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Development of Robotics Arms for Rehabilitation Process

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Abstract-This paper presents a biomechatronics approach to the design and fabrication of an artificial robotic arm called robotic arms consisting of a shoulder, arm, elbow, forearm, wrist and hand. Detail 3D designs of the AHG are described including an elbow powered by a car's power window motor, DC motor powered wrist and a string actuated AHG with 5 artificial fingers which acts as slave controlled by a Smart Glove (master). Moreover, the Smart Glove is attached with force sensitive resistor sensors give this device the capability to evaluate the strength of the patient's hand grasp. The data from the sensors are sent to an Arduino microcontroller for data processing and then transmitted to PC via HyperTerminal software for data analyses. The proposed design provides a novel tool towards upper limb amputee rehabilitation process. The AHG incorporates a master-slave system which proven suitable for Mirror Visual Feedback (MVF) therapy experimented on subject towards the completion of this research. Although there are many hand prostheses which are commercially available, however, due to the disadvantages such as weight, high-cost and complex mechanisms, this paper proposed new ideas on solving these problems by designing an artificial arm which gives good cosmetic appearance, functional, low-cost and users friendly

Keywords: Rehabilitation, monitoring, testing of upper and lower arms.

1.0 INTRODUCTION

The purpose of designing an artificial hand or robotic hand is to replicate or imitate sensory-motor capabilities of the human hand [1]. Robotic technology is actively being introduced in the development of new methods and devices which contributes in assisting human limbs rehabilitation processes. At present, due to the advancement of robotic technologies, it has changed the method of utilizing grippers with only two rigid fingers, and no phalanges, to the development of human-like hands with at least three to five functional fingers, each with two to three phalanges [2].

A master-slave robotic system is a popular tool in application related to rehabilitation and remote handling operation [3]. This system enables the personnel to maintain safe working distance from hazardous work environments [4-5]. Moreover, in the field of healthcare such as tele-surgery and rehabilitation, remote handling tools involving the usage of robotic hands are also employed to improve human limb function. There are many types of five fingers robotic hand has been developed. The robotic hand, involving innovative mechanisms or Myo-electric control systems are an example of the advanced types. R.Vinet et. al. develop a five finger adult sized anthropomorphic hand called the Montreal hand with passive adaptive capabilities by means of a clutch, a cable system, and a spring-loaded pulley mechanism [5]. Doshi et. al., developed a multiple motor and sensory feedback robotic hand ,which can grasp objects [6]. From both cases, the robotic hand gave a more human-like finger function. But there are many setbacks mainly due to oversize, overweight and costly. It is proven that imitation is an element which is important in proper improvement of social and communicative skills[7-8]. Mirror Visual Feedback (MVF) therapy or mirror therapy is an imitation method introduced back in early 1990s, which is based on mirror illusion to help patient's limb practice due to cerebral vascular accident (CVA) injuries, post-stroke or amputated. When human limbs such as leg or arm is amputated, the patients may still feel the presence of

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the limb and in some cases the patients still feel the pain such as burning, cramping, crushing or lancinating[1-7]. Ramachandran et al. utilizes a 2x2 foot mirror in a MVF therapy. The patient places his paralyzed left hand on the back of the mirror and the healthy, normal hand on its right . When the patient looks the reflection of the normal hand in the mirror, he was surprised to see the phantom hand moved and can follow his command although it was the normal hand's reflection. The patient also noted that the pain due to the phantom hand instantly reduced and felt good. Several other research regarding these findings has been done, including the usage of virtual reality technology gave encouraging results in partially effectively reducing pain due to phantom hand (Ramachandran V.S, 2000) . But few researches have been done in incorporating robotic hand technology in MVF therapy. The development of a master-slave robotic hand rehabilitation device that has 5 finger functions by means of a cable system through computer controlled servo motors. The light-weight servo motor mechanism will be controlled by a glove worn by the user's normal hand. Once the glove is worn, the robotic hand will be substituting the phantom hand as in MVF therapy process. In this thesis, the concepts of the hardware and software design of the robotic hand are presented.

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2.0 Method

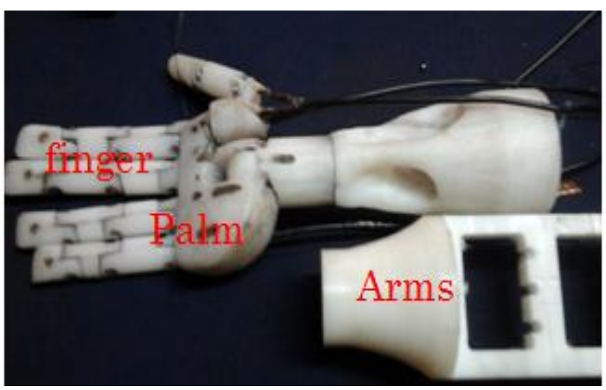

Figure 1: White polymer

The robotic arms made of Polymer is frequently employed to cover artificial hand mechanisms to give them kinematic and degree of freedom (DOF). These materials served to increase the passive adaptability of an artificial hand to the shape of a grasped object and to increase the coefficient of friction of the hand. This material is also to increase the force and grasping function is a restricted range of motion and hindered performance (speed/force output) of the hand. Limb replacements should be anthropomorphic in general shape, outline, and size. Each actuator module is a self-contained drive unit with a built-in motor, controller, amplifier, and communication interface.

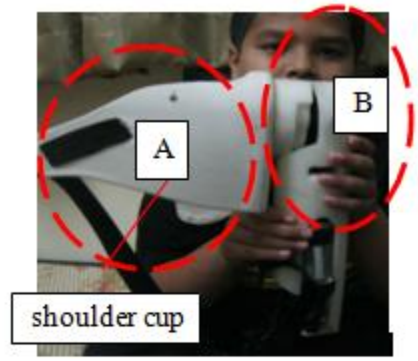

Figure 2: Shoulder cup attach at upper arms.

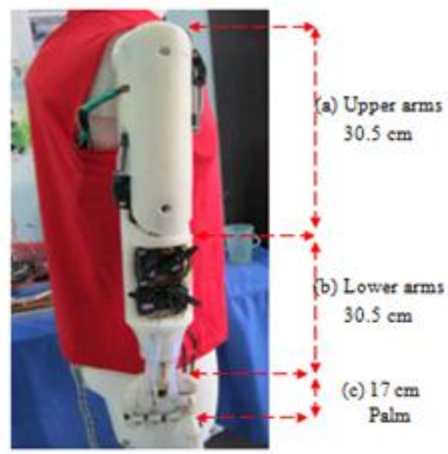

Figure 3: Design and position of robotic arms.

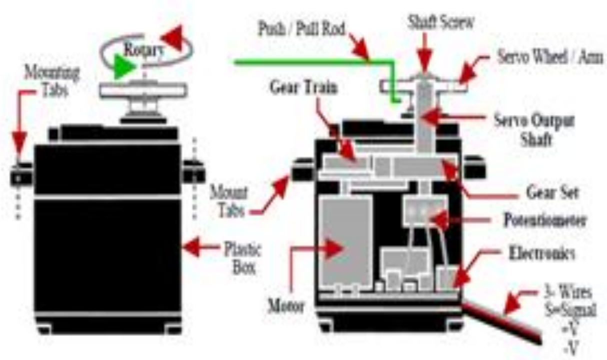

Figure 4: The servo motor actuation system

The parameter of the shoulder cup shown in Figure 2 is 20cm x10cm x 30cm and made up of 2 plate of steel connecting Part A with Part B. Part A is shown in

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Figure 2. Technically, the structure of the shoulder does not in contact with the motor located in Part B. The movement and angle of the shoulder is limited from 0 degrees to 90 degrees only as shown in Figure 6. A stopper mechanism is designed to limit the movement for only up to 90 ° according to rotation. In the experiments, the friction created during the movement of the motor was detected, and this problem solved by lubricating the surface involved.

3. Hardware system

Figure 5: The process of robotic arms to perform exercise

The elbow flexes on a common axis that can be considered to run through the centre of the Artificial Bicep and the centre of Artificial Elbow .Therefore, an analogy was considered by placing all the proximal articulations on a common flexion and extension axle. It was understood that if the spherical bearing was connected to an arms, it would require a small range of spherical articulation to permit flexion and extension movements. Table 1 shows the measurement of AHG and graph 6(a and b) shows the voltage specification of each motors and its location within the artificial arm.For shoulder joints available are also passive, manually positioned units that use friction or a lock to hold their position.

In this project, the gear system design is vital to control the mimic of robotic arms as shown in Figure 3, a total of three revolute joints are used, connected at each joint or Degree of freedom DOF,. Each phalanx consists of one internal gear and external gear. The fixed axis (with a stopper) of rotation in each phalanx are called the internal gear and each rotational axis is called the external gear. The power window motor is fitted at the elbow and shoulder shown in Figure 2. One of the most critical components of these devices is the motor shaft. Twelve motor shaft teeth are individually sized at a microscopic 13/16-inch and positioned at the center of the shaft plate. The total measurement in length of the motor shaft is 0.555-inches. Shaft plates include three minor bolt holes to keep the plate attached to the motor body with Bolt holes are each 0.258-inches in diameter. The next process of this project is to establish a robotic in mechanical structure. For every mechanical structure that runs on electrical drives normally uses motors as their actuators. In most robotic projects, researchers will look into type of motors which are DC Motors, Power window Motors (Figure 3 and 4) and Servo Motors.

Table 1: Measurement of Artificial robotics arms

Part	Measurement (cm)	Material /kg
Shoulder (Upper Arms)	23cm/19cm	PVC
Bicep (Upper Arms)	30.5 cm	2.5 Polymer
Lower Arms	30.5 cm	2.5 Polymer
Palm to arrow finger	17cm	2 Polymer

4. RESULT AND DISCUSSION

In this experiment the movement of the each human finger and wrist area is record and analyzed by the processor in degree. Than the output from the flex sensor will be amplifier by the Arduino Microcontroller. The graph of the experiment is shown in Figure 6. Figure 7 ilustrated angular corresponding between degree of bending and voltage measured at

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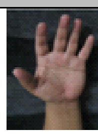
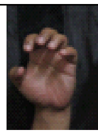
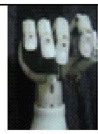
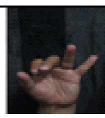
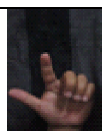
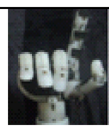
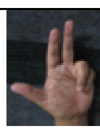
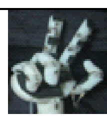
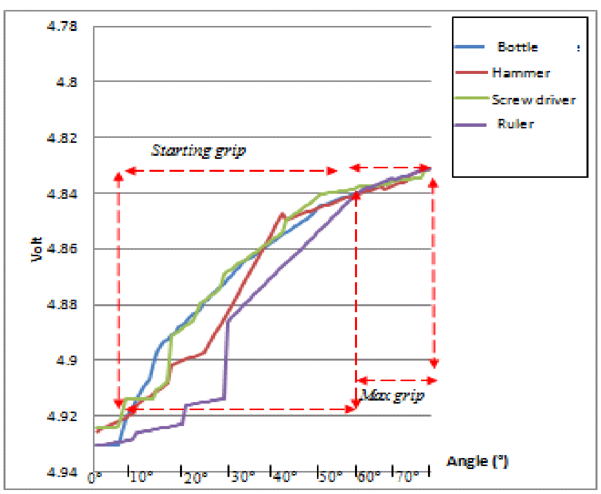
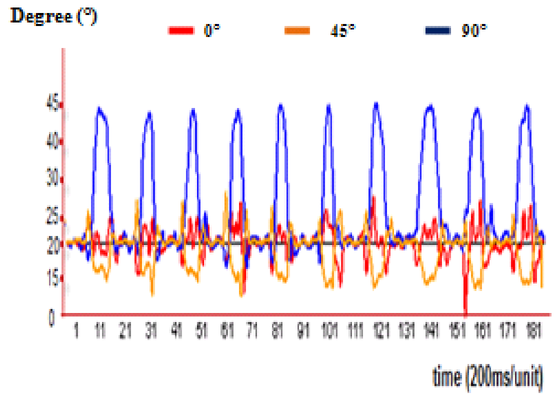
AN pin of ARDUINO (UNO). Data taken are divided into five segments that each of data gives static value especially value of degree vs resistance .

Table.2: Measurement of Artificial hand gripper

Movement	Sample movement	Artificial hand gripper(AHG)	Remark
Opened hand (initial position).			High similarity
Closed hand.			High similarity
Three finger Thumb/arrow /middle.			Moderate
Three finger Pinky/ring/ Middle.			Moderate
Two finger Pinky/ring.			Low similarity



(a) Upper arms analysis – Resistance vs Angle.



(b) Lower arms analysis - Resistance vs angle

Figure 6: The movement of the upper and lower arms for artificial hand gripper (AHG)

Figure 6(b), shows the result of degree vs. time(s) output from flexi force sensor attached to Bicep and Shoulder. The result displays ten peaks which is the position where the strength of the artificial hand gripper is at the maximum use. It is concluded that the effect of the loads against flexi force's voltage output, where the lowest voltage output recorded when the flexi force is in the 0°, 45° and 90° state. From this signal, it shows that the flex sensor records the artificial hand gripper kinematics in different angle in time(s).

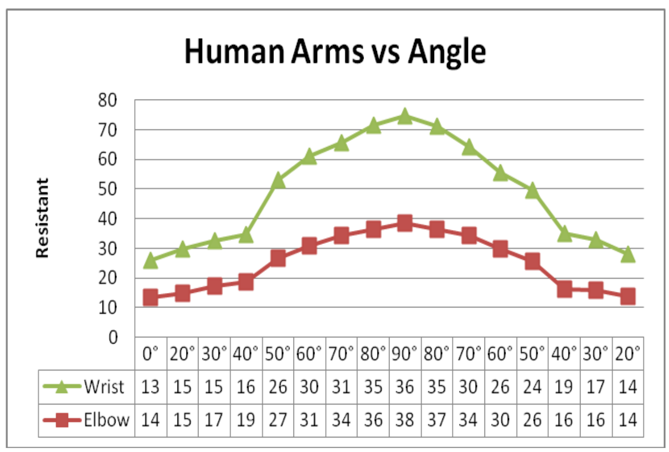


Figure 7: The movement of Artificial hand during (a) standing (b) sitting.

5.0 CONCLUSION

The artificial hand gripper design was improved its durability by housing the cable string system for the finger movement. It was experience that the string system was unable to withstand any load over 5kg due to the excessive frictions. The experiment result with string housing obviously enhancing the artificial hand gripper performance without breaking any of the string at 10kg. This improves the conventional systems that rely on the grease and the lubricant that cause discomfort to the patients. The developed artificial hand gripper had been clinically tested and proven to be efficient, it was not only restore a real hand but improves a human hand functionality under aspects of precise, firm and agile. A best accomplishment in artificial hand gripper system was achieved with availability of the gear system that prevents injuries to the amputee when the motor is over travelling. The gear system was retrofitted at the shoulder and elbow to limit the movement at 90°. This promoting extra capability of the artificial hand gripper system for lifting and hauling any of the heavy loads with the gear and motorized functions located at shoulder, elbow and fingers.

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