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An Empirical Framework for Controlling Artificial Hand Gripper System using Smart Glove

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Abstract- A human hand is a very complex grasping architecture which can handle objects of different sizes and shapes. When such important feature is lost, the replacement artificial hand should capable to imitate the real hand capability, hence ensuring user comfort. This paper proposes a system to control multi finger grippers with emphasis on the finger tips and finger joints. It consists of two modules namely smart glove in master module and hand gripper in slave module. The former responsible to infer user control command while the latter controlling the robot arm movement according to the user instruction. In master module, the system comprises combination of flex sensors and force sensor mounted under the glove to determine fingers bending angle and the force value. Such information is useful to control the artificial gripper for grasping objects in various shapes with right amount of force. In the slave module, the robot arm consist combination of power window motor and servos to initiate the arm and finger movement. Experimental results have shown the feasibility of the proposed system for controlling the artificial gripper and arm precisely according to the user command.

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Keywords: Biomechatronic, Rehabilitation, Artificial arms.

Nomenclature

AHG	Artificial hand gripper
DOF	Degree of freedom

1. Introduction.

In science, the gripper can be defined as subsystems of handling mechanisms which provide temporary contact with the object to be grasped. It ensures the position and orientation when carrying and joining the object to the handling equipment. Prehension is achieved by force producing and form matching elements. The term gripper is also used in cases where no actual grasping, but rather holding of the object as in vacuum suction where the retention force can act on a point, line or surface [1]. One of an application of gripper is in prosthetic hand development. Such a system has been extensively tested at the Orthopedic University Hospital in Heidelberg Grip which capable to operate almost like a natural hand. The hand can hold a credit card, use a keyboard with the index finger, and lift a bag weighing up to 20 kg. It is known as the world first commercially available prosthetic hand that can move each finger separately and has an outstanding range of grip configurations. Another example of prosthetic hand is the “i-LIMB Hand” [2]. The hand is controlled by a unique, highly intuitive control system that uses a traditional two input “Myoelectric” (muscle signal) to open and close the hand. One

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unique capability of the system is that, each individual powered finger can be quickly removed by simply removing one screw.

The purpose of designing an artificial hand or robotic hand is to replicate or imitate sensory-motor capabilities of human hand [4]. 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 have changed the method from 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 [5] . A master-slave robotic system is a popular tool in application related to rehabilitation and remote handling operation [6]. This system enables the personnel to maintain safe working distance from hazardous work environment [7]. Moreover, in the field of health-care such as tele-surgery and rehabilitation, remote handling tools involving the usage of robotic hands are also employed to improve human limbs function. There are many types of five fingers robotic hand which here been developed and most of them involve innovative mechanism or myo-electric control systems. As an example, a five finger adult sized anthropomorphic hand that is known as the Montreal hand with passive adaptive capabilities by means of a clutch, a cable system, and a spring-loaded pulley mechanism was developed [8].

Rajiv and Doshi (1992) had developed a multiple motors and sensory feedback robotic hand which can grasp object. From both cases, the robotic hand gave a more human-like finger function. But there are many setbacks mainly due to oversize, overweight and it is costly. It is proven that the imitation is an element which is important in proper improvement of social and communicative skills [9]. 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 the limb and in some cases the patients still feel the pain such as burning, cramping or crushing [9]. Several research were conducted that based on these findings and continued with the use of virtual reality technology. The outcome was encouraging and proven partially effective for reducing pain due to the phantom hand [10]. Other researchers also had applied different approach by incorporating robotic hand technology in MVF therapy. A master-slave robotic hand rehabilitation device was developed which incorporates five fingers functions that are supported with a cable system via a computer controlled servo motors. The light-weight servo motors mechanism was controlled with a user glove that worn by the normal hand. Once the glove is worn, the robotic hand will be substitute the phantom hand through MVF therapy process. In this paper, the concepts of the robotic hand development that cater to the hardware and software design are presented.

2. Methodology

2.1 Smart Glove and Artificial Hand Gripper (AHG) System.

The development of this project involves the designing of a sensors equipped in Smart Glove and an Artificial Hand Gripper (AHG) as shown in Fig. 1. The AHG will move based on a human operator's finger movement that issued using the Smart Glove. The proposed smart glove is based on the integration of several sensors: flex sensors and flexi force while the hand gripper system is constructed using combination of power window motor and servo motors. In the following section detail explanation about each part will be given.

Fig.1: Overall setup of Artificial Hand Gripper

2.2 Flex Sensors.

Flex sensors were attached on the back of the Smart Glove as shown on Fig. 2 to detect human operator finger bending activity. The Smart Glove incorporates a sensory system which can detect finger flexion hence, the name Smart Glove was given to this hand glove. The sensor is connected to an Arduino microcontroller for analog signal detection. To read the sensor, its variable resistance is converted to a variable voltage and amplified with an operational amplifier. Then, the analog signal is transmitted to the 10 bits A/D converter in the microcontroller for controlling servo motors according to the hand gripper's fingers. Each of the hand gripper's finger will move similarly to the flexion of flex sensor attached on the Smart Glove.

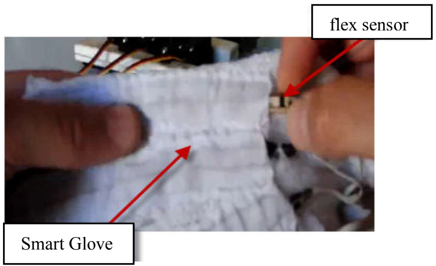


Fig. 2: Flex sensor attached at the Smart Glove.

2.3 Flexi Force sensor.

In this paper, Flexi-force sensors were attached on each of the gripper's fingertips as shown on Fig. 3. Flexi-force sensor is suitable to measure pressure force between body and external surfaces. By attaching the sensor to gripper's fingertips, the analysis of force distribution applied on the fingertips can be done. However, preliminary experiments on Flexi-force sensor need to be carried out to determine the suitability of the sensor on detecting small forces. There are studies shows that force sensitive sensors can be used to detect and measures small amount of forces including individual muscles [11][12].

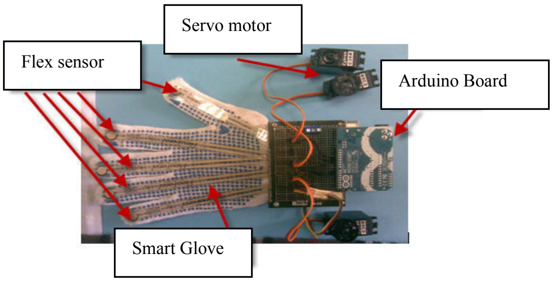


Fig. 3: Flex Force Sensor attached on the Smart Glove.

2.4 Hand Gripper System.

The AHG made of Polymer, is frequently employed to cover artificial hand mechanisms to give them kinematic and 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. Based on Fig. 4, it shows the elbow flexes on a common axes that can be considered to run through the centre of the Artificial Bicep and Elbow. Therefore, an analogy is considered by placing all the proximal articulations on a common flexion and extension. It was understood that if the spherical bearing was connected to an arm, it would require a small range of spherical articulation to permit flexion and extension movements. Table 1 shows the measurement of the finger and also the voltage specification of each motor which is located within the artificial arm.

Table 1: Measurement of AHG.

Part	Measurement (cm)	Material/kg
Shoulder (Upper Arms)	23/19	PVC
Bicep (Upper Arms)	30.5	3kg /Polymer
Lower Arms	30.5	3kg /Polymer
Palm to arrow finger	17	1kg /Polymer

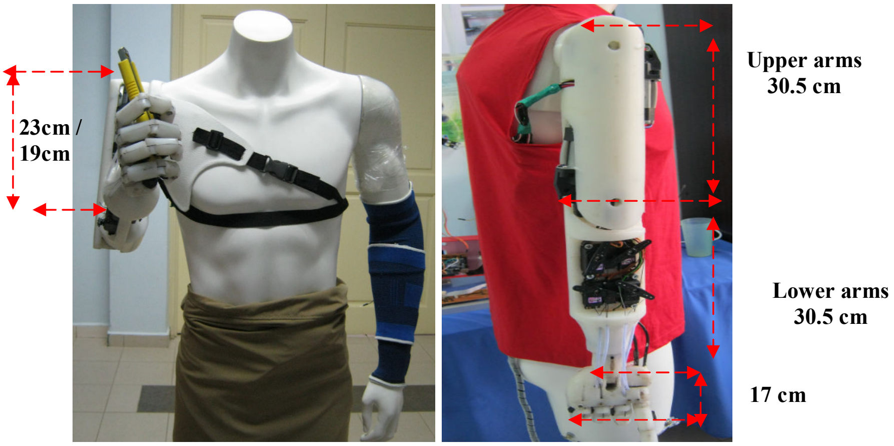
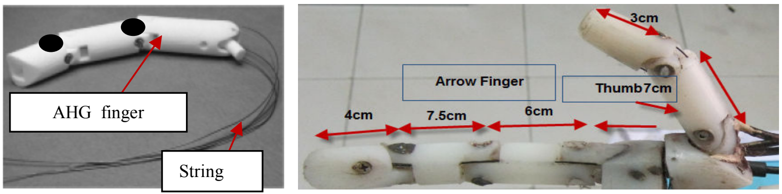


Fig. 4: Overall setup of each Phalanx and joint

2.5 The characteristic of String System

Fig. 5(a) shows a cut away view of the channels within the finger for routing of the cables used for actuation. These pathways, 0.254 cm in diameter, were designed to guide the cables through the finger links so as to decrease the stress on the cables while maintaining the required tension. One channel through the middle link appears in a diagonal pattern, as seen from this side view, for the above-mentioned purpose. In addition, the cables intended for flexion and extension of the distal link travel over top of the revolute joint between the middle and proximal links. The channels through the proximal link fan out around the ball and socket (which could be seen from a dorsal view). Two cable pathways, one for flexion and one for extension of the modified spherical joint, run through the socket on the "Palmar" and "Dorsal" sides to allow 90° rotation during actuation. Currently, abduction and adduction movement at the finger spherical joint is passive. This is due to the modified spherical joints natural side to side motion when the cables from the proximal joint are pulled. Fig. 5(b) shows the AHG fabricated finger with the tendons (cables) attached in a post-fabrication phase. As in the previous AHG constructions, the joints fully reach the designed range of motion.



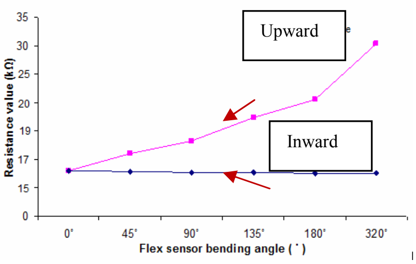
(a) (b)

Fig. 5: (a) AHG finger built with polymer material, (b) AHG finger actuated with string wires and the measurement sizes.

3. Result and Discussion.

3.1 Flex sensor

The characteristic of flex sensor has been recorded, the flex sensor is a resistance-varying strip that increases its total electrical resistance when the strip is flexed in one direction (in the other direction the resistance does not vary significantly) shown in Graph 1. This angle is measured between the two tangent lines at the ends of the flex sensor's body. The flex sensor has a typical electrical resistance variation when flexed or bent. From the experiment, resistance value against the flex sensor bending angle can be plotted as shown on Fig. 6. The experiment shows that when flex sensor is bend inward, resistance value increased significantly as the angle of flex sensor is bend further. However, when it is bent outward, the resistance value decreased gradually. These findings suggest that flex sensor is clearly suitable to detect finger bending angle by utilizing inward bend of the flex sensor.



Graph 1: Inward and upward bending measurements.

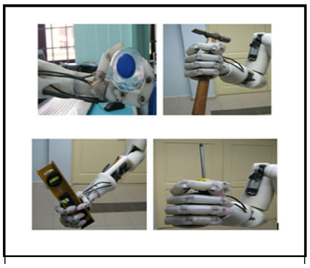
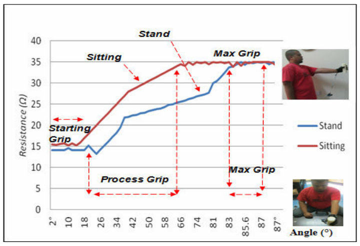
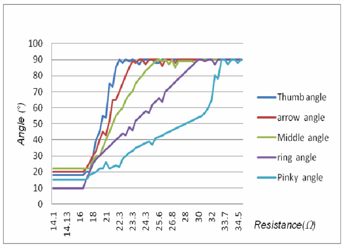


Fig. 6: AHG testing and experiment on subject.

Graph 2 and 3 shows the results of experiment done on the flex sensor. We applied bending on the flexi sensor active surface 5 times, and the graph shows 5 peaks which suggest that the sensor can be used to detect bend when the glove bending 90°, 60° and 30° . By attaching this sensor to the gripper fingertips, the flex sensor will act as a detector which sends data to the microcontroller to inform about the gripper is grasping an object. We expected to be able to control the amount of deferent object generated on the grasped object based on the resistant value generated from the flex sensors.



Graph 2: Resistance vs. Angle (°)



Graph 3: Finger and Thumb with Angle (°) vs. Resistance.

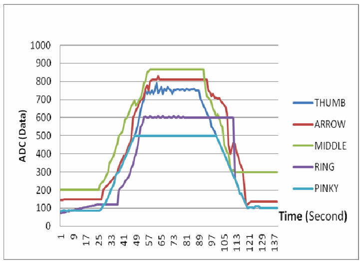
3.2 Flexi-force Sensor

Fig. 7 shows the setup of an experiment to determine the characteristics of a flexi-force sensor. We attached the flexi-force sensor to the Smart Glove. By pressing the active round surface of the flexi-force sensor, we recorded the analog raw data. We mapped the analog data (0~1023) received from the sensors to voltage value (0~5 volt). A simple experiment was carried out to monitor the characteristic of flexi-force sensor by pressing the active surface 5 times.

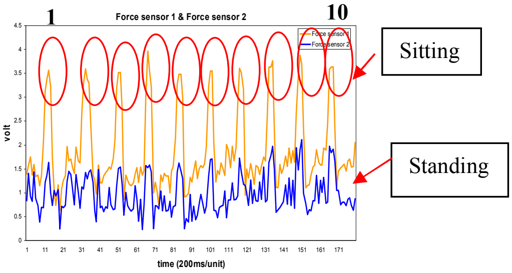
(a) (b)

Fig. 7: Grasping and lifting activity, (a) Side View, (b) Top View.

Graph 4 and 5 shows the results of experiment performed on the flexi-force sensor. We applied force on the flexi-force sensor active surface 10 times, and the graph 3 shows 10 peaks which suggest that the sensor can be used to detect force when pressure applied to Polymer. By attaching this sensor to the gripper fingertips, the force sensor will act as a detector which sends data to the microcontroller to inform about the gripper is grasping an object [12][13][14]. We expected to be able to control the amount of force generated on the grasped object based on the voltage value generated from the flexi-force sensors.



Graph 4: Each finger bending activity.



Graph 5: The flex-force measurement of 10 repetition for sitting and standing positions.

The movement of the arms is controlled by the gearing system inside the power window housing [9]. The ability of this movement depends on the DOF of each connection. Each movement starts from 0 degree until 90 degree DOF. Fig. 9 shows the 3D design of the actual artificial arm and the limit of movement of the artificial arm. Fig. 8 (a) shows the movement of the hand from 0° to 90 °. Fig. 8 (b) shows the movement of the shoulder from 0 to 45 degrees and wrist movement from 0° to 45 °. Fig. 8 (c) shows the normal position of the artificial arm.

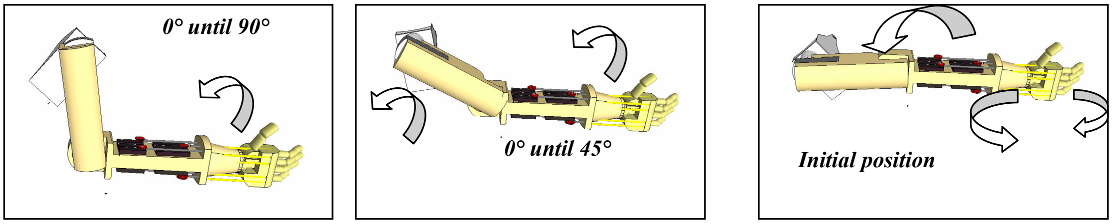


Fig. 8: The movement of AHG from 0° until 90°

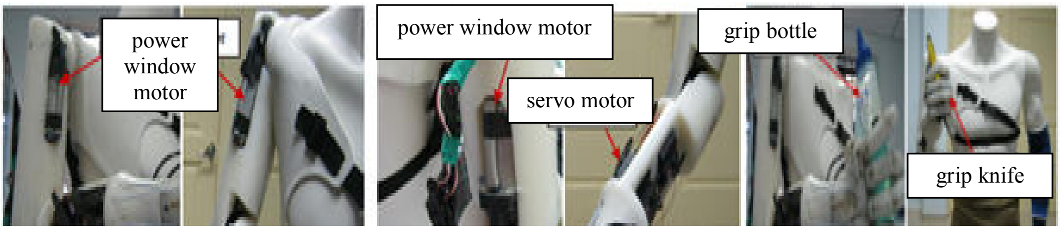


Fig. 9: Final and complete design of AHG

Although the weight of the arm is quite heavy (3-Kg), the motor which is powered with 9V of power supply and the side gears in the motor casing permit the arm to move to a maximum of 90 degree position as shown in Fig. 8 (a). Fig. 9 shows the final design of the artificial arm. The artificial arm was developed specifically for the right arm [10][11][13][14][15]. While a Smart Glove which controls all the servo motors inside the artificial arm are worn on the left of the subject's hand, refer Fig. 9 (a) and Fig. 9 (b). The main aim of these experiment is to verify the movement of the artificial arm to move according to the movement of the left arm and also to measure the angle between the wrist and shoulder when the subject move the left arm from 0 to 90 degree [16][17]. The artificial arm is equipped with two belts in order to prevent it from slipping as shown in Fig. 9 (c).

4. Conclusion

The different kinematic structure of human and robot hand requires the implementation of appropriate force and position. The evaluation in first real hardware experiment showed a good and promising performance of the position mapping as a variety of different grasp types ranging from precision to power grasps can be performed. The design approach based on cable mechanism hand gripper in a novel artificial arm has been proposed and applied to the Artificial Hand Gripper (AHG) field with the aims of improving the artificial hand flexibility, maintaining the intrinsic actuation solution and implementing simple control algorithm. The proposed dynamic model can provide a useful tool for simulating the expected grasping capabilities. Suitable control strategies will be investigated further in order to develop a user friendly design which will be ideal and useful to assist the handicap patient.

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