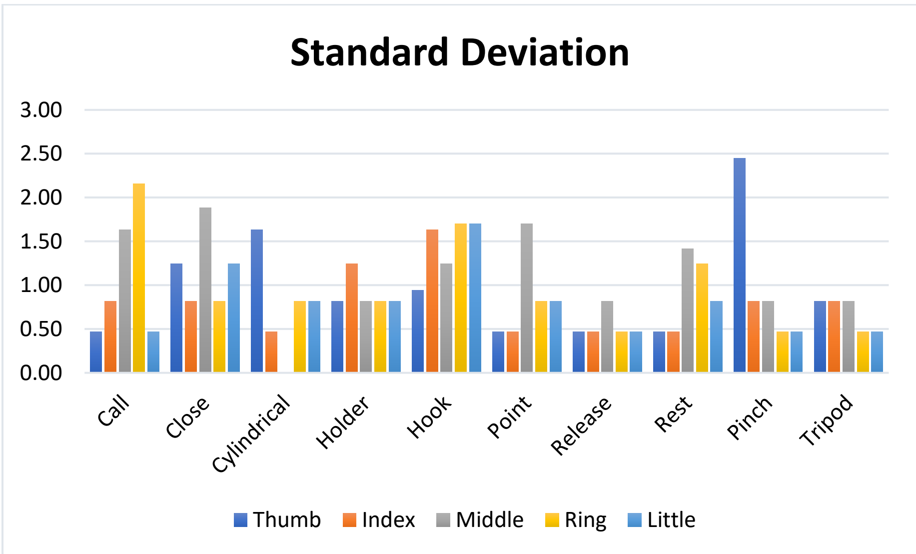


Figure 8. Standard deviation of bending level of finger for different hand gesture

The standard deviation is a measure that used to evaluate the amount of variety or scattering of a set of data values. A low standard deviation shows that the data points incline toward to the mean of the set, while high standard deviation indicates that the data points are spread out over a wider range of values. Therefore, the lower the standard deviation, the higher the efficiency of the system.

Figure 8 shows the standard deviation of the level of bending of each finger during performing the hand gestures. From the graph, the value of standard deviation for neutral/release gesture is low, reveals that this gesture performs with high efficiency. The highest standard deviation is the thumb on the pinch gesture, result in the lowest efficiency among the gestures. The location of the thumb on the side of the hand is one of the factors of difficulty to maintain a smooth movement. The binding of string line on the thumb is not straight from the servo motor proportional to the finger. Therefore, the smoothness of the string line to pull and release the finger is affected while performing the hand gesture movements.

4. Conclusion

In this project, it was demonstrated that it is conceivable to build up a prosthetic hand with moderately little exertion, minimal effort, and straightforward operation yet practical and with high productivity. The utilize of the 3D printing technology as an early advance to build up the assembling of prosthetic with minimal effort where everyone can print their own particular bionic prosthetic hand. As conclusions, the implementation of motorized bionic prosthetic hand project is successful. The mechanical design of the bionic prosthetic hand has met the design expectations. The bionic prosthetic hand can perform all the ten human basic hand gestures with high level of efficiency. The highlights of this bionic hand venture are that it mechanized structure framework that can control every one of the five fingers independently.

The experimental result shows that the level of bending depends on the angle rotation of the servo motor. With the high efficiency of this design, the operators can control the prosthetic hand to carry out more prehensile hand gestures. However, there are few factors that should be considered, for example, the types of components used, such as the string line and 3D printing materials, to develop a higher quality of bionic hand that is intended to be replacement of the lost limb for long term uses.

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