Abstract—Most parts in this research are dedicated to control of multi finger grippers with emphasis on the finger tips or finger joints. By controlling a multi finger gripper, we enable the gripper to handle an object; in another words, controlling a multi finger gripper can be viewed in terms of controlling an object’s pose and the forces between the object and its environment. Hence, an object pose controller with feedback from an object pose sensor suits multi finger gripper control. Also due to the non-linear dynamic system behavior in the joints of most multi finger grippers, an effective, easily-adaptable joint controller is employed. The paper discusses the object pose controller with great detail in a new joint controller. Since the joint controller is based on microcontroller thus, we do not use an exact analytical model for this case.

Keywords: Rehabilitation; Flex Sensor; Assistive Device; Force Sensor; Monitoring Device.

I. INTRODUCTION

The technology developments since ‘70’s era until now are rapidly changing the robotic hand engineering history [1]. Currently, existing robotic hand can be divided into four types which is; Robot hands of 80’s. Commercial hands, Research hands and Prosthetics. Development of robot hands early in the 80’s start with, Soft gripper Hirose Soft Gripper by Shigeo Hirose from Tokyo Inst. Technology. This development began in the late 70’s with 1 DOF when it utilized pulleys at joints and create evenly distributed forces [2]. Then, in 80’s, Tomovic and Bekey pioneering effort in development of first robotic hand prototype called Belgrade / USC hand after World War II which consists of four DOF (1 for each pair of fingers and two for thumb) [3].

In the same era, more development and researches done in this field to upgrade the prototype technology. For example Stanford/JPL hand prototype with nine DOF design. Feature such as four tendons and finger also were designed for fingertip manipulation which is combined with strain gauge fingertip sensors [4]. 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 20kg. 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 construction artificial hand gripper’s individual 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 [5-6]. Barrett hand from Barrett Technology Incorporated used 4 motors, one motor per finger for three finger and plus another spread motor for palm. The breakaway technology allows fingers to adapt to object geometry. It’s also including the optical encoder for position sensing. Fischer et. al. [7] and Hong et. al. [8] presented three fingered, multi jointed robot gripper for experimental use. 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 were reported. Basically, prosthetic hand gripper can be used to develop and evaluate different approaches of stable grasping and object manipulation. 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.

Hence, the research and development in this discipline increased and more prototypes being commercialized due to high demand by industries. In our previous studies, several sensors were analyzed to be implemented in our hand gripper project [10-12]. Further project were done to develop the mechanical parts of the project based on a master-slave system [14]. This artificial limb looks and acts like a real human hand and consists of a Smart Glove and an artificial hand gripper. We also utilized this prototype for mirror visual feedback (MVF) therapy in assisting paralyzed patients rehabilitation process [13]. This will be followed in this study for the development of an enhanced version of artificial hand gripper, where a capability of detecting pressure on each finger is presented. The aim of this research is to assist handicapped individual in providing them with an enhanced version of prosthetics hand that can be used in rehabilitation process, which is economical and affordable.
II. Method

The development of this project based on master-slave system which involves integrating a Smart Glove and an artificial multi-finger hand gripper as shown on Figure 1. The hand gripper will mimic the actual finger movement made by a human operator through the Smart Glove.

There are two different sensors used in this project, i.e. flex sensors and flexi-force sensors which were attached to the glove. The former is meant for resembling the movement of finger’s joint, while the latter is for controlling the pressure of the gripper. These sensors and the gripper are then wired to an Arduino Uno; a microcontroller board based on the ATMega328. The data from the Smart Glove will be fed into the Uno, processed, and then channeled to the hand gripper.

![Figure 1. Block diagram showing the overall system of proposed Smart Glove controller for artificial hand gripper.](image)

The most important part after assembling the hardware is to program the microcontroller. The program was written in C. It needs to be tuned accordingly so that the gripper will mimic the finger movement. The methodology flowchart of this project is shown as in figure 1. The followings are the explanation regarding the flex sensors and flexi-force sensors.

A. Flex Sensor

In this project we use two type of sensor to measure the capabilities of the smart glove (Master). It is flex sensor and force sensor. The flex sensors were attached on back of the Smart glove, as shown in figure 2. 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 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 10 bits A/D converter in the microcontroller side for data processing. The data will be used to control servo motors which move the artificial hand gripper’s fingers. Each of the hand gripper’s fingers will move similarly to the flexion of flex sensor attached on the Smart Glove. The angle is measured between 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 done in [10],[11] and [13], 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 preliminary finding suggest that flex sensor is clearly suitable to detect finger bending angle by utilizing inward bend of the flex sensor.

![Figure 2. Figures showing how flex sensors assembled on the back of Smart Glove.](image)

B. Flexi-force Sensor

In this paper, flexi-force sensors were attached on each of the glove fingertips as shown in Figure 3. Flexi-force sensor is suitable to measure pressure force between body and external surfaces. By attaching the sensor to glove’s fingertips, the analysis of force distribution applied on the fingertips can be done.

However, preliminary experiments on Flexi-force sensor have been carried out to determine the suitability of the sensor on detecting small forces. Studies shows that force sensitive sensors can be used to detect and measures small amount of forces including individual muscles.
III. RESULT & DISCUSSION

A. Flex sensor

This paper consists of several experiments for flex sensor. The characteristics of the sensor will be recorded by using HyperTerminal software. The capability of flex sensor to follow the bending of hand finger is very good. Flex sensors were attached on the back of the Smart Glove as shown on figure 4 to detect human operator's finger bending activity. The sensor is connected to a microcontroller for analog signal detection. Two types of data were recorded, the first is to measure a flex sensor manually using a multi-meter and the second is though the data recorded from flex sensors attached on the Smart Glove through HyperTerminal. Flex sensor presents 10K Ohm resistance value on zero degrees bending and about 35K Ohm on 90° bending. The experiment below shows four type of bending for a finger. They have four position of bending 0°, 30°, 90° and 120°.

Graph 1 and graph 2 shows the results of experiment done using flex sensor on thumb, arrow finger and middle finger. We applied bending activity, and the graph shows increase of resistance value when the sensor was bent which suggest that the sensor can be used to detect finger bending activity when it is flexed. By attaching this sensor to the back of the glove, the flex sensor will act as a detector which sends data to the microcontroller to inform about the gripper is grasping an object.

B. Flexi-Force Sensor

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). As shown on figure 5, we did a simple experiment by attaching flexi-force sensors on the thumb and arrow finger. Then, subject will press the thumb and arrow finger on a flat surface (example a table surface) to record the data from force sensors.

Graph 3 and graph 4 shows the results of experiment done on the flexi-force sensor. We applied force on the flexi-force sensor active surface and graph shows increase of resistance value when the sensors were pressed, which suggest that the sensor can be used to detect force when pressure applied to its active surface. 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.
IV. CONCLUSION

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.

ACKNOWLEDGMENT

The authors would like to take this opportunity to express his heartfelt appreciation to his respectful supervisor Dr. M. Mahadi Abdul Jamil for his supervision, encouragement, contradictory ideas, patience, guidance and invaluable advice.

REFERENCES


