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Development of Artificial Hand Gripper by using Microcontroller

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Abstract : This paper focuses on the development of a measurement hand gripper to help handicap patient due to accident and diseases. Basically, when the patient needed to perform exercises they must get an appointment with a doctor. Normally this will take few weeks or months. This is because the rehabilitation devices at Physiotherapy Department in hospital are very limited. From this problem, we suggest to develop a reasonably cheap home-based rehabilitation measurement devices which can perform the task of assisting paralyze patient at home. The basic movement of the patient was limited from a wrist, elbow and shoulder. The development of this project involves the designing of a sensors equipped Smart Glove and a measurement hand gripper device. The hand gripper device will move based on a human operator's finger movement using the Smart Glove. The purpose of our project is to design and develop a master-slave system robotic hand which can be a substitution for the paralyzed hand in therapy to aid in recovery process of patients upper limb function. The project involves an Arduino microcontroller for the instrumentation, communication and controlling applications. A series of flex sensors are fitted in a master glove to get readings from the movement of human fingers. Microcontroller will further use this information to control multiple servos that controls the movement of slave robotic hand.

Keywords: Artificial hand gripper, flex sensor, rehabilitation and medical robotics

1. Introduction

In science, the definition of “gripper” is subsystems of handling mechanisms which provide temporary contact with the object to be grasped. They ensure 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]. In another study, a new prosthetic hand is being tested at the Orthopedic University Hospital in Heidelberg Grip which functions almost like a natural hand. It can hold a credit card, use a keyboard with the index finger, and lift a bag weighing up to 20 kg. It's the world's first commercially available prosthetic hand that can move each finger separately and has an outstanding range of grip configurations. The “i-LIMB 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’s [2]. The construction of the artificial hand gripper which is each individual powered finger can be quickly removed by simply removing one screw.

Thus, the developed prosthetics can easily swap out fingers which require servicing and therefore patients can return to their everyday lives after a short visit to the clinic [3-4]. A three fingered, multi jointed robot gripper for experimental use is presented. The mechanics as well as the control architecture is designed for this special purpose. The gripper system provides the basic means in terms of position and force control to perform experiments about grasping and object motion in a useful way. The gripper can be used to develop and evaluate different approaches of stable grasping and object manipulation. Results of the control of the gripper on joint level, the Cartesian behavior of the fingers and some experiences with the grasping and manipulation experiments using the presented system are reported [5]. Touch Bionics is a leading developer of advanced upper-limb prosthetics (ULP). One of the two products now commercially available from this company, are the “i-LIMB Hand”, is a first to market prosthetic device with five individually powered digits [6-7]. This artificial limb looks and acts like a real human hand and represents a generational advance in bionics and patient care. This later concept will be followed as in this study for the development of a artificial hand gripper [8-10]. The aim of this research is to assist handicap individual in providing them with an enhanced version prosthetics that is economical and affordable.

2. Method

The development of this project involves the designing of a sensor equipped hand glove and a prosthesis multi-finger gripper. The prosthesis multi-finger gripper will move based on a subject finger movement using the hand glove. The proposed multi-finger gripper system will be based on

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**Corresponding author: abdulmalikmohdali@yahoo.co.uk* the integration of several sensors : flex sensors and flexi-force sensor.

2.1 Arduino microcontroller

This paper took a different approach by using an inexpensive and less hassle Arduino Romeo microcontroller rather than the usual PIC. To use PIC microcontroller, one have to decide types of board, circuitry, language, compiler for the language, hardware programmer and etc. Arduino provides a complete, flexible, easy-to-use hardware and software platform that is widely used by artists, designers and even hobbyists [12-13].

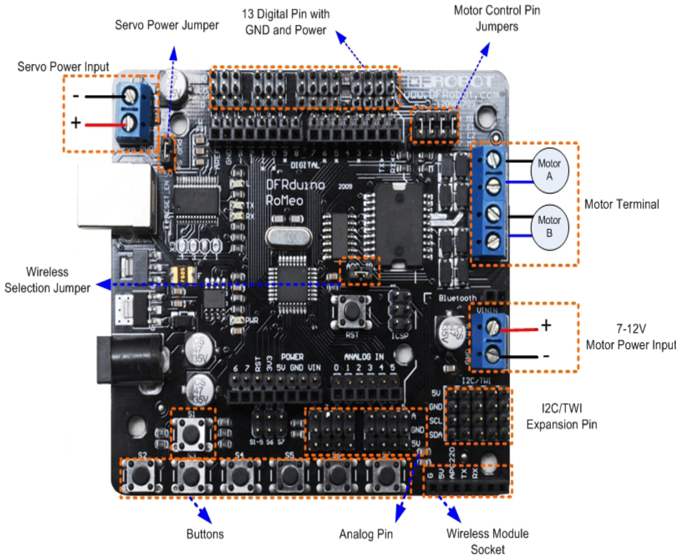


Fig. 1: The picture above shows all of the I/O lines and connectors on the Romeo microcontroller

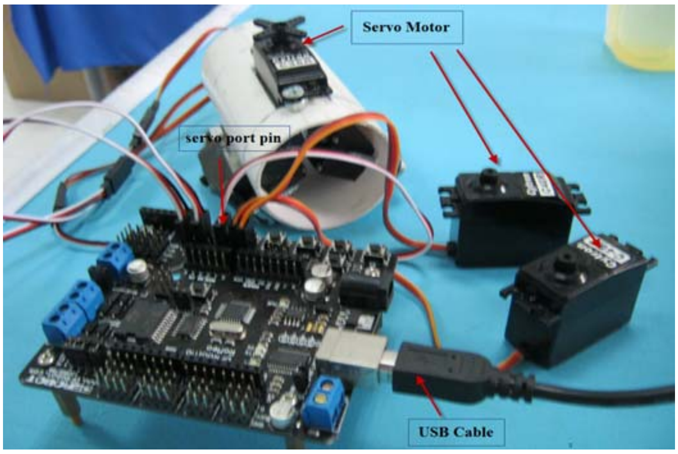
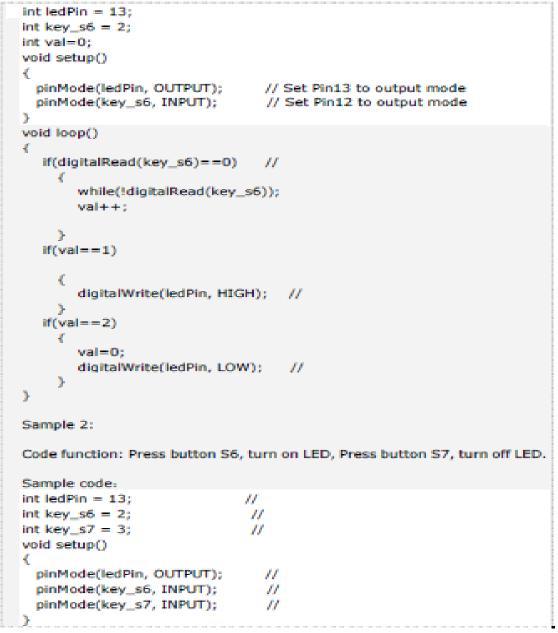


Fig. 2: The servo motors connection with microcontroller.

Arduino software is free open source which includes full development environment that can be easily downloaded from the internet. Arduino has one serial interface module header for AP22o /Bluetooth Module, 13 digital pin with GND and power, 7 buttons on /off for testing motor/sensor, one regulated motor power input terminal (6V to 12V), one unregulated servo power input terminal (4V to 7.2V), one servo input power selected jumper and one 12C/TWI port- SDA, SCL, 5V and GND.



```
int ledPin = 13;
int key_s6 = 2;
int val=0;
void setup()
{
  pinMode(ledPin, OUTPUT);        // Set Pin13 to output mode
  pinMode(key_s6, INPUT);         // Set Pin12 to output mode
}
void loop()
{
   if(digitalRead(key_s6)==0)     //
     {
        while(!digitalRead(key_s6));
        val++;

     }
   if(val==1)

     {
        digitalWrite(ledPin, HIGH);    //
     }
   if(val==2)
     {
        val=0;
        digitalWrite(ledPin, LOW);     //
     }
}

Sample 2:

Code function: Press button S6, turn on LED, Press button S7, turn off LED.

Sample code:
int ledPin = 13;                //
int key_s6 = 2;                 //
int key_s7 = 3;                 //
void setup()
{
  pinMode(ledPin, OUTPUT);       //
  pinMode(key_s6, INPUT);        //
  pinMode(key_s7, INPUT);        //
}
```

Fig. 3 Simple code for Arduino language which uses Arduino integrated development environment [12].

2.2 Software

Arduino is programmed in C/C++ language which uses Arduino IDE (Integrated Development Environment), which is a free software (shown on Fig. 3), that enables you to program the Arduino board. The IDE which is available for Windows OS and Linux systems enables the user to design a computer program, to be uploaded into Arduino. The Atmega chips inside the Arduino Romeo board will process the programs and interact with the world outside. In the Arduino world, programs are not called as source codes but known as sketches. There are extensive documentation of tutorials and manuals can be found in the internet which can be used to easily solve common problems [13].

2.3 Flex sensor

Flex sensors will be attached on the back of the Smart Glove as shown on Fig. 4. The hand glove incorporates a sensory system which can detect finger flexion. The sensors are 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 op-amp.

Then, the analog signal is transmitted to the A/D converter in the microcontroller side for data processing. Each of the multi-finger gripper's finger will move according to the flexion of flex sensor attached on the Smart Glove. Preliminary experiments were done to determine the characteristics of a flex sensor before being attached on the Smart Glove.

2.4. Flexi-force Sensor

A Smart Glove system is developed in order to effectively demonstrate the grasping of objects for a certain tasks. The process involving transmitting electrical signals from the smart glove (master) to Artificial hand Gripper (slave) is the most challenging task in the circuit design. The system is designed so that the robotic hand can reproduce the similar motion applied on the Smart Glove including keeping the robotic hand's finger angle, direction and speed as similar as the master's motion. The problem regarding time delay which is seldom occurs in master slave system will not be considered.

Arduino Romeo microcontroller has been used in this device to process and control signals generated from sensors. The Arduino microcontroller needs to be powered by constant 5V power supply via USB connection to a personal computer's COM port. Movement from master will provide raw data signals from each five of flex sensors to be processed in Arduino board. Arduino will process the raw data collected and provide the torque input for servo motors in slave robot hand.

Five Cytron C40R servo motors are used for slave control input with 50 Hz Pulse Width Modulated (PWM) signal. The plastic gear servos able to provide 180° rotation angle and maximum torque 6 Kg.cm. operated from a 5V power supply from Arduino.

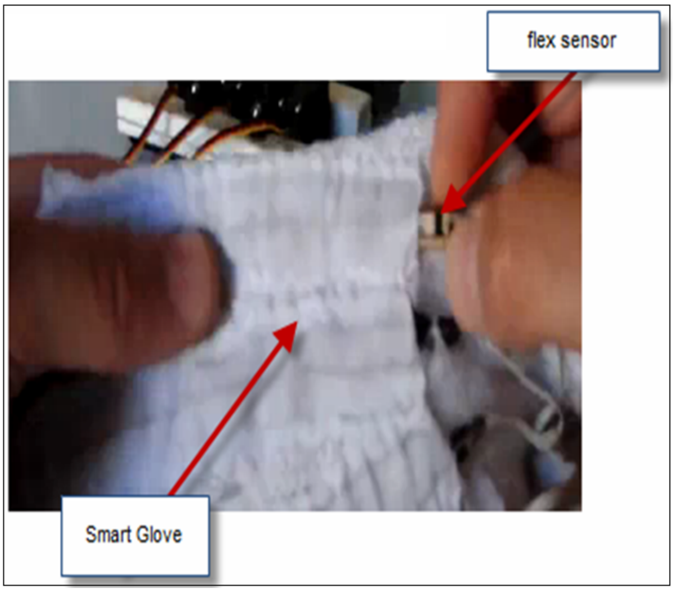


Fig. 4: The flex sensor attached on the back of the glove.

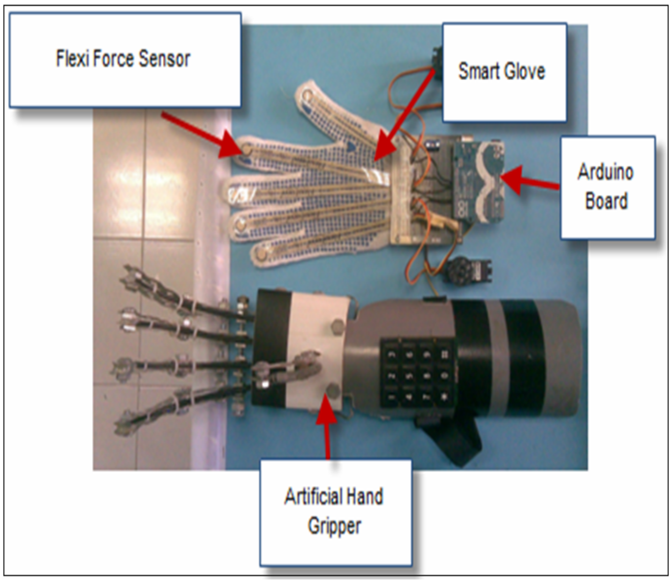


Fig. 5: Above figure shows an initial setup of the sensors on the Smart Glove.

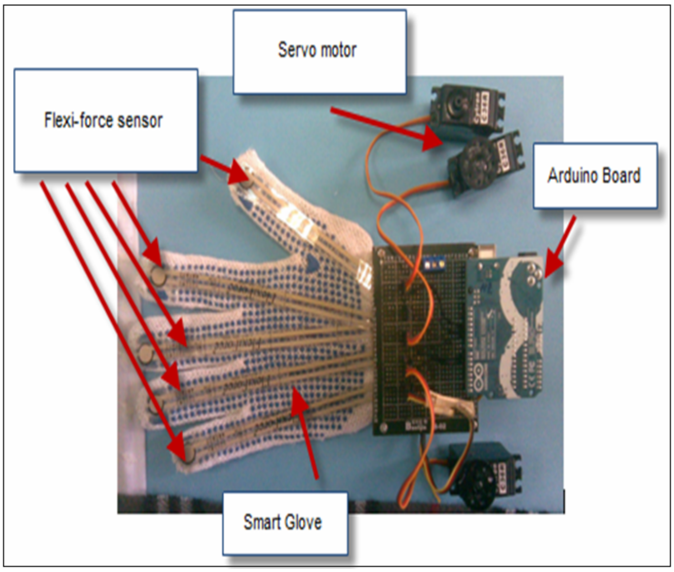


Fig. 6: Flexi-force sensor attached on Smart Glove.

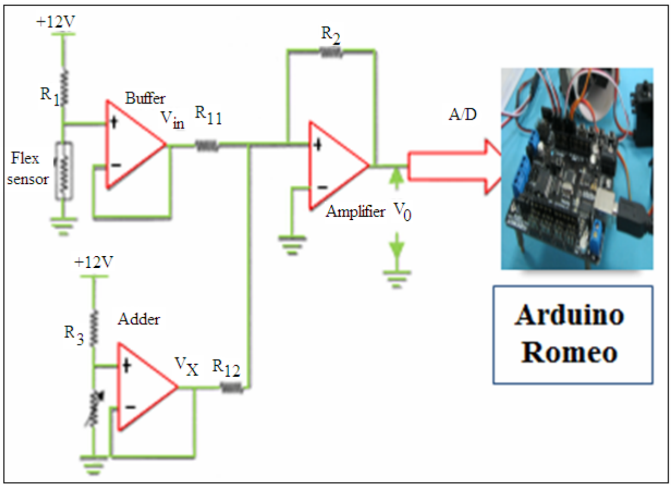


Fig. 7: Electronic circuit diagram of flex sensor [2].

2.5. Smart Glove sensors

The sensors that are selected to be attached to the glove are the flex sensors, made with the same principle as the Flexi-force sensor (changing their resistance on the bending occasion), but they have large resistance differences. They present 10-KΩ resistance on zero degrees bending, and 35-KΩ on 90 . This produces less noise when the signal is fed into the data acquisition system.

Cyanoacrilic glue is selected as the adhesive material, and the sensors are firmly attached to the rubber glove. Many materials are used for the glove, including leather, cotton, and plastic. The latex dipped cotton gloves proved to be ideal for this application, since the sensor is attached firmly and the glove can easily be removed without destroying the sensors [2].

The Smart Glove is shown in Fig. 6. The overall circuit diagram for the flex sensors are presented in Fig. 7.

The AD voltage is equal to ,

$$Vo = -\left[\frac{R_2}{R_{11}}V_{in} + \frac{R_2}{R_{12}}Vx\right]$$

Assuming $R_2 = R_{12}$,

$$V_0 = -\left[\frac{R_2}{R_{11}}V_{in} + V_x\right]$$

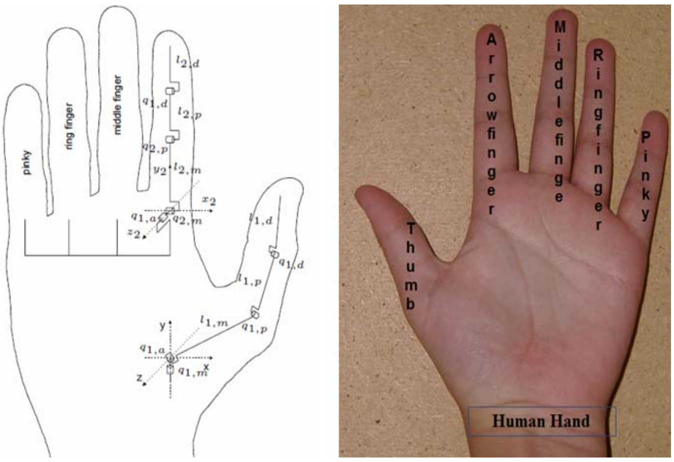
For example, if $R_{F\,min}$= 10KΩ , $R_{F\,max}$= 35 K , and at the equilibrium it has the value of R_{Fq} =10KΩ . The Vx is selected to be equal to the voltage presented to the flex sensor at the equilibrium: Vx= 4.21V. The resistance value for R_1 is chosen to be 24 KΩ and R_2 = R_{12} =10 KΩ . The voltage on the A/D has to vary from 0 to 5 V, since the reference is selected equal to the microcontroller's supply voltage. Following this, it is concluded that the quotient R_2/ R_{11} has to be equal to 1.25. This voltage is fed to the A/D of the Arduino microcontroller [2].

2.6. Method of Kinematic Model of the Hand

Recovering hand pose and finger posture is done through inverse perspective and inverse kinematics computations. One important prerequisite to these computations is the definition of a kinematic model of the hand. [3]

Our hand model is designed to remain simple enough for inverse kinematics computations to be done in real time, while still respecting human capabilities and span of motion. The hand is modeled by a 26-degree-of-freedom skeleton whose location is given by the wrist's middle point and whose orientation is given by that of the palm. The fingers are enumerated from I to V from the thumb to the little finger. Each finger has four degrees of freedom, namely one in abduction/adduction and three in flexion/extension.

Inspired from [10], the segments of articulation of each finger are concurrent at the wrist's middle point C, as show in Fig 8. The abduction angle characterizes the angle of the finger in the palm's plane, whereas the flexion angle corresponds to the folding of the finger in the plane perpendicular to the palm. Each finger but the thumb is assumed to be a planar manipulator [3].



(a) (b)

Fig. 8: (a) Kinematic model of the right human hand (b) Anatomy of the hand [3].

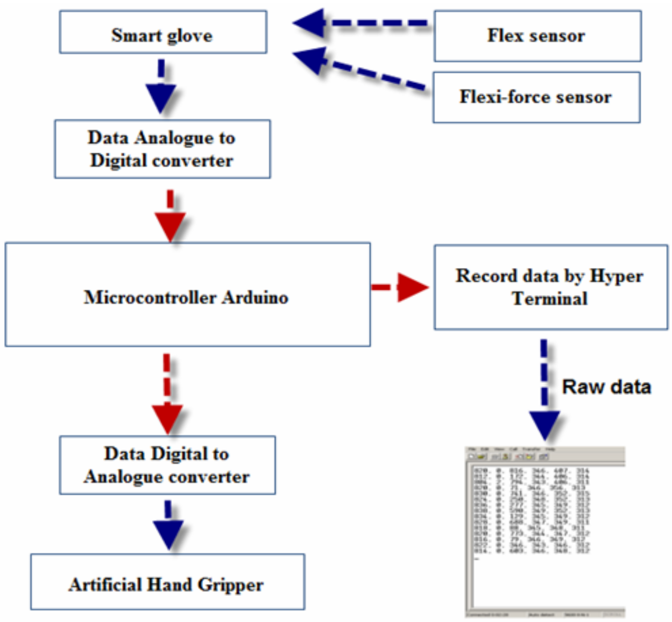


Fig. 9: Overall hardware setup for this project.

2.7. Sensing system

Fig. 9 shows the overall hardware setup diagram. First is the Smart Glove which performs as the sensor device. Second is the microcontroller as the brain function to record, control and measure the activity of the glove. And lastly is the artificial robotic hand gripper, which will follow commands from the microcontroller.

2.8. Experiments

2.8.1. Flex Sensor

In this first experiment, we focused on the flex sensor characteristics. Whereby, this sensor will be attached on the Smart Glove. By using a multi-meter, we simply verify the characteristics of flex sensor by monitoring the value of the resistance when the flex sensor is bent.

As shown on Fig. 11, the more the flex sensor is bent, the more resistive value will be displayed by the multi-meter.

Next, we determine the analog voltage value of the flex sensor at certain angles: 0˚, 45˚, 90˚. We proposed the use of these angles as indication for arm bending state to monitor arm bending movement progress. Furthermore, the flex sensors were connected to HyperTerminal software. This software are used to capture or logging the value of the bending on the glove. The result will be described later in this paper.

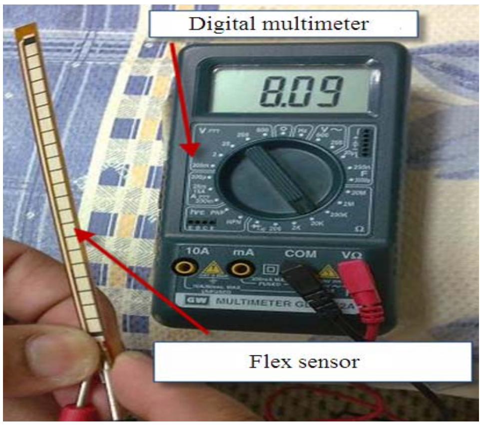


Fig. 10: By using a multi meter, the charactersitics of flex sensor were verified..

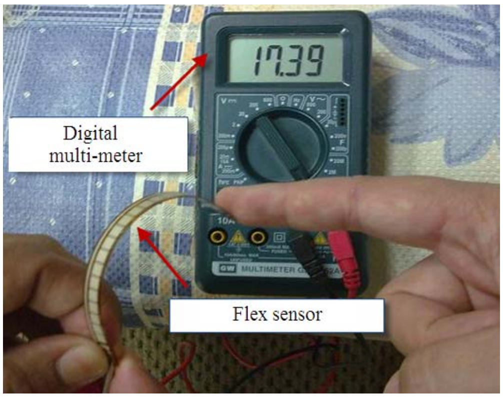


Fig. 11: Figure shows readings of resistivity when flex sensor was bent.

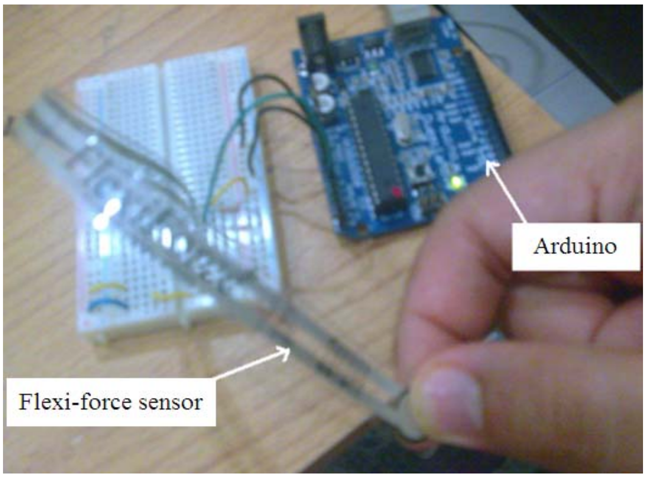


Fig. 12: Preliminary experiment to verify the characteristics of flexi-force sensor.

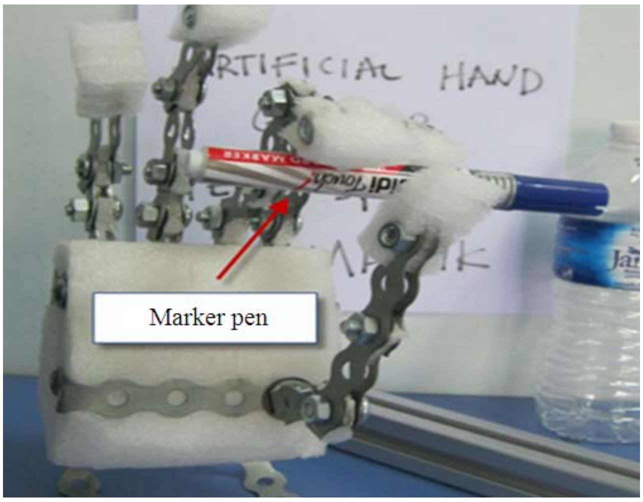


Fig. 13: An experiment done to show the artificial hand gripper gripping a marker pen using three fingers.

2.8.2. Flexi-force sensors

In this second experiment, flexi-force sensors are connected to Arduino microcontroller. Fig. 12 shows the preliminary setup of an experiment to determine the characteristic of a flexi-force sensor.

We connected the flexi-force sensor to an Arduino microcontroller. By pressing the active round surface of the flexi-force sensor, we recorded the analog raw data. By mapping the analog data (0~1023 unit), we converted it to voltage value (0~5 volt). We did a simple experiment by pressing the active surface 5 times and record the analog data.

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. 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. As shown on fig. 12.

3. Results and Discussion

Recovering finger posture is done through inverse perspective and inverse kinematics computations. The important information from the movement is computations of a reverse and forward kinematics of the model artificial hand gripper. This hand finger is designed to remain simple enough for inverse kinematics computations to be done in real time, while still respecting human capabilities and span of motion.

Each finger have four position respectively it is 0° , 30°, 60° and 90° degree. Fig 14 shows the results of experiment done on the flexi-force sensor. We applied force on the flexi-force sensor active surface 5 times, and the graph shows 5 peaks which suggest that the sensor can be used to detect force when pressure applied to it.

The positioning of this finger will be measured by the flex sensor. The positioning of force will be computed according to the bending of flex force sensor. Each result will be recorded in real time [18].As show on fig. 15.

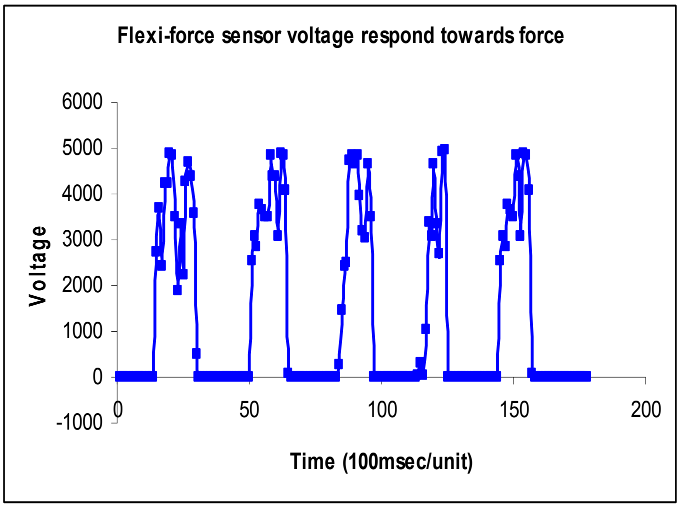


Fig.14: The graph above shows the performance of flexi-force sensor when active surface was applied with force (5 times).

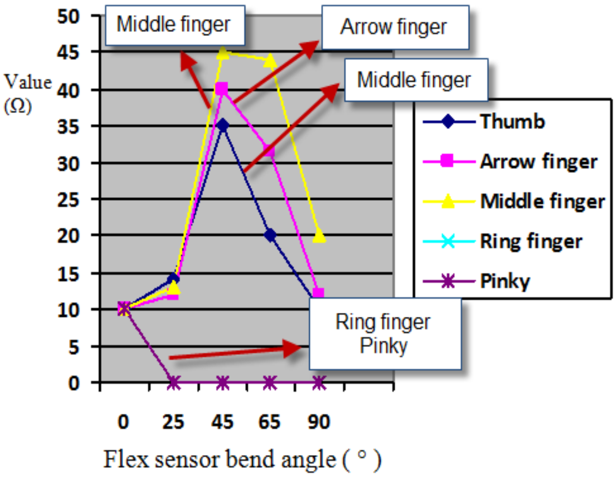
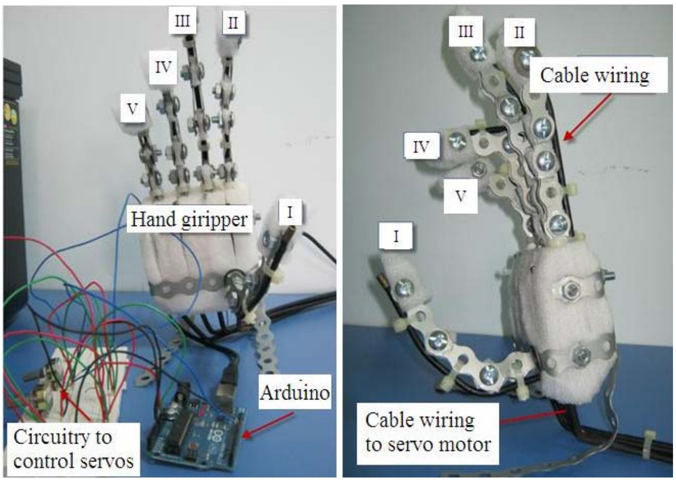


Fig. 15: Graph above shows the performace of flex sensor during bending activity.



(a) (b)

Fig. 16: (a) The sensors are connected to microcontroller for analog signal detection and (b) side view of the artificial hand.

No	Labeling hand	Type of finger
1	I	Thumb
2	II	Arrow finger
3	III	Middle Finger
4	IV	Ring Finger
5	V	Pinky

Table 1: Corresponding label for the finger

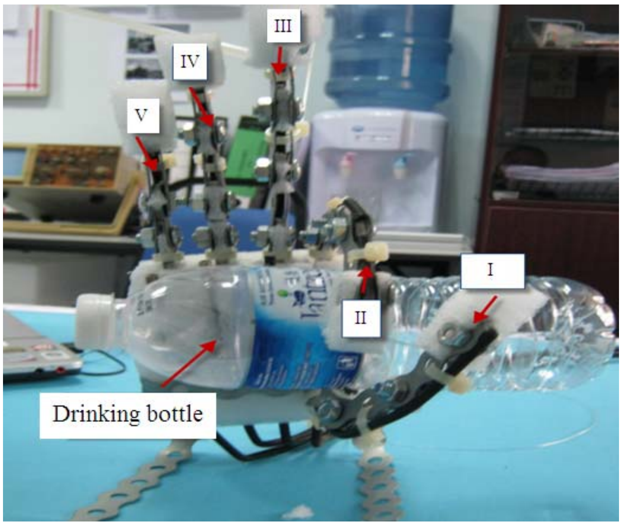


Fig. 17: Gripping test performed by the artificial hand gripper where two artificial finger gripping bottle.

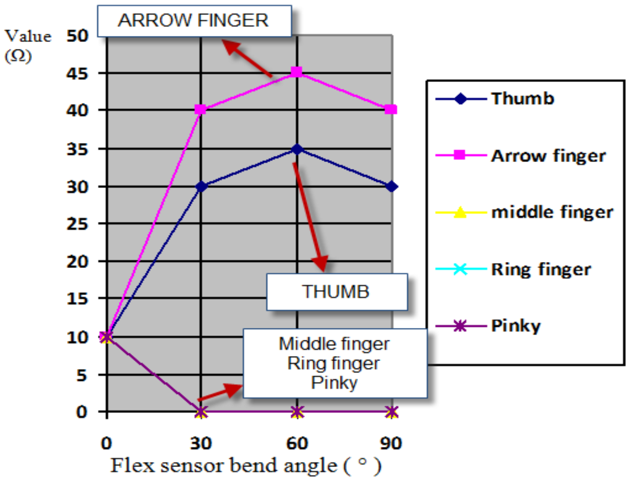


Fig. 18: Resistance value against flex sensor bend angle for the artificial hand gripper – (bottle gripping activity).

From the experiment shown in Fig. 10, resistance values between flex sensors against the bend angle were collected. The previous experiment shows that when flex sensor is bend inward, resistance value increased significantly as the angle of flex sensor is bend further. But, when it is bent outward, the resistance value would gradually decrease. For this project, flex sensor is clearly suitable to detect finger bend angle by utilizing inward bend of the flex sensor [13]. The graph plotted on Fig. 15 shows the relation between resistance value against flex sensor bend angle. The experiment shows that when flex sensor is bend inward, resistance value increased significantly as the angle of flex sensor is bend further. But, when it is bent outward, the resistance value would gradually decrease. Thus, the corresponding output can be produced in relation to the resistance values and bending angle consistency as verified in Fig. 18 for bottle gripping tests.

From this study, we have identified that the flex sensor used in this project is clearly suitable to detect hand finger bend angle by utilizing inward bend of the flex sensor which does match with the nature of human finger [15-16].

4. Summary

A multi-fingered real-time system has been presented, whereby a human operator controls a five-finger robotic gripper and force-feedback via leather glove as the ultimate aim of this study. The different kinematic structure of human and robot hand requires the implementation of appropriate force and position. On this account forward kinematics of the human hand and inverse kinematics of the Hand gripper were derived and a position mapping algorithm based on a projection of the human fingertip position on the gripper trajectory has been proposed.

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 quality of the force feedback is strongly affected by the maximum torque measurable by the Hand gripper and the performance of the force controller.

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