Gesture Control Robot With Adaptive Gripper

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Abstract

The primary aim of implementing the robots is to decrease the human efforts. The field may either be industrial or domestic. It is user who decides the use of robot according to the applications involved in the process. The industrial robots are constrained for required operation. This research concentrates on the domestic use of the robot as a helping hand application. The research has been concentrated on the design and development of the end-effector with adaptive abilities to hold the various objects in day to day life. The gripper parameters have been obtained using the FESTO’s manual for calculation of gripping force. The design of the gripper has undergone improvisations for two times. The flex sensors have been used as the filtering out the low frequency signals in accelerometers is tedious. The four bar mechanism has been simulated and simulation results have been obtained. Considering the complexity in manufacturing of four bar mechanism, the LO configuration has been used on actual model. The wireless communication has been implemented to establish the connection between transmission and receiver end. The data transmission efficiency has been checked to ensure that the wireless modules work properly. The simulation results of four bar mechanism along with the gripping force calculations have discussed. The development of algorithm for control system of robot is prepared but yet to be tested for various test cases. The objective of this research is to provide the helping hand for physically disabled/physically challenged people.

Keywords: Flex sensors, four bar mechanism, LO configuration, adaptive gripper, gripping force.

1 Introduction

Robot, now a days, is a device that can perform a single or multiple tasks at a time. The robot has got ability of performing work, defined for a particular area of interest. Generally, robots are widely used to minimize human interventions in daily work right from domestic work to industrial work. Industrial robots are very sophisticated robots and used for very specific applications such as pick and place, welding, painting, assembling etc. Based on type of gripper used, robots are classified. Most of the grippers are designed for specific industrial application. In spite of the various benefits of the grasping techniques developed to realize grasping processes, their current limitations make them expensive with low flexibility. The key point in the grasping system is the gripper. The gripper performance is very important when fragile objects of different stiffness and shapes are manipulated and hence a reliable force control is crucial. This problem can be overcome with the use of deformable or flexible fingers which improve the limited capabilities of rigid robotic fingers. For an example, the pick and place robot has limited bandwidth of picking an abject and place the same on predetermined location. It can either be autonomous or manually controlled. Such systems have got complex control system for user and it becomes necessary to use such robots after certain practice. The robot has three adaptive fingers which can adapt the shape of the object yields more grasping capabilities. Gestures are
used for control of robot. Typical set of gestures are considered which user does not need to remember but can easily utilize for day to day life. Robots during household usage tend to decrease human efforts. This paper deals with the design, fabrication and control of robot using hand gestures for household application and to perform daily tasks.

Attempts have been made to build the gesture controlled robots to perform various tasks. Sandesh and Nithya Venkatesan [1] have developed a prosthetic arm using gestures through Flex Sensors. The system of equations was developed to obtain the motor characteristics. The hand developed is multi fingered and MATLAB is used to obtain the DC motor data. Giovanni Saggio [2] in his article shows the characteristics of bend sensors. The variations in resistance for different angles have been measured and the results are shown graphically and results are obtained. The method involved outward and inward bend with variable radii. This is helpful for obtaining the correct behavior of human postures and kinematical data for biometric applications. Miqdad et al [3] have performed the research to compare flex sensors and flexi force sensors. The smart glove has been introduced on which the sensors are mounted. The sensors have been used with Arduino board and the behavior of the sensors is put graphically. Mr Prashant Chaudhari et al [4] has performed review on the gesture recognition system. Filtering out the low frequency signals from accelerometer sensor is very hard. Further, too sensitivity of accelerometer sensors results into huge change in digital output. Hence, use of less sensitive system becomes beneficial when it comes to the gesture recognition. Alice Linsie and Mangaiyarkarasi [5] have developed a wearable prototype using MEMS accelerometer. The system is capable of recognizing eight hand gestures. Templates have been formed for corresponding hand gesture input. The corresponding output is displayed on the LCD and the same is played through speaker. Embedded C platform is used for programming. The simulation has been carried out in Proteus-Lab Electronic center. Abidhusain Syed et al. [6] have used flex sensors as well as accelerometer for development of gripper. The flex sensors were used for wrist and finger movement whilst the accelerometer sensor was used for elbow movement. Use of stepper motor and servo motor has been done as actuators. Petković, Dalibor et al [7] have discussed as new flexible adaptive grippers has the ability to detect and recognize objects in their environments. Mostly robotic manipulators are highly nonlinear systems, so an accurate mathematical model is difficult to obtain, thus making it controlling it an adaptive neuro fuzzy inference strategy (ANFIS) is used for controlling input displacement. Embedded sensors are used for gripper displacement measurement. Widhiada et al [8] discussed as most of the times manufacturing and fabrication is an easy task but controlling it is a tedious task. For the control, PID controller is used and tactile sensor is installed on figure tip for finger movement as input. Amir Feizollahi et al [9] have developed a three finger gripper. The research has been concentrated on grasping a cylindrical object. Same gripper has been developed and fabricated. The simulation results have been compared with real time results by fabricating the prototype. The two characteristics, form closure and force closure have been defined to maintain the stability. Kyoung Taik Park et al [10] have proposed the three finger gripper with multilink mechanism. Vacuum Pads have been used to ensure that object is held properly in gripper fingers. The application remained limited to pick the metal sheets up and place them down. Even if the three finger gripper has been designed, the prototype was limited to one finger. Samavati et al [11] mentioned as with the increasing use of robotic arms in industry, grasping and holding have great importance. Hence, proper design of grippers plays a key role in efficient performance of robotic arms. Here robotic gripper is designed for installing on a robot with the task of holding and moving cylindrical object with firm gripping. For firm gripping an arm is provided from down side of object which is movable is provided. This helps for firm gripping of an object and giving a support to object while picking operation. Krishnaraju et al [12] mentioned as so far there are so many mechanisms available for robot gripper in three fingered robot gripper mechanism is a type of mechanism which is used in industrial robots for moving object, which has higher gripper ratio. And also three finger grippers are best option to hold the object in a balanced way. Majid Tolouei-Rad et al [13] discussed as many of the times robot becomes useless without end-effectors for many instances are in the form of friction grippers. Usually friction grippers concerns with applying a frictional forces to different objects. This puts a
limitation on the effectiveness of gripping force that may result in unclamping of damaging an 
object. Redwan Alqasemi et al [14] have made a robotic gripper for activities of daily living 
which is used with a new wheelchair mounted with a robotic arm. Here mechanism produces 
parallel motion for effective gripping. The designed paddle is to grasp a wide variety objects with 
different shapes and sizes that are used in everyday life. Telegenov Kuat et al [15] mentioned as 
many of times a simpler mechanism instead of complicated mechanism is used for grabbing an 
object. Here, an under actuated finger and gear train mechanism is used with use of servo motor. 
A flexible gripper with use of compliant materials (i.e., rubber) with pneumatic inflation. They 
investigate the effects of process and design parameters, such as pressure, friction, rubber 
material, initial jaw displacement and parametric finite element analyses were done. Ho Choi and 
Muammer Koc [16] have designed and build a simple, single rubber pocketed flexible gripper. It 
was found that objects with different shapes like cylindrical, prismatic and types like egg, steel 
hemisphere, wax cylinders may be picked and placed without any loss of control of the object. 
Aslam et al [17] made a new design with a miniature Smart Robotic Foot (SRF), equipped with 
an integrated vacuum pump, a suction cup, a pressure sensor and a micro-valve is fabricated and 
tested. The SRF supports weights in the range of 1.2–3.5 kg under various test conditions and 
surfaces. Luo, Minzhou et al [18] made few design considerations for improving grasping 
capabilities of a low-cost easy-operation three-finger robotic gripper. By a proper mechanism 
design, a special planetary gear mechanism has been designed to adjust the position and 
orientation of two fingers during the assembly of hand gripper. This significantly improves the 
flexibility of a robotic hand in terms of sizes and shapes of objects which can be grasped.

From the literature review, it can be seen that grippers are normally controlled through 
gestures using accelerometers. Somehow, controlling robot using flex sensors is uncommon. 
Moving to grippers, several efforts have been made to fabricate five finger grippers. The question 
arises do we really need five fingers for gripper? How productive are they? At the same time, 
there are lots of complexities while designing and fabricating them. The adaptive grippers have 
got the capability of adapting the shape of objet to be held. Moreover, the grasping capability of 
adaptive gripper is also high. The adapting feature further increases the degree of utilization in 
domestic or household use.

2 Problem Definition

The objective of this research is concentrated on the design of the three finger gripper 
along with setting up the four bar mechanism for moving the gripper up and down. Available 
alternatives for sensors have been studied and the Flex Sensor has been chosen. The aim has been 
set to develop the algorithms and the programs for the full proof controlling of robot with 
adaptive gripper. The complicated component in design of multilink mechanism has to be 
removed. Also, the angle limits and link lengths needs to be determine to calculate lift. Some 
alternative has to be found to minimize the cost as well as the complexity. The LO configuration 
is supposed to use as it is simpler than four bar to construct.

3 Methodology

A Flow Of Research

The research is started with the defining the area of research. Later, the area of 
research is defined and the objective has been set. The software required for coding, modeling and 
simulation have been selected. The model has been fabricated along with the fabrication of glove 
with flex sensor mounted over its middle finger and index finger. Following block diagram in 
Figure 1 shows the flow of the research.
To make understanding in simpler way, the whole system is represented in the form of block diagram. The basic idea is to take the input from the flex sensors. Set these inputs for either gripper or drive mechanism. Accordingly, the input from the sensors is processed in the microcontroller development board. Model of gripper is done with CAD software solidworks. Figure 2 shows the block diagram for system.

B. **Design and Simulation of Four Bar Lifting Mechanism**

The basic reason behind selection of the four bar mechanism is, this mechanism can travel vertically up with horizon i.e. the travelling path does not produce a circular arc profile. The model has been developed in CATIA. The basic mechanism without any attachment is shown in following figure 3. Following are the lengths of links:

- Link AB: 194.946 mm
- Link BC: 276.25 mm
- Link CD: 96 mm
- Link DA: 376.5 mm

The total vertical lift is 261mm. Following images shows the 3D design and drafting of four bar mechanism.

C. **Linear-Orthogonal Configuration**

To overcome the high cost of manufacturing of four bar mechanism, the linear orthogonal configuration has been developed and fabricated accordingly. The figure 5 shows the
drafting of L-O configuration. The linear movement is obtained with the use of the slider element. The slider has got the travel of 25 cm. This 25 cm of travel is restricted to 23 cm to prevent the slider from shocks and jerks at the free end. Orthogonal travel is the result of piston in double acting cylinder. For testing purpose, the pressure has been increased from 1 bar to 4 bar which correspond to range 14.5 psi to 58 psi. For testing, the electro-pneumatic setup has been used at 3 bar to observe the behaviour of pneumatic components like solenoid controlled valves, double acting cylinder, relays etc. The on board pressure required will be produced by small compressor that runs on 12 volt DC supply. The compressor is capable of generating 250 psi pressure in continuous run of 15 minutes. The pneumatic circuit has been developed and the same is simulated before implementing it on actual practice. The time required to lift the end effector by orthogonal movement by 12 cm is 1.5 seconds and 2 seconds for moving it down by controlling throttle during inlet and outlet.

Figure 5- L-O Configuration designed in CATIA

D. CAD Model Of Adaptive Gripper

The gripper has been designed in Solidworks. The gripper consists of three fingers in M shape. The inner end of the finger is connected to the plate. This upper plate is connected to the piston of the double acting cylinder. Similarly the inner end of other two fingers has been connected to the upper plate. The outer end of the finger has been connected to the fixed plate. The limitation of this design is the components are fully constrained so the motion of the piston is restricted. The fingers have been placed 120° apart from each other. Keeping fingers at 120° is not beneficial as the objects cannot be held properly. The 1st stage design of gripper is shown below in figure 6. The provision for connecting links between inner and outer flanges of gripper has been made to improve the ability to withstand heavy objects.

Figure 6- Adaptive gripper

Figure 7-Proposed design of adaptive gripper

To lift any vertical object from its side is possible with this new design of gripper. A new improved design is shown in figure 7. This design is best suited for lifting of a cylindrical object such as water bottle. This gripper design has two fingers on one side of rectangular plate and another finger on other side. As shown in figure 7, a CAD model is designed with new refined idea. Pivot joints are provided on outer periphery of gripper with use of L-camp. All arrangement is made to create pivots at lower end of inner fingertip. Pivot allows the
finger to grab the object. A metal rod piece has been used to join all L clamps at finger and is attached to a big L clamp at piston. When the piston is retracted all assembly will be retracted as they are connected. When piston retracts, then fingers will adapt shape of object. As hinges are created to allow fingers to change their shape according to shape of object. L clamp will rotate about a centre rod move finger inwards or outwards.

4 Fabrication and Testing

A. Fabrication

According to new model of gripper assembly, fingers are fabricated. Model of gripper is made up of sheet metal. Thickness of sheet metal is very less so layers of sheet metal are used to give support along with magnetic separator is used. Magnetic sheet is used to hold the layers of sheet metal or gripper faces. Grippers are connected with L-clamp as shown in figure 4. A small rod is used in common with all L-clamps inline. Shape of finger is made like M, because when finger grabs any object with its inner face, the outer face will follow it for better support. Gripper assembly is shown in figure 9.

B. Working and actuation of gripper assembly

The double acting pneumatic cylinder has been used for actuating the gripper inward and outward. The double acting cylinder has bore diameter of 16mm. Flex sensors mounted on glove are used to generate the control signals to displace the piston. Fully open position is produced when piston extends as much as it can. Fully closed position represents the complete retraction of the piston. The pneumatic circuit has been simulated in Pneumo-Sim and implemented accordingly. The flow control of inlet air and outlet air is achieved using meter-in and meter-out circuits respectively. The flex sensor works on the principle of change in resistance. Fully bent position of sensor provides the maximum resistance whilst the unbent position provides minimum resistance. When connected to Arduino IDE, the sensor provides the range of numerical values for bent and unbent position. These numerical values are further mapped to a particular range. The reason behind this is to save the time of execution. This mapped range is divided into two parts to achieve the inward and outward movement of gripper fingers. These values are sent to the receiver end where the conditions are prescribed for corresponding input. XBEE modules are coupled with Arduino development board using XBEE shield.

C. Sensor Mounted Glove

The glove has been developed to mount the flex sensors and to connect the analogue joystick. These sensors are coupled with the Arduino board. The XBEE shield is used for interfacing the Arduino and the XBEE module. The glove can be visualized by following image. The glove is made up of nylon mixed cotton and comfortable to any hand as shown in figure 11. The transmitter end has XBEE configured with AT configuration during initial testing. As the data transfer rate is limited to 250 Kb/s, it takes longer time than expected to send the data in form of strings. This delay while receiving the data string creates further delay to actuate the respective hardware. Also, the XBEE modules cannot withstand the voltage fluctuations, so it becomes necessary to use protective shields at both receiver and transmitter.
The shield is provided with on board LM 293D motor driver IC. The non-uniformity during sending and receiving a data results into data loss. Though the data loss is limited, Arduino board at receiving end takes more time to identify the respective data strings from each sensor. When the sensors are subjected to bend, it provides the numerical value as an output. For continuous bending it provides the set of numerical values. This set may or may not be same for distinct sensor. The maximum and minimum numerical values are obtained for each sensor. This provides the position of sensor for corresponding value. The output from flex sensor has been used to control the movement of robot whereas output from analogue joystick is used for movement of gripper fingers. The reason behind for not using flex sensor as an input to control the gripper is small change in resistance causes the movement of gripper fingers.

D. DC Motors-

It is very important to select the proper motors for drive mechanism as they carry the total weight of the robot as well as they provide the motion to the robot. The simulation results provided the best choice of motors having specification of 12 volt dc supply with 120 rpm. To meet this result, the motor of 12 volt DC with 100 rpm has been used which provides the torque of 34kg-cm. The maximum current consumption is 5ampere at full load. This limits the use of motor driver LM293D as it supplies the maximum current 1.4ampere, and sometimes up to 1.7ampere. But, drawing such huge current from driver unit damages the development board.

E. Testing of Hardware Module-

The simplest wireless interface has been used. The wireless modules from DIGI of Series 2 have been purchased. The pair of modules has been configured as transmitter and receiver. The AT configuration has been preferred instead of API configuration for initial setup. The testing has been carried out to check the signal efficiency. The figure 12 shows the setup for testing.
5 Results and Discussion

The simulation results for four bar mechanism provided the vertical lift of 261mm. The linear travel obtained is 250 mm whereas the orthogonal travel is 120 mm. The maximum and minimum analogue input values of analogue joystick for x and y axes are 1023 and 0 respectively. These values are further mapped to 0 to 9 for purpose of processing and actuation of motors. MATLAB simulation results have shown that the motor with 100 rpm will behave best at 12 volts and it would provide sufficient torque. Taking this into consideration, the motor with 100 rpm at 12 volt DC has been used which supplies the 34 Kg-cm torque. The pneumatic system is adopted to ensure the better stability. Pressure of 3 bar is used while testing pneumatic system which is the best suited for this setup. After actuation of gripper fingers, displacement of one finger is 140 mm. The signal efficiency for serial communication is more than 85% which indicates the normal behaviour of the XBEE module though there is lag between transmission and receiving.

<table>
<thead>
<tr>
<th>Pressure (N/m²)</th>
<th>Time for opening (Sec)</th>
<th>Time for closing (Sec)</th>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>4</td>
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<tr>
<td>5</td>
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Table 1- Pressure vs Time for gripping

<table>
<thead>
<tr>
<th>Pressure (N/m²)</th>
<th>Gripping force per finger(N)</th>
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<tbody>
<tr>
<td>1</td>
<td>6.7</td>
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<tr>
<td>2</td>
<td>13.4</td>
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<td>4</td>
<td>26.81</td>
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<tr>
<td>5</td>
<td>33.51</td>
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Table 2- Pressure vs gripping force

For wireless communication, 30000 byte of analogue data was sent and received. This procedure has been repeated for thirty times. The average data received was 27965.13 byte. The average percentage of deviation was found to be 6.79.
Conclusion

Design, modelling, fabrication and experimental investigation for three fingered adaptive gripper was developed based on new proposed design and model is made using solidworks. Two different designs are made and appropriate design has been selected based on application. As the horizontal travel using four bar mechanism was very less, the linear orthogonal configuration has been introduced though the vertical lift has been compromised. A simple mechanism has been used for holding gripper fingers together. Fingers have ability to grab an object firmly. Design is done to have adaptive capabilities and fabricated with single sheet to have better continuity during bending and holding capabilities. Shape of gripper finger is like letter M because it gives strength to grip an object. Magnetic separators are used for holding of layers of sheet metal and to give better support while grabbing an object. This gripper is installed and setup is made ready for deployment. Direction control valve is installed and is ready for actuation. By use of pneumatic power, compressed air is given to mechanism by controlling direction of flow to actuate fingers outward or inwards. The cost is minimized by replacing the two flex sensors with analogue joystick. Even if the linear travel is reduced, the gripper is able to grip object neatly. The main aim of this research is to produce the helping hand for people to carry things from one place to desire.

In current scenario, the dual bridge motor driver LM293D cannot meet the current requirement. This leads to use of electronic speed controller (ESC) so that the enough amount of current can be supplied to the drive motors. Double acting cylinder with more piston displacement can be used to increase the vertical displacement. Actuation of direction control valve (DCV) can be done with joystick as analogue input wirelessly. Different types of materials can be used for fingers to have firm gripping. Gripper model can be tested for different shapes of object, to study variation in time for closing and opening of gripper.

References


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