Gesture Controlled Robotic Hand with Feedback Control

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Abstract - Limb amputation is a life-defining situation which makes the life of the disables more crucial. It is indispensable to tailor a device which enables them to perform specific tasks. In order to facilitate the purpose, there are several techniques which have been developed where robotic hand is one of them. One of the major issues faced by the usage of robotic arm is the unstable and ineffective grasping movement of the robotic hand. This paper presents the development of a robotic hand which can be controlled by an individual along with an approach to gain an enhanced grasping through a feedback control where simple sensors and an Arduino microcontroller are employed. Performance of certain sensors for motor as well as feedback control has been analyzed.

Keywords - Amputation, Robotics, Enhanced grasping, Feedback control, Sensor.

I. INTRODUCTION

Today the science and technology is being a boon to the society especially in the field of healthcare. Rehabilitation engineering is the technological fusion of engineering and medical science to assist and aid in recovery of individuals with disabilities where robotics plays a major role in patient analysis and recuperation process. Robotic rehabilitation is one of its applications which imply certain integrants to bring off the normal actions lost due to impairment in affected ones. This may be a perfect countermeasure for the upper limb amputee patients who face both physiological and psychological complications because of their inability to use their extremities. Normally, a person with neurological limb disorders and disabilities caused by injury can improve their activities through rehabilitation therapies but, in case of amputees this may be an ineffective solution. In addition to that, the cost of such robotic as well as the prosthetic hand is the major controversy. The main objective of the paper is about developing a simple low cost wireless gesture controlled robotic hand with improved performance.

II. LITERATURE SURVEY

The study on various research works has revealed the performance of several sensors for feedback control and finger movement detection. IR sensor had been employed in Pisa/IIT Soft Hand for slip detection of objects which holding it. The closeness of object and time in which the object is under IR sensor were considered to find out the slippage of object. The sensors were placed in the tip of three fingers such as thumb, index and middle finger with one sensor on each. These fingers are selected due to their combined effect in holding a thing and as the middle finger lags behind the other three in synergy. But the operation showed reciprocal positioning effect as a consequence of IR ray of one sensor being captured by the other. This cause required a conditioning circuit in order to overcome the effect by activating only one sensor at a time. It has also been recommended to use electric field sensor and tactile sensor for its good performance [3].

A review on tactile sensation conducted on different upper extremity prosthesis explored the pros and cons of different sensors in finger position and slip detection while rendering feedback. In human hand, there are certain receptors called mechanoreceptors to detect the force, pressure and vibration in the skin. In robotic applications, sensors such as strain gauge, piezoresistor, piezoelectric sensors, capacitive and optical sensors can be utilized to measure the force or pressure imparted on it [9]. In such electronic based sensing techniques electromagnetic interference will be an issue. In some devices, electroencephalogram (EEG) and myoelectric signals (EMG) are used as control signals however, these tiny signals necessitates the need for amplification.

To gain the force signals applied on the robotic hand a low cost, miniaturized photointerrupter was designed by S.H. Jeong et al (2017). It consists of an LED light source and a phototransistor on each side of a frame. To avoid scattering of the light rays which would lead to instability in output signals, the screen is covered with IR absorbing material. The screen is attached to the elastic frame which moves downwards when a force is applied. This interrupts the path of light between the LED and the phototransistor where the collector current changes according to the amount of light detected by the phototransistor. This type of sensor showed less non-linear output [8]. Position and force sensors were used to improve grasping capability of KNTU Hand [4]. Degree of freedom refers to the number of independent movement possessed by a system component. For the purpose of achieving a rigid grasp two aspects such as form closure and force closure were considered. In form closure, application of force in one way would obstruct all degrees of freedom whereas in force closure, force applied at the contact points would restrict all degrees of freedom [4].

III. SYSTEM COMPONENTS

The intended project constitutes five major elements such as microcontroller, flex sensor, transceiver, servo motor and force sensitive resistor. The specifications and descriptions of the required components had been briefed as follows.

A. Microcontroller

Arduino Uno R3 with ATmega 328 microcontroller is used read both the analog and digital signals and process them accordingly. It is an integration of hardware and software technology which provides an open source platform to develop a prototype as per the user's intent. It demands an operating voltage of about 5V and has a clock speed of 16 MHz. It is specified to have 32 KB flash memory, 2 KB SRAM and 1 KB EEPROM. The processing will be based on the coding which will be uploaded. The microcontroller will include inbuilt library for distinct peripheral components comprising of functions to be used while developing the code.

B. Flex Sensor

The flex sensor is a thin film which senses the bending movement through change in resistance. The value of resistance will be proportional to the bending angle of the film [6]. It is 2.2" long and specified to have a resistance range of 10kΩ to 50kΩ. On testing the sensor, it produced 38.4kΩ and 49.4kΩ of resistance at almost 45º and 90º respectively and 20.2kΩ when left flat. A simple flex sensor can be designed using aluminium foil and connecting wires. Such a sensor resulted in a resistance range of 11.17kΩ to 19.94kΩ but the sensor lacked precision. A 10kΩ resistor connected along the ground side will lead to decrease in analog voltage input as resistance increases.

C. Transceiver

The nRF24L01 is a single chip 2.4GHz transceiver which uses GFSK modulation and operates under the ISM frequency band ranging from 2.4GHz to 2.4835GHz. It is specified that it requires 1.9 to 3.6V of power supply and a maximum data rate of 2000kbps. It can communicate data at a range of 10m to 100m. It enables a communication network of about six transmitters and one receiver. It is one of the transceiver models with comparatively low power consumption.

D. Servo Motor

Tower Pro SG90 micro servo motor with a rotational range of 180º is employed as an actuator. It operates at an input voltage of 4.8V with a speed of 0.12 seconds per 60º. It rotates under a pulse width signal between 500µs and 2400µs (to bring out a rotation of about 0º and 180º respectively). It has three connecting pins, color coded as red, brown and orange where the former one connects to Vcc and the latter two connects to ground as well as the digital pin of the arduino. It is particularized to have a stall torque of 1.80 kg cm.

E. Force Sensitive Resistor

Force Sensitive Resistor (FSR) is a thin film sensor which detects the pressure applied over the sensing area of 0.3" through variation in resistance. As the magnitude of force applied increases the value of resistance decreases. The resistance range was about 3.44 kΩ to 19.85 kΩ. A 10 kΩ resistor is given as a voltage divider near the ground.

IV. PROPOSED DESIGN

The proposed work comprise of two sections, the glove part and the robotic hand part. In the first part, five flex sensors for five fingers each will be incorporated in the glove and in the latter one, a simple hand model will be controlled by the servo motor with appropriate feedback control. The block diagram of the whole setup has been depicted in Figure 1.

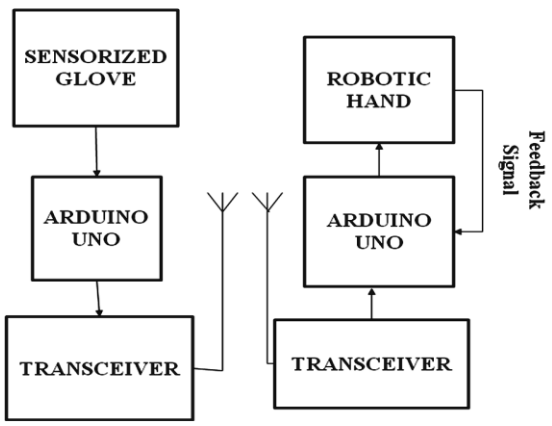

Fig. 1 Block Diagram of the Proposed System

A. Functional Description

Flexion and extension, adduction and abduction and circumduct are the three types of movements which a human finger could have. Each finger has a particular range of motion. In this approach, the finger position will be detected by the flex sensor and the analog voltage signal will be read by the arduino microcontroller [5], [7]. A particular range of signal will be transferred to the nRF24L01 transceiver which in turn be transmitted to the receiver part where a similar type of transceiver picks the signal provide it as an input to the microcontroller. The component process the signal compatible to the servo motor which is connected to the digital input side of the arduino. The motor obtain the pulse width modulated signal from the controller and drive the shaft to a particular angle. The transceiver can be connected to nRF24L01 adapter for convenience. Each transceiver will have a particular address that track the exact destination device to which the signal is to be transmitted.

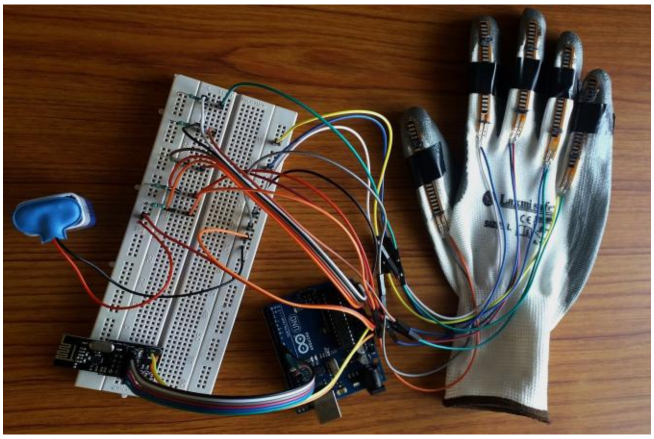

Fig. 2 Sensorized Glove Section

A hand model will be developed whereas 3D printed hand model can be designed for a better product. The motor shaft will be connected to the hand part using connecting cables. As the motor turns to an appropriate angle, the cable pulls the hand section attached to that. The FSR will be placed in the thumb, index and ring finger due to their synergy. The sensor will measure the force applied by the clamped object in the robotic hand. The data will be given back as feedback signal to the microcontroller consecutively. In the event that the measured value comes down the threshold value, the angle in which the servo motor is driven will be incremented which would lead to a tight grasp. Antecedently, piezoelectric sensor which converts stress into electrical signal has been chosen to measure the pressure but the sensor remained highly sensitive thus resulted in dynamic voltage output (voltage output decreased over time)[2]. The voltage varied between 0.22mV and 18.34 mV. To outlive such cons FSR has been selected to use.

B. Coding Algorithm

The arduino microcontroller will perform the processing operation based on the coding which has been uploaded in it. In order to define a function, it is essential to include appropriate libraries whereas here SPI (Serial Peripheral Interface), RF24, nRf24L01, Servo are the libraries included. The transmitter side coding includes defining input variables, activation of serial communication, etc. The algorithm of the glove part and the hand part arduino has been given in figure 3 and 4 respectively.

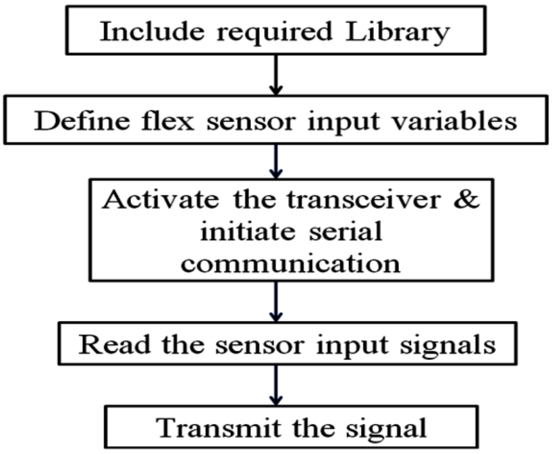

Fig. 3 Transmitter Section Coding Algorithm

In the receiver part, the code has to be as such as to check the availability of the transmitting data so that the controller could read and process the signal that has been conveyed.

C. Degree of Freedom

Hand finger contain three joints such as distal interphalangeal joint (DIP), proximal interphalangeal joint (PIP) and metacarpophalangeal joint (MCP), each bring out a distinct degree of freedom (DOF). Generally, the MCP have 2 DOF including adduction or abduction and flexion or extension movements. PIP and DIP joints combine to exhibit one DOF that is flexion or extension. In the hand model, the working of MCP joint will be imitated. This would bring out one DOF that is, flexion and extension. Typically, the MCP joint will have range of motion of 40º and 90º during adduction/abduction and flexion/extension respectively.

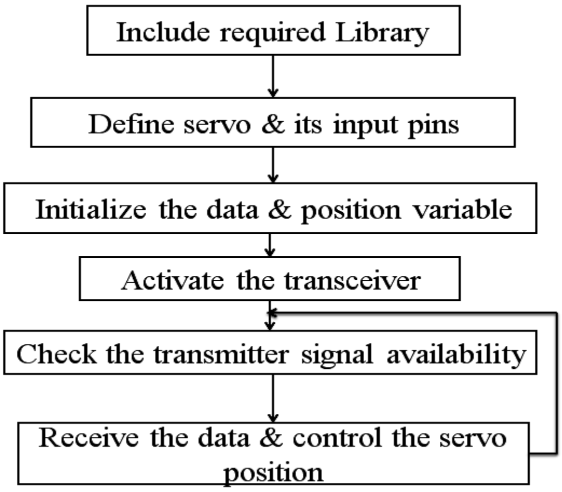

Fig. 4 Receiver Section Coding Algorithm

V. RESULTS AND DISCUSSION

The analysis on the efficiency of both the piezoelectric sensor as well as force sensitive resistor in producing a constant output has been performed. A particular stress was applied on each of the sensors and the outputs are examined using a multimeter and compared. The comparison graph between the sensors is shown in Figure 5. The x-axis indicates the particular pressure that had been given as input whereas the y-axis shows the output produced correspondingly. The dots represent the exact output gained with respect to input. The piezoelectric sensor provides a drastic output change in mV within seconds of applying force meanwhile the FSR produced almost constant output in kΩ which proves that FSR is the preferable and compatible one compared to piezoelectric sensor.

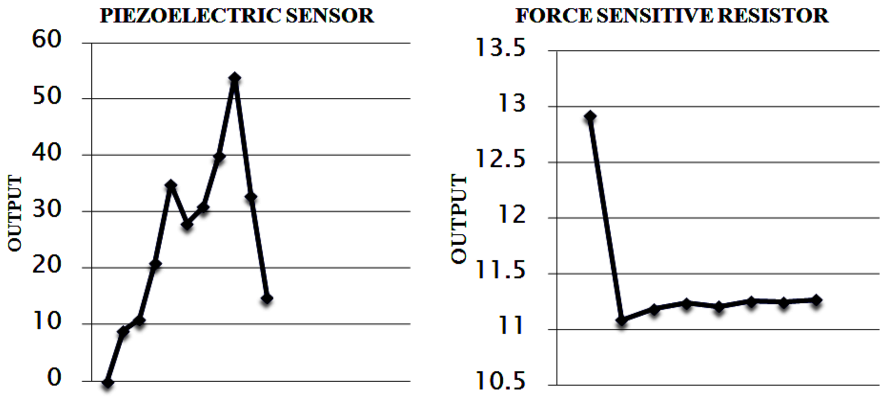

Fig. 5 Comparison Graph

The FSR showed an output of ~450 in the thumb finger, ~250 in the index finger and ~235 in the ring finger through serial monitor while grasping an object of 130 g. These values are set as a threshold for the respective force sensitive resistors. The nRF24L01 transceiver was capable to transfer the data to a distance of less than 1 meter which is comparatively less than the specified integer. More noise effect has been noted which resulted in network latency. In the coding part the analog input range of 0 to 1023 has been mapped to an angular range of 0 to 180 degree. The motor was effective in controlling the model fingers with respect to the angle defined in the program. The FSR performance was productive in feedback control of servo motor.

VI. CONCLUSION

This paper has described a simple prospective to develop a robotic hand, thus providing an idea of controlling it by another individual or even by the single upper extremity amputees. The cost of development is comparatively low in contrast to other prosthetic and robotic limbs. Provision of tactile sensation is under research and in future instead of gesture mind controlled robotic hand could be developed making use of EEG signal in a more effective way. Other than this the range of signal communication between the controller and the robotic hand could be increased through advanced transceivers and internet of things technology and the noise issues could be reduced through proper shielding or any appropriate transfer media.

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