“Pole climbing robot for connecting distribution lines”

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Declaration

We, hereby declare that the thesis titled "Pole climbing robot for connecting distribution lines" is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronics Engineering. This is our original paper that reflects our work and was not submitted elsewhere for the award of any other degree or any other publication.

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Abstract

The basis of this project is to create a pole climbing robot which can reduce the risk of an electrician to connect the distribution lines for supplying purposes. Pole climbing robot, nowadays, is a very common and interesting idea to the people. We call it as EPDRO (Electrical Power Distribution Robot). EPDRO will connect the distribution lines according to the directions given to it. In this modern era robots are being developed for various purposes to accomplish many tasks which seem to be too complex and life endangering for humans. Benefits of using robots have been immense in terms of risk-free, speed and efficiency of doing required tasks compared to that of humans. Our goal is to save at least a life where a number of people die from electrical injuries every year. According to a stat, since January 2007 to June 2008, 67 workers died from electrical accidents and 7.5% of these workers died in the distribution line [8]. Focusing on that issue, in our thesis we designed, built and simulated a pole climbing robot that can hook the electric connection. Our robot works on the principle of linear motor and it is partially autonomous. This makes the robot efficient and simpler to handle. With the installation of our project, risk of human injuries and death can be minimized while working in the distribution lines which is the main objective of this paper.

Contents

Chapter 1: Introduction

1.1 Motivation

For many years working labors have been losing their lives or sustaining injuries performing risky jobs. Deaths and injuries from monotonous jobs in dangerous environments have been very common in developing countries. One of the countries is Bangladesh where electrical injuries constitute about one third of the total burn injuries in the country. Electrical injuries caused 42% of the deaths [9]. The main causes for the numerous numbers of such accidents are due to lack of safety precautions, lack of proper training to the workers and dangerous working environments. These are few of those many problems prevailing in our country that needs to be eradicated if the human deaths are to be reduced. During the last decade, different types of pole climbing robots were developed for numerous purposes. So it is an outstanding idea to develop a pole climbing robot for a unique application which has a great necessity for developing countries like Bangladesh as well as other power growing countries. Hence building up a pole climbing robot that can imitate the actions of an electrician and does his work can save his life. The robot can be made to perform the monotonous dangerous task by climbing mechanism and hooking mechanism. It saves time taken for connecting distribution lines, efficiency of performing the task can also be increased, risk of human lives can be reduced.

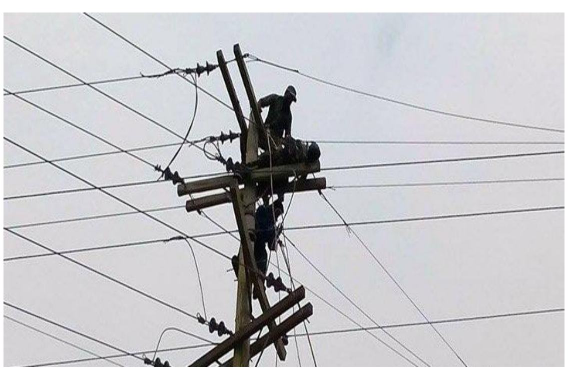

Fig: Electrician at Work

Fig: Accident While Working

The pictures above are of the accident that took place on the 1st of January 2015 in Bhavanipur near Bogra [18]. The body hanging on the wire is not of someone working but the dead body of the worker. Due to the negligence of the electricity board, the worker had to lose his life. He was working on the repair of the wire, knowing that the electricity would not be back before a few more hours. But then the electricity came back all of a sudden and the electric shock took away his life.

1.2 Literature Review

Investigations over a pole climbing robot have been going on for the last20 years due to inspections, cleaning and maintenance of high rises , nuclear experiment, pipes and so on [1], [2]. Brushless motors have widely been used so far to construct a pole climber. Actuators are nowadays used to increase the efficiency minimizing the power losses.

Brushless DC electric motor also known as electronically commutated motors are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. DC motors are being used since the very beginning of the idea of a pole climbing robot. These motors provide energy for both climbing and griping purposes. For gripping purpose DOF, more specifically 4DOF or 6DOF structure is used which means more power loss to the corresponding motor [3]. Usually three DC Brushless motors are used to fulfill this task. Two motors to grip and the other one is used to climb the pole. The motor that grips the pole actually enables the DOF structure to move and hold on to the pole and vice versa. Other one pushes the upper hands upward as well as pulls the lower hands. Three motors and two

DOFs make the structure a little bit complex. Although it is the most common process, it causes a huge loss which is to concern. Again usage of brushless motors means high maintenance. It also causes noise pollution and may cause EMI. Electric controller is required to keep the motor running. It offers double the price of the motor [3]. Brushless motors have a lower speed range since friction increases at high speeds at the rotor. These DC motors are simple to control but efficiency is not good enough. That is why some modifications were required.

Fig: 3D-Climber

A number of experiments have been performed to increase the efficiency of pole climbing robot. For industrial purposes nowadays, AC motors are used in the climbing robot. For instance, the most important application is performing periodical inspections by NDT probes in order to detect the progression of material degradation and welding defects [4]. Dangerous and difficult jobs for human are easily performed by these robots. Industrial pipe containing chemicals where a human cannot go, a climber robot can easily get inside climbing the pipe to investigate. This robot is very safe, cheaper and faster process to do than using human workers that is why the demand of this pole climbing robot is increasing day by day to the industries. In the 3D-Climber project this group aimed to build an industrial PCR with good maneuverability skills. After a survey on the already developed PCRs, they focused on the current available technologies, the following objectives were chosen for the 3D-Climber. The robot should be able to climb from the designed structure, scan the whole surface of the structure, autonomously navigate across the structure, modularity and simplicity should be considered in the design of the robot etc. The Plan of the 3D-Climber project was to develop an industrial PCR able to climb over 3Dcomplex human-made structures including T-junctions and perform test and maintenance tasks in those structures and also be able to semi-autonomously climb over 3D structures and perform in target tasks assisted by a remote operator [3].

Greater degrees of freedom (DOFs) are required for serial multi-legged robots for climbing purposes. This project aimed to build a simple robot using less no of DOFs in order to increase the efficiency. Actuators were used to climb and grip the pole for autonomous climbing according to the developed controlling codes. With the progress of technology autonomous controlling is the most popular process that every industry prefers for. Actuator played here the vital rule to fulfill the demand of autonomous climbing of a pole climbing robot since it is easy to control with the microcontroller or arduino codes [5].

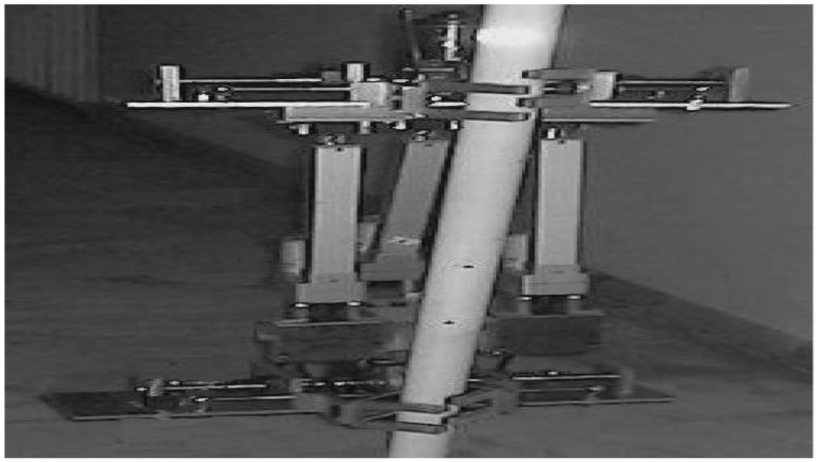

Fig: Hybrid-Pole Climbing Robot

Other projects: Different types of climbing robots have been developed for climbing over a flat or curved surface for about last two decades. A short note on various projects of climbing robot is given here. Climbing robots nowadays are getting popular for climbing wall, smooth surface suction cups and so on. For climbing inside pipes, pole climbing robots have received an increasing attention due to their applications in pipe inspection [3], [10]. However, different types of pole climbing robots have been designed and developed. For example, a continuous motion PCR is developed in University of Tehran for cleaning the poles, “ROMA” is a pole climbing robot with a 6-DOF serial climbing mechanism, “Trepa” robot is a pole climbing robot with a 6-DOF parallel climbing mechanism, The biologically inspired pole climbing robot “RISE” can climb from straight structures with soft and non metallic materials. A six- DOF parallel robot with pneumatic actuators has been modeled and simulated by Saltaren et al. The modeled robot has a large load capacity which is an important issue for industrial pole climbing robots [5], [7]. This robot was built for autonomous climbing along tubular structures. Application of actuators instead of motors, to make a pole climbing robot, minimizes the power loss to the project.

1.3 Objective

Pole climbing robot is a multifunctional robot which can serve several purposes according to our demand. The main objective of our pole climbing robot is to reduce the risk of the people who work in the distribution line. Due to lack of resources hooking and repairing electric connection in distribution line is a very common scenario in Bangladesh. Moreover, the people who are working in the distribution line do not have proper safety measures. Accidents are very common and it's increasing day by day. That is why we became motivated to do something to reduce the sufferings of the people. We have designed our robot in such a way so that we can avoid this kind of difficulties. The goal is achieved by using the gripper which is covered with rubber material and it helps to climb the pole smoothly. An additional sensor has been used to determine the pressure of the gripper so that we can avoid extra pressure, power loss and mechanical damage to our robotic hand and the pole as well. When the robot goes up and reaches the point we want it to be, it automatically stops and starts its further command. According to our command stored in the Arduino, the robot stops climbing by getting the signal from a sensor that has been used for this dedicated purpose. This sensor detects a black point which is previously marked in the pole. As soon as the black point is marked, it sends a signal to the Arduino and the Arduino makes a command to stop the climbing of the robot by receiving signal from the sensor. The robotic hand has been made of steel sheet to reduce the weight of the robot which is very important. As the robot goes up, the pressure becomes high. The only effective way to minimize this problem is to reduce its weight. Our objective is also satisfied. Now the most important part of our project is that we have a steel hand over the top of the robot to hook the connection. This steel hand has been connected with servo motors to rotate its direction. This part of our robot has been manually controlled through wireless Radio frequency transmitter. We are going to implement a new system that is more flexible compared to fastening wire. We want to use a port system where we can plug in the connection instead of fastening the wire. This is safer, simpler and more flexible. When the robot reaches close to the port, we are going to use RF transmitter to plug the subscriber line into the port. If the port is not straight to the steel hand, we can move the steel hand to the right or left according to the port and then plug it correctly. That's how we are going to fulfill our objective through this robot. If it works properly, the sufferings, risks and deaths related to the work of distribution line can be minimized. If we can save one people through this project or through this paper by making people concern about these hazards, we will feel very satisfied with our project.

1.4 Advantages

Our pole climbing robot has huge benefits in power distribution system and electrical work in power distribution line. Sometimes workers may die during the work in power distribution line because of power failure or short circuit. They even don't use any kind of protection during the work time. So their life becomes more vulnerable. We can reduce this kind of death by the help of our robot what is made for working in distribution line. When workers work in distribution line the electricity may off for many hours and this creates many problems in many working areas what are mainly depended on electricity and for this people may loss much money. But our robot can work when the electricity will on. There have no need to off the electricity when our robot will work in distribution line. So there will have no problem for anyone whose work is mainly depended only in electricity and no money will be lost during the working time.

1.5 Outline of the paper

We have in chapter 2 the mechanical structure of our robot, its control circuit, flowchart for the upward and downward climbing, the robot's communication mode and its power source. Chapter 3 has the experimental results analysis. Chapter 4 has graphs for the pressure sensor. Chapter 5 has the discussion that comprises of the limitations of our robot and discusses the challenges we faced during the making of our robot. This chapter also has subtopics that contain future scope of our project and the conclusion.

Chapter 2: Implementation

2.1 Mechanical Structure

Picture of the implemented structure is given below.

Fig: Full Mechanical Structure

2.1. A Gripper

The robot's gripper consists of two U-shaped bodies. These bodies are made of steel over aluminum since steel makes the robot more adaptable to the weight of the robot that it has to carry. Steel allows the gripper to withstand the pressure it experiences when it is holding onto the pole. Grippers have rubber placed on them which adds friction between the pole and the gripper to ensure proper gripping of the pole. Rubbers also reduce the risk of current flowing through the robot since it is an insulator. Each of the gripper has one sensor which is attached to the rubber. Force Sensitive Resistors (FSR) are attached to each pair of (Upper and Lower) gripper in order to measure force on different locations of the gripper, which not only provides information about the amount of force exerted by grippers, but also provide information on how grippers are connected to the structure. We use FSR to measure the pressure from the gripper to the pole. While actuator works, the FSR placed on the gripper gives pressure as the feedback output to the Arduino. When the gripper will properly grip the pole that is when sensor would sense maximum pressure only then would the arduino signal the actuator to stop working. According to that output Arduino maintains the gripper control. Gripping and releasing the pole is hence determined by the actuator. Of the two grippers, one gripper is fixed and the other one moves along with the actuator. Only one actuator would work at a time for smoother gripping.

2.1. B FSR

Force sensing resistor (FSR) is basically a polymer thick film device [12]. It is a device whose resistance varies when a pressure is applied to it. It shows a relation between the increase in the force applied to its sensing area and the decrease in resistance. The FSRs used in this project are of a length of 1.75" and width of 0.28" having a sensing diameter of 0.16" each [13]. These sensors determine the pressure applied to the pole by the grippers to ensure proper gripping.

Sometimes proper gripping may occur before an actuator contracts fully and it may cause power losses. Again, excessive pressure on the pole by the grippers may break the robot’s arm. FSRs are used here for the safety of the arms and also to minimize the power losses.

2.1. C Arms for Climbing

The pole climber has been given four arms (Upper and Lower) in place of wheels for climbing to avoid slipping and toppling over. The robot’s arms too are made of steel so that they can carry the weight of the body without breaking. Two arms are crossed connected by an actuator. Of the two arms one arm remains fixed while the other arm’s closing or opening is determined by the actuator. They are cross connected to maintain a balanced pressure on the actuator. The steel grippers are welded onto the arms.

2.1. D Climbing Procedure

A visual explanation is given by the pictures below.

Step-1: Upper arms released

Step-2: Middle Actuator Released

Step-3: Upper Arms Gripped

Step-4: Lower Arms Released

Step-4: Middle Actuator Contracts

Step-5: Lower Arms Gripped

The design has advantages of both climbing and gripping modules. Instead of using motors for the working mechanism, we have used three actuators. Actuators made the robot light, minimized cost and reduced power consumption. Only one actuator would work at a time for smoother climbing and gripping. One actuator has been used in the main body of the robot that expands and contracts to make the robot climb while the other two actuators are connected with the upper and lower arms to determine gripping. For both of the upper and lower arms as they grip the pole fully, the FSR sensors in the gripper send signals to arduino that maximum pressure has been attained. Arduino then signals the corresponding actuator to stop to prevent energy loss. Here, climbing mechanism follow some sequences which starts with gripping the pole by both of the upper and lower arms fully as soon as the robot is powered on. As the user commands the arduino via Bluetooth to start climbing procedure, upper arms release the pole and the main body's actuator pushes them upward. Then the body's actuator stops and the upper arms start to grip the pole again. As soon as it grips fully, the actuator of the lower arms then sets to motion and expands to release the pole. The body's actuator then contracts to pull the lower arm up. The body's actuator stops contracting and the lower arms grip the pole fully then. The robot continues to climb the pole following this process until it reaches at the desired height which is determined by an IR sensor. A black mark was drawn before at the desired point on the pole and as soon as the sensor finds it, the robot stops climbing making sure that both of the upper and lower pair of arms grip the pole properly. Similarly, while getting down to the ground, the robot follows the process just in the reverse way.

2.1. E External Hand & Hooking

The external hand that is to be used for hooking the distribution line is a steel rod that has been cut in between to give it a U-shape considering a plug in-out wiring system to the distribution lines. For example, like a connector will be at the end of the wire to plug it in a desired port on the electric pole. The robot will carry the wire and plug it in to the desired port according to the instructions given by the user. The hooking will be determined by the movements of the hand. The hand's horizontal and vertical movements would be controlled by a Bluetooth. We have used a servo motor for the angular motion of the hand. The robot moves its arms by the turning of a servo motor which is turned by using mobile through Bluetooth connection.

Fig: External Hand

2.2 Block Diagram & the control Circuit

Block Diagram actually shows how the control circuit has been implemented for EPDRO to serve its purpose. Bluetooth controller is used to give the robot instructions when to start climbing or when to break. As soon as the controller gives a signal to the bluetooth shield, connected to the arduino, gives signal to the arduino for running the climbing program. Actuators work according to the arduino command where actuators give a measurement of pressure as a feedback to the arduino. Depending on that feedback arduino continues working. Actuators are actually connected through relays. Relays give signals to the actuator when to extend or contract. An IR sensor is connected to the robot. This sensor detects the black mark drawn before on the pole by the user in order to determine at what distance the robot needs to stop climbing.

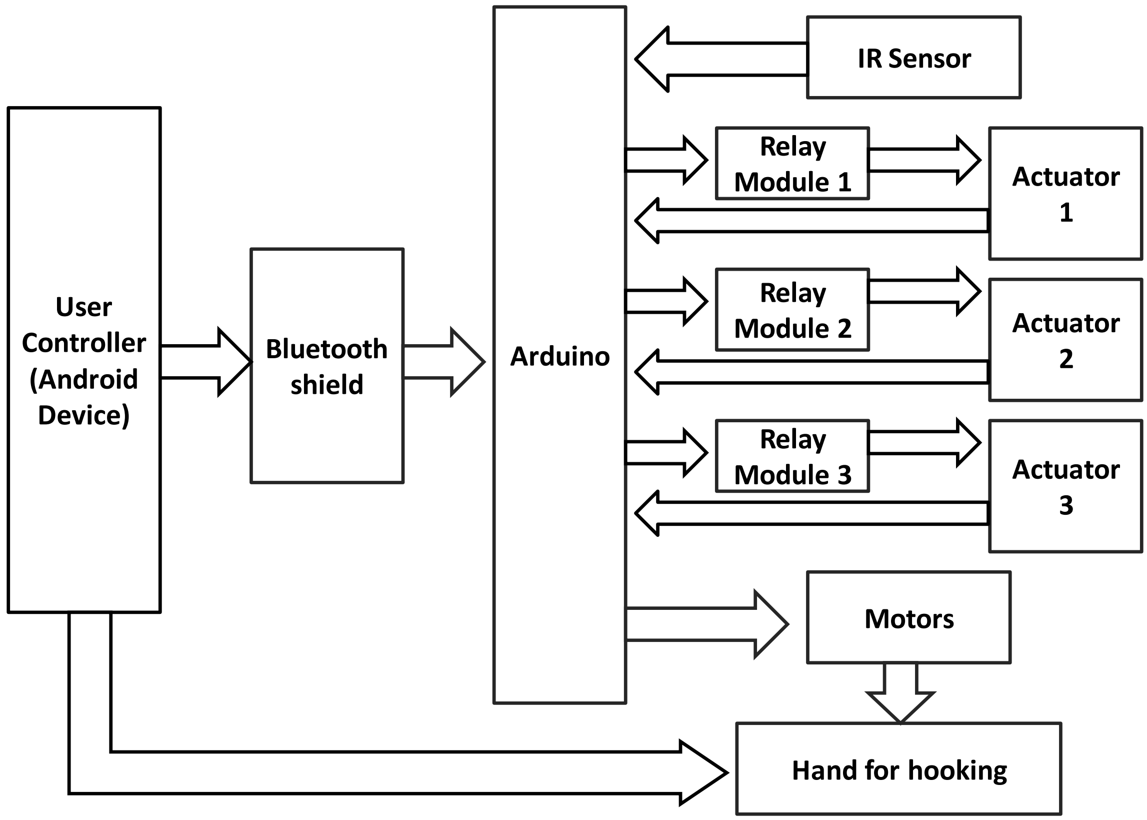

Fig: Control Circuit Block Diagram

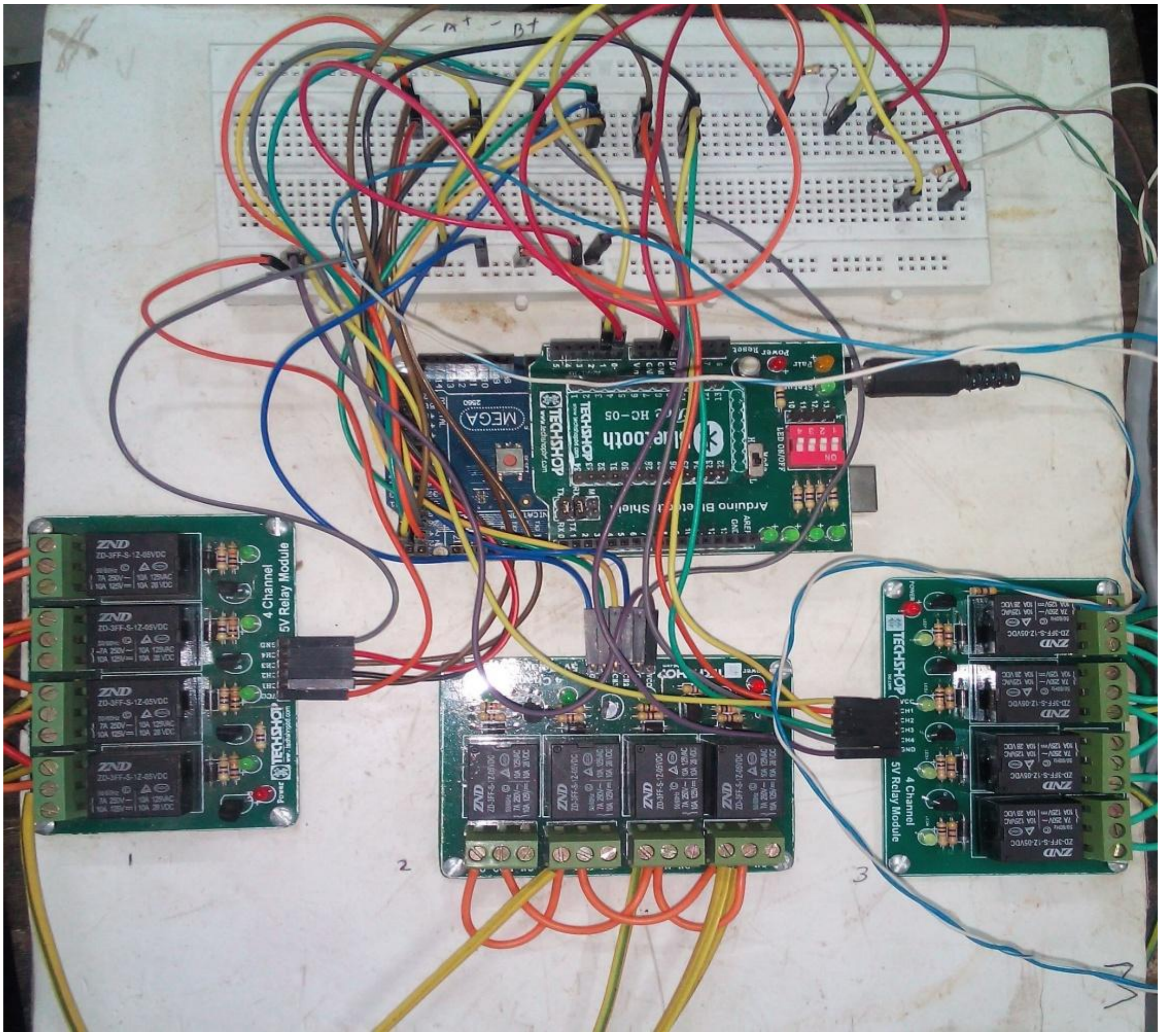

Fig: The H-bridge connected whole control circuit

2.3 Algorithm

The flowchart basically shows in detail how the robot is programmed for climbing the pole. Initially it is made sure that the robot grabbed the pole properly and then starts to climb. Here, for climbing, upper pair of hands first release the pole and the main body's actuator extends. Then, as the upper hands grab, the lower pair of hands release the pole. After that the body's actuator contracts and finally the lower hands grab the pole. According to the code, this procedure continues until the IR sensor gives a signal to stop. Getting a signal from the IR sensor arduino stops the climbing loop and ensures the robot's proper gripping which is the most significance of using arduino.

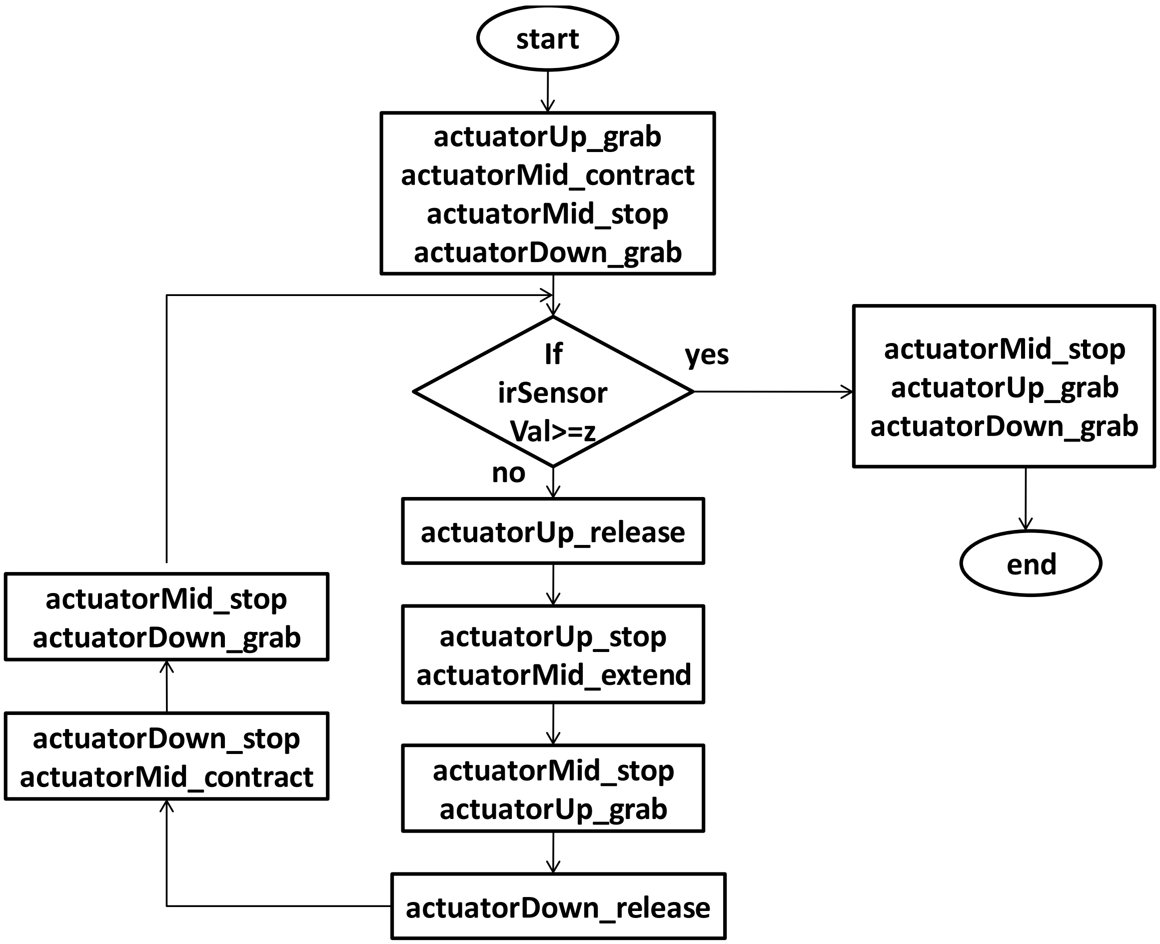

Fig: Flow chart for upward climbing

For coming downward the arduino code is very similar to the climbing code. Here lower hands release the pole first and then the main body's actuator extends. After that lowers hands grab and upper hands release the pole. Then the body's actuator contracts and uppers hands grab the pole. This is just the opposite process of climbing procedure. This process continues until the IR sensor gives a signal to stop working, detecting the black mark drawn before by the user.

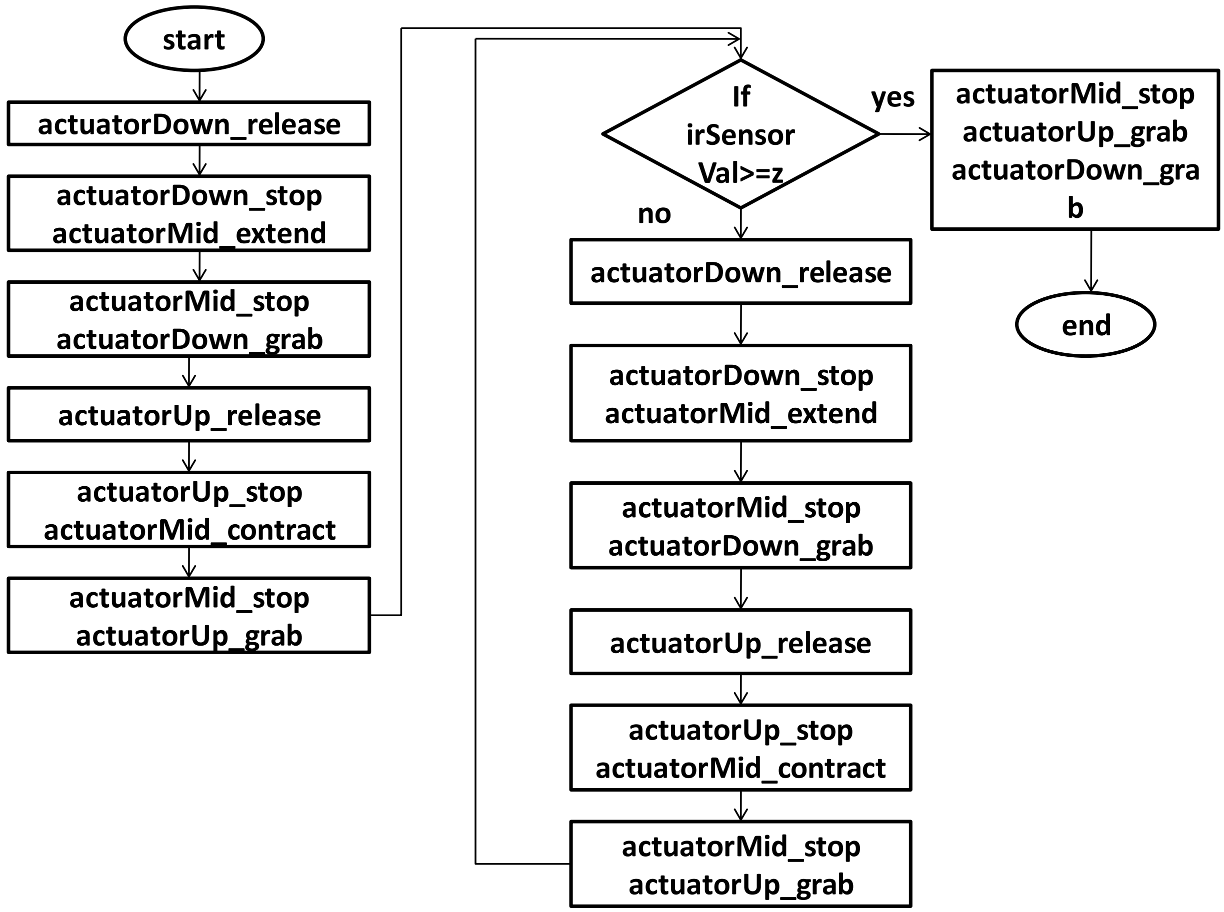

Fig: Flow chart for coming downward

2.4 Communication

A Bluetooth shield was placed on the arduino in such a way that the Rx and Tx pins of the shield get connected to the Tx and Rx pins of the arduino respectively.

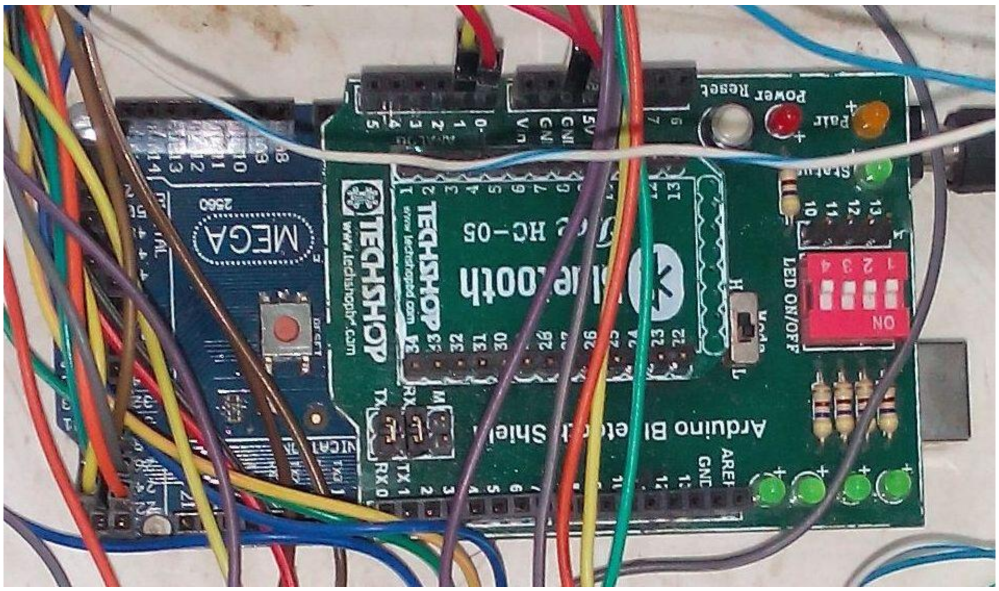

Fig: Bluetooth shield on arduino for communication

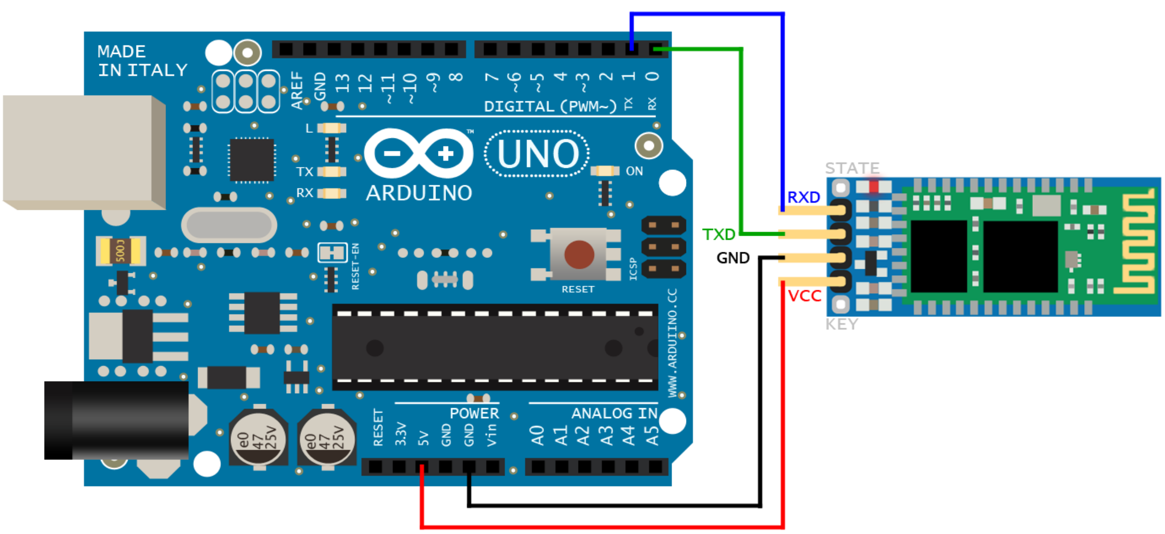

Fig: Interfacing Bluetooth Shield with Arduino

Bluetooth shield was used to provide a wireless serial communication between the arduino and the user (Android device). Arduino reads the command of the user through the Bluetooth Shield and works according to it. It needs an input voltage of 3.3V where up to 10m it can easily communicate without obstacles [11]. High and Low mode can be determined by a selector switch [6]. We have used an android phone that we connected with the Bluetooth shield and using software we sent commands to the robot. To make the robot go up for example we have used the button 2 on our phone and similarly we will use the stop command to make it stop and a command to make the robot come down, making the robot move autonomously.

2.5 Power

We have used two 12V DC batteries of 20AH rated current for running the actuators. We have two 12V DC linear actuators and one 24V DC linear actuator. We made a series connection between two 12V DC power supplies for running the 24V DC linear actuator and we directly connected a 12V DC battery to other two 12V DC linear actuators. To change the direction of actuators we simply swap the polarity of power supplies and DC linear actuators. We could use any other power supplies for running these actuators at a higher or lower than rated voltages but the limit switch circuit is not designed for higher or lower voltages. So the actuators may be damaged or burned. So we use the exact power supplies to run these DC linear actuators.

Chapter 3: Experimental Results

After numerous experiments carried out on the pole, our robot finally worked according to the algorithm autonomously. As per our set target, it climbed up and down sensing the pressure. The robot has been tested for 10 times. The robot took one and a half minute to climb a step and took one minute to climb down by a step. One limitation of our result has been the speed of the robot which decreases as it goes up, this is something we can work on later in the future which we assumed is occurring due to moving against gravity. The diameter range of the robot is 10-14cm.

Chapter 4: Graphs from Data Sheet

4.1 Resistance versus Pressure

Since Force Sensitive Resistor responds to the pressure applied to it, a resistance versus force graph can be built by applying variable forces on it. This graph from the data sheet of FSR, made by the producing company, is given below [14].

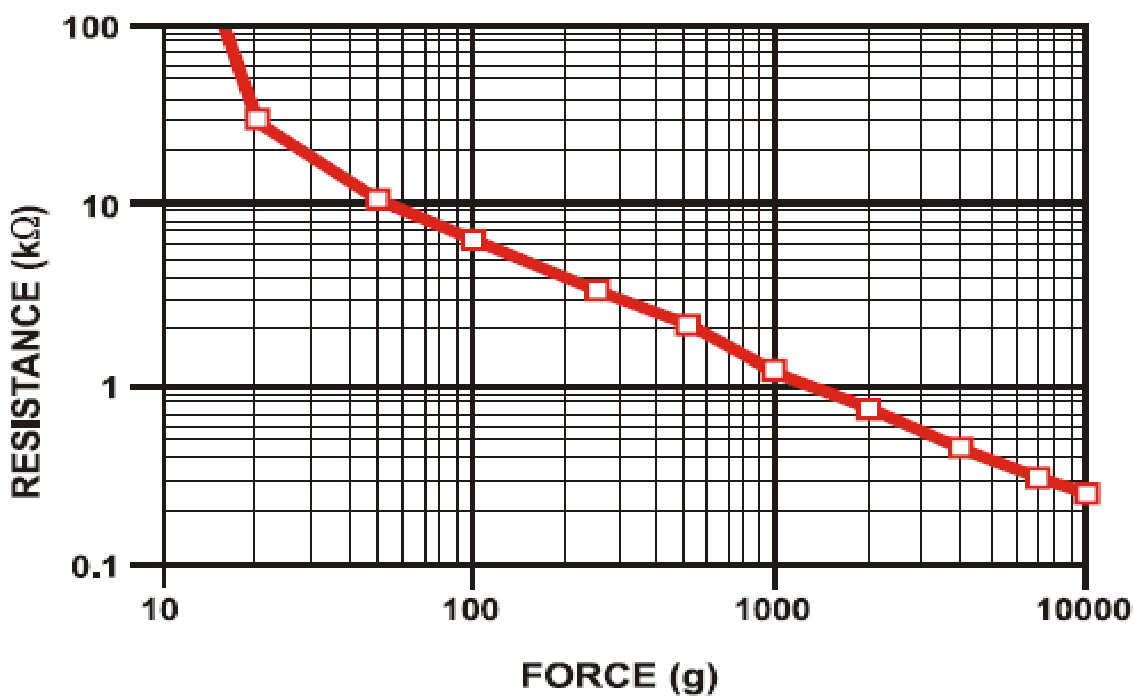

Fig: Resistance versus Force (Pressure)

4.2 Voltage versus Pressure

FSR gives a voltage signal as output of the applied force on it. It is basically an analog output which is converted in digital by arduino. Using LCD display this values can be gathered to have a graph between voltage output and the applied force. From the data sheet of FSR this graph is given below [14].

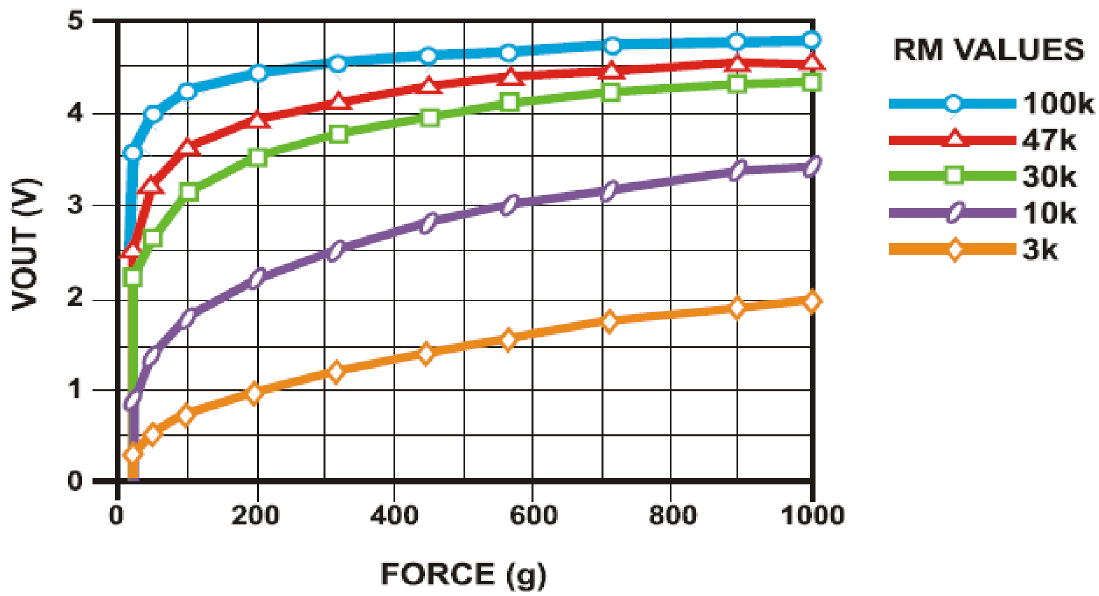

Fig: Output voltage versus Force (Pressure)

Chapter 5: Discussion

Instead of using motors we used actuators. This was our expected initial climbing module design. Using actuators we minimized our cost and reduced our power consumption too. One hand of the gripper was fixed to the module and other one moves to avoid the climbing complexity. Only one actuator would work at a time for smoother climbing. We succeeded to complete that climbing structure. Hands were made of Aluminum alloy and grippers of rubber. Rubber grippers were used to hold the pole to reduce the risk of current flowing through it.

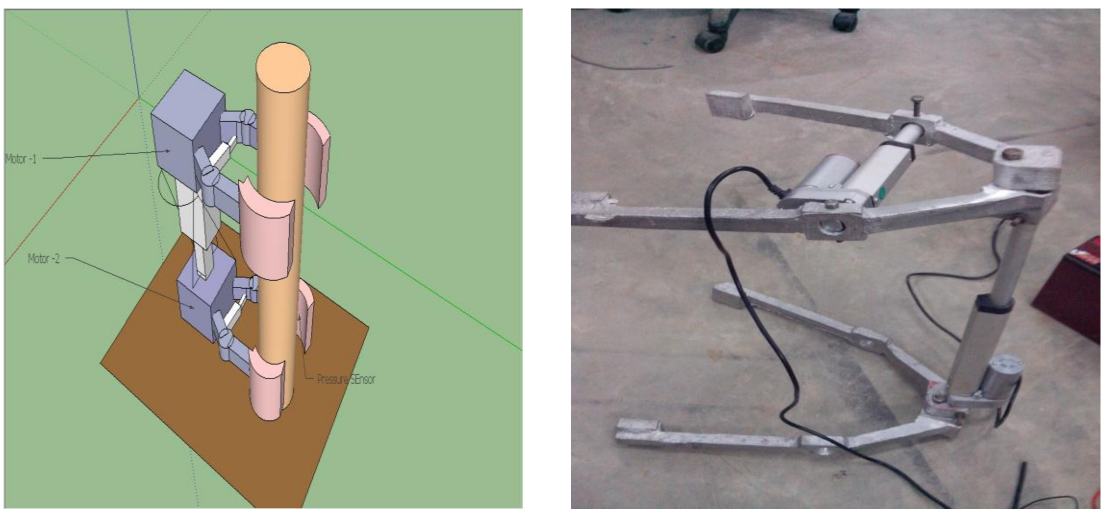

Fig: Implemented Initial Model

But the middle actuator was at risk of breaking down since the weight on actuator was unbalanced. That is why we had to redesign our model. Then the gripping arms were cross connected to make the design stable since the weight on the middle actuator is made balanced. The pictures of the cross connected design is given in Appendix B. The robot was made of aluminum. When we took the robot for pole testing the robot's arms broke down. Then we had to change the material of the robot to steel. Then again we took the robot for testing and it was found that it was not climbing smoothly and it was toppling over. To overcome this problem we used rubber on the surface of the gripper to increase friction and reduce the power consumption. The other problem we faced was that the FSR sensor was not being able to sense the pressure, was either gripping too tightly or was not tightly gripped, for which we had to adjust the FSR sensor. Another time during testing one of our relays got burnt and then for safety we used H-bridge to increase the relay capacity. Another challenge that we faced was that the speed of the robot decreases as it goes up. This problem can be somewhat minimized if the batteries are fully charged.

5.1 Future Work

Future improvement that can be done is the robot's arm can have a rotational wrist instead of a hook to make the electric connection. With the rotational wrist it can also swipe away an obstacle that comes on the robot's way. This way the robot can make sure the path is clear and can make the connection smoothly. To access any point in space (within reach) from any angle, a robot needs six degrees of freedom: three arm movements and three wrist movements. For better performance, robots may have more than six degrees of freedom depending on the kind of work they do [15]. Furthermore, the robot can have a backup power source attached to it so that in case of a power failure the robot can safely get back to the user. A video camera can be attached on the extra hand which may enable the user to have a good look if the robot has connected the desired point. If in case the Bluetooth connection gets lost then the robot should wait for two to three minutes for further command and then should come down automatically.

5.2 Conclusion

The technology in the field of robotics has advanced remarkably in the recent years. In this modern era robots are being developed for various purposes to accomplish many tasks which are dangerous, complex and monotonous for humans. This paper comprises of all the steps and procedures that have been undertaken to build the pole climbing robot that would climb a pole get the necessary wiring done and then climb down. The robot has been designed and programmed to climb up the pole by sensing pressure and get down in a similar manner. This robot promises to be beneficial to the electric industry where the importance of such type of robot as explained in this paper is immense. This robot is very helpful to the society in terms of reducing the number and risk of accidents that usually happen to electricians while connecting wires.

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[15] http://www.thetech.org/exhibits/online/robotics/universal/page08.html, 22nd January, 2015

Appendix

Appendix- A

Arduino Code

```
#include <Servo.h>
Servo myServo;
int pin=9;

const int a1r1 = 22;   //For controlling ActuatorUp
const int a1r2 = 23;

const int a2r1 = 24;   //For controlling ActuatorDown
const int a2r2 = 25;

const int a3r1 = 26;    //For controlling ActuatorMid
const int a3r2 = 27;

const int fsrUp = A0;
const int fsrDown = A1;
//const int irSensor = A2;

int x = 10;   // Here x is fsr reading at No pressure
int y = 925;  // Here y is fsr reading at Max pressure
//int z = 800;  // Here z is irSensor reading at Max height(marked
BLACK)
int fsrUpVal=0;
int fsrDownVal=0;
int valup=0;
int valdown=0;
//int irSensorVal = 0;




String command = ""; // Stores response of the HC-06 Bluetooth device


void setup() {
    myServo.attach(pin);

    pinMode(a1r1,OUTPUT);
    pinMode(a1r2,OUTPUT);

    pinMode(a2r1,OUTPUT);
    pinMode(a2r2,OUTPUT);

    pinMode(a3r1,OUTPUT);
    pinMode(a3r2,OUTPUT);
```

```
    pinMode(fsrUp,INPUT);
    pinMode(fsrDown,INPUT);
    //pinMode(irSensor,INPUT);

    Serial.begin(9600);
    Serial.flush();

    fsrUpVal=analogRead(fsrUp);
    fsrDownVal=analogRead(fsrDown);
    Serial.print("FSR Up Value= ");
    Serial.println(fsrUpVal);
    Serial.print("FSR Down Value= ");
    Serial.println(fsrDownVal);

//   if(fsrUpVal <= x && fsrDownVal <= x){
//       actuatorUp_grab();
//       actuatorDown_grab();
//   }

   Serial.println("Type AT commands!");

  // The HC-06 defaults to 9600 according to the datasheet.

}

void loop() {
  // Read device output if available.
  if (Serial.available()) {
    while(Serial.available()) { // While there is more to be read,
keep reading.
      command += (char)Serial.read();
    }

    Serial.println(command);

    if(command=="1"){ //For Grabbing
      actuatorUp_grab();
      actuatorDown_grab();
      Serial.println("Grabbing Complete!");
    }
    else if(command=="2"){ // This is Only For Climbing Up

      //while(true){

          Serial.println("Climbing up sequence initialized!");

          actuatorUp_release();

          actuatorUp_stop();

          actuatorMid_extend();
```

```
        actuatorMid_stop();

        actuatorUp_grab(); //problem

        actuatorDown_release();

        actuatorDown_stop();

        actuatorMid_contract();

        actuatorMid_stop();

        actuatorDown_grab();

        Serial.println("A climbing up sequence completed!");

    // }
  }
  else if(command=="3"){// Fow Down

    //while(true){

        Serial.println("Climbing down sequence initialized!");

        actuatorUp_grab();

        actuatorUp_stop();

        actuatorDown_release();

        actuatorDown_stop();

        actuatorMid_extend();

        actuatorMid_stop();

        actuatorDown_grab();

        actuatorUp_release();

        actuatorUp_stop();

        actuatorMid_contract();

        actuatorMid_stop();

        actuatorUp_grab();

        Serial.println("A climbing down sequence completed!");

    //}
```

```
    }
    else if(command=="4"){//Force Stop
      Serial.println("Force stop initialized!");
      actuatorUp_release();
      actuatorMid_contract();
      actuatorUp_grab();
      actuatorDown_grab();
      Serial.println("Force stopped!");
    }
    else if(command=="5"){ //For Release
      actuatorUp_release();
      actuatorDown_release();
      Serial.println("Ready to remove!");
    }
//    else if(command=="6"){
//      for(int i=0; i<=180; i++){
//        myServo.write(i);
//        delay(15);
//      }
//    }
//    else if(command=="7"){
//      for(int i=180; i>=0; i--){
//        myServo.write(i);
//        delay(15);
//      }
//    }

    command = ""; // No repeats

  }//Serial input loop ends

}// loop ends


       void actuatorUp_grab(){
          Serial.println("Grabbing Up!");
          boolean a=true;
          while(a){
                valup = check_pressureUp();
                if(valup <= y){
                    digitalWrite(a1r1,LOW);
                    digitalWrite(a1r2,HIGH);
                    //delay (7000);//depends on the time actuator
takes to fully grab
                }
                else if(valup > y){
                    Serial.println("High Pressure! ActuatorDown
Stopped");

                    actuatorUp_stop();
                    a=false;
```

```
            }
        }
    }

    void actuatorUp_release(){
      Serial.println("Releasing Up!");
      digitalWrite(a1r1,HIGH);
      digitalWrite(a1r2,LOW);

      delay(7000); //depends on the time actuator takes to release
    }

    void actuatorUp_stop(){
      Serial.println("Actuator_Up stopped!");
      digitalWrite(a1r1,LOW);
      digitalWrite(a1r2,LOW);

      delay(2000);

    }


      //check_pressureDown();

          void actuatorDown_grab(){
            Serial.println("Grabbing Down!");
            boolean b=true;
            while(b){
                valdown = check_pressureDown();
                if(valdown <= y){
                    digitalWrite(a2r1,LOW);
                    digitalWrite(a2r2,HIGH);
                    //delay (7000);//depends on the time actuator
takes to fully grab
                }
                else if(valdown > y){
                    Serial.println("High Pressure! ActuatorDown
Stopped");
                    actuatorDown_stop();
                    b=false;
                }
            }

          }



    void actuatorDown_release(){
      Serial.println("Actuator down released!");
      digitalWrite(a2r1,HIGH);
      digitalWrite(a2r2,LOW);
```

```
      delay(7000);  //depends on the time actuator takes to release
    }
    void actuatorDown_stop(){
      Serial.println("Actuator_Down stopped!");
      digitalWrite(a2r1,LOW);
      digitalWrite(a2r2,LOW);

      delay(2000);
    }

    void actuatorMid_extend(){
      Serial.println("Actuator_Mid Extending!");
      digitalWrite(a3r1,HIGH);
      digitalWrite(a3r2,LOW);

      delay(20000);   // depends on the time actuator takes to extend
    }
    void actuatorMid_contract(){
      Serial.println("Actuator_Mid contracting!");
      digitalWrite(a3r1,LOW);
      digitalWrite(a3r2,HIGH);

      delay(20000);   // depends on the time actuator takes to
contract
    }
   void actuatorMid_stop(){
     Serial.println("Actuator_Mid stopped!");
      digitalWrite(a3r1,LOW);
      digitalWrite(a3r2,LOW);

      delay(2000);
    }

    int check_pressureUp(){
        Serial.println("Checking pressure Up!");
        fsrUpVal=analogRead(fsrUp);
        Serial.println(fsrUpVal);
        return fsrUpVal;

    }
    int check_pressureDown(){
        Serial.println("Checking pressure Down!");
        fsrDownVal=analogRead(fsrDown);
        return fsrDownVal;
        Serial.println(fsrDownVal);



    }
```

Appendix- B


বাসা বাড়ি পাল্টানোর জন্য
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