A DISSERTATION ON

DESIGN AND DEVELOPMENT OF SKETCHING ROBOT

# By

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**C E R T I F I C A T E**

This is to certify that the *Mr. shashank joshi, Ms. Sneha koli, Mr. Dineshkumar vhankade, Ms.kirtee dubal have* successfully completed the dissertation entitled ***“DESIGN AND DEVELOPMENT OF SKETCHING ROBOT*”** under my supervision, in the partial fulfilment of Bachelor of Engineering - Mechanical Engineering of Savitribai Phule Pune University during the academic year 2021-2022.

Date: Place: Pune

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Mr. Shashank S. joshi Ms. Sneha V. koli Mr. Dineshkumar D. vhankade Ms. Kirtee dubal

**LIST OF CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **SR. NO.** | **TOPIC** | | **PAGE NO.** |
| **I** | **Introduction** | | 7 – 10 |
| 1 | Introduction | 7 |
| 1.1 | Problem Statement | 8 |
| 1.2 | Objective | 8 |
| 1.3 | Scope | 8 |
| 1.4 | Methodology | 9 |
| 1.5 | Organisation of Dissertation | 10 |
| **II** | **Literature Survey** | | 11 – 17 |
| **III** | **Design Scheme** | | 18 – 37 |
| 3.1 | Construction | 19 |
| 3.2 | Design Implementation | 21 |
| 3.3 | Working of System | 25 |
| 3.4 | Motor Selection | 31 |
| 3.5 | Actual Assembly of the System | 37 |
| **IV** | **Experimental Result** | | 38 – 41 |
| 4.1 | Programming | 38 |
| 4.2 | Key Details of the Robotic Manipulator | 41 |
| **V** | **Cost Estimation** | | 42 |
| **VI** | **Concluding Remarks and Scope for the Future Work** | | 43 – 44 |
| 5.1 | Concluding Remarks | 43 |
| 5.2 | Scope for the Future Work | 44 |
| **VII** | **References** | | 45 |

**LIST OF FIGURES**

|  |  |  |
| --- | --- | --- |
| **SERIAL NO.** | **FIGURE NAME** | **PAGE NO.** |
| A, B. | CAD Model | 18 |
| C. | Reference Model | 20 |
| D. | ANSYS Analysis | 21 - 24 |
| E. | Overview of Circuit | 25 |
| F. | HC – 05 Bluetooth Module | 26 |
| G. | Application Connectivity | 27 |
| H. | Bluetooth Interface | 28 |
| I. | Line Diagram of manipulator | 31 |
| J. | Torsional force on joints | 31 |
| K. | Force on various joints | 32 |
| L. | Axial load on joints | 32 |
| M. | Servo motors used | 35 |
| N, O. | Actual manipulator | 36 |
| P. | Arduino Programs | 37 - 39 |

**LIST OF CHARTS**

|  |  |  |
| --- | --- | --- |
| **SERIAL NO.** | **CHART NAME** | **PAGE NO.** |
| A. | Scope | 8 |
| B. | Methodology | 9 |
| C. | Dissertation | 10 |
| D. | Control Process | 29 |
| E. | Control Cycle | 29 |

**LIST OF TABLES**

|  |  |  |
| --- | --- | --- |
| **SERIAL NO.** | **TABLE NAME** | **PAGE NO.** |
| A. | Literature Survey | 11 |
| B. | Arduino Specifications | 25 |
| C. | Connection Circuit | 28 |
| D. | Servo MG996R Specification | 30 |
| E. | Servo SG90 Specification | 30 |
| F. | Calculated torque | 34 |
| G. | Manipulator Details | 40 |
| H. | Pricing of Material | 41 |

**ABSTRACT**

The main focus of this project is to design and develop the mechanism for robotic arm for material handling. The robotic arm is designed with four degrees of freedom and is programmed to lift a solid block and place it at the desired location. The aim of this project has been to develop a concept of a lightweight robot using materials such as aluminium.

The construction of the manipulator as robotic arm is based on the human hand, therefore having the ability to manipulate objects such as pick and place. The design of the manipulator as robotic arm was done on CATIA software and analysed for stresses in ANSYS. Here the joints of the robotic arm are coupled using servo motors, which give motion to the manipulator. . Servo motors are selected by applying various torques calculations which are appropriate for the load carrying capacity of manipulator. The basic objective of this project is to develop a versatile and cost effective robotic arm which can be utilized for Pick and Place operation. Here controlling of the robot has been done by using servo drives and Arduino microcontroller. The control is made simple with the utilization of ARDUINO UNO. We are using Bluetooth module with a low range for easy wireless communication for the control of manipulator as we are building a prototype.

Hence, including electronics to control it through programming is easy and flexible. The robotic arm was under testing and validation through software like Robo-Analyser to analyse specific degrees of freedom. The robotic arm has been developed successfully as the movement of the robot can be controlled precisely.

**CHAPTER - I**

1. **Introduction**

The field of robotics has its origins in science fictions. The word robot comes from the Czech word "robota" means forced labour in 1920. It took another 40 years before the modern technology of industrial robotics began. Today, robots are highly automated mechanical manipulators controlled by computers.

In modern industry, innovation by automating process provides companies with competitive advantages in speed, efficiency and production value. Robots are the machines generally used to perform critical tasks like arc welding, assembly, painting, material handling, etc. The application of robots is widely used in the industrial work to automate processes and reduce human errors. Hence, pick-and-place robots are essential in industrial systems due to their effect on saving labour costs and doing required tasks rapidly and accurately. The construction of the manipulator as robotic arm is based on the human hand, therefore having the ability to manipulate objects such as pick and place. Hence the robotic arm is often used to move any object from one place to another. The object can be anything from a small box to large containers.

Industrial Robotics differ by size of the fixed bodies, the type of joint, the sequence in which the joints are connected and the range of motion acceptable at each joint. The individual fixed bodies are called links. Robotic arms are manufactured by using different parameters like number of axis, degree of freedom, working envelope or working space that arm cover, kinematics, payload, speed and working space that arm covers, kinematics, payload, speed and acceleration, accuracy and repeatability, motion control a drive of an arm.

The use of Industrial mechanical arm characterizes some of contemporary trends in automation of the manufacturing process. However, present day industrial mechanical arm also exhibits a monolithic mechanical structure and closed-system software architecture. They are concentrated on simple repetitive tasks, which tend not to require high precision. The construction of the manipulator as robotic arm is based on the human hand, therefore having the ability to manipulate objects such as pick and place.

Although the use of pick-and-place systems in industrial applications has been operative for many years, the design process must deal with many challenges which have yet to be overcome. Hence our project is about such a prototype manipulator which is used in the modern-day industry.

* 1. **Problem Statement:**
     1. The material handling manipulator is being implemented to ease the process of sorting and the process of moving heavy materials.
     2. Usually, the transfer process of heavy materials is being carried out using man power and if the transfer process is repeated for a period of time, it can cause injuries to the operator.
     3. Also, operators can make mistake or could possibly drop the material which would result in the loss of time and money.
     4. Hence by using this robotic arm, operators will no longer have to bend and lift the heavy loads thus preventing injuries and increasing the efficiency of the work.

### Objective:

* + 1. To design a robot which can handle critical situations and to perform work in bulk.
    2. To control the displacement of the robotic arm so that the arm can pick and place the objects from any source to destination.
    3. To implement a robotic arm with 4 degrees of freedom on a stationary base to increase its capability and stability.
    4. Focus areas of this project include work in design, manufacturing and development of robotic handling device.

### Scope:

Robotic arms have a wide scope of development. In the near future these arms will be able to perform every task as humans and in much better way. These robots bring into play in an industrialized manufacturing atmosphere. Hence the research and development to develop a low-cost integrated system for development of pick and place robot have thus far resulted in the iterative development of a tested, proven hardware platform. The software stack has been developed for localization, navigation and radioactive element detection. Future-work can be done on the robustness of court localization and further code optimizations, which are two necessary steps for the integration of these components. The eventual goal for this project fully automated pick and place of a square block with minimum space. The communication from the Robot to Arduino can be implemented with different methods and using minimum programming. The future work can make the system robust to environmental variations, it can also aim to develop the decision-making functionality of the platform to create a truly autonomous system.



Objective

- To Pick and Place

Type - Robotic Arm

Research Papers

CAD

Design

Fabrication

[Chart (A): Scope]

### Methodology:

**Line diagram**

**Study of different research papers**

**Design of model in CATIA and stress**

**analysis in ANSYS**

**Dimensions of links, specification of**

**motors for setting up a model**

**Fabrication of links, base and other components at workshop**

**Simulation of the model in Robo- Analyser**

[Chart (B): Methodology]

**Assembling the manipulator and operating it**

### Organisation of Dissertation:

**Analysing Problem Statement & Researching**

**Primary Design Phase**

**Requirements &**

**Redefinition**

**Research on Various Design Elements**

**Basic design of Robot with kinematic definition**

**Actual concept and pre-design factors**

**Detailing in Design &**

**Re-analysing**

**Analysis of weight, stress on ANSYS**

**Manufacturing & Programming on Arduino**

**Testing & generating desired output**

[Chart (C): Dissertation]

**CHAPTER – II**

1. **Literature Survey**

|  |  |  |  |
| --- | --- | --- | --- |
| **TITLE OF RESEARCH PAPER** | **PUBLISHER** | **PUBLISHING YEAR** | **FINDINGS** |
| Review on Development of Industrial Robotic Arm | International Research Journal of Engineering and Technology (IRJET; vol 4, issue 3) | MARCH 2017 | Reviews on researches by various authors. |
| Survey on Robotic Arm Controlling Technique | International Journal of Emerging Technologies in Engineering Research (IJETER; vol 5, issue 2) | FEBRUARY 2017 | Applications and literature surveys for the project. |
| Review on Design and Development of Robotic Arm  Gen - I | International Journal of Innovative Science and Research Technology (IJISRT; vol 3, issue 3) | MARCH 2018 | Designs and working principles of robots. |
| Review Paper on Industrial Pick and Place Robotic Arm | International Journal of Innovations in Engineering Research and Technology (IJIERT) | DECEMBER 2018 | Design and analysis of grippers and end effectors |
| Robotic Arm Control Using Arduino and Bluetooth Module | Journal of Emerging Technologies and Innovative Research (JETIR; vol 07, issue 06) | JUNE 2020 | Synchronizing Bluetooth and Arduino |
| Design Analysis & Implementation of a Robotic Arm on wheels  – The Animator | American Journal of Engineering Research (AJER; vol 02, issue10) | DECEMBER 2013 | Implementation of actual robotic manipulator systems. |

[Table (A): Literature Survey]

### Review on Development of Industrial Robotic Arm:

The aim of this project has been to develop a concept of a lightweight robot using lightweight materials such as aluminium and carbon fibre together with a newly developed stepper motor prototype. The wrist also needs to be constructed for cabling to run through on the inside. It is expensive to change cables and therefore the designing to reduce the friction on cable, is crucial to increase time between maintenance. A concept generation was performed based on the function analysis, the specifications of requirements that had been established. This research paper deals with a robotic arm whose objective is to imitate the movements of a human arm using accelerometers as sensors for the data acquisition of the natural arm movements.

Based on this research works discussed robotic arm and their different parameters. Understands which factor affecting the performance of a robotic arm and how it changes a robotic arm in work efficient arm. Know how multiple axis uses to change the mass of an arm, DOF increased by simply by adding joints, working envelope and space should decide according to the situation, kinematics improved movement of the robot, speed and acceleration vary in different works, accuracy and repeatability is the important factor for any robotic arm. Distributed intelligent control involves matching the control model more closely with the physical system. The system robotic arm based on real-world haptic. The primary goals of haptic guidance is to facilitate the learning of complex human motion skills by providing haptic cues that are helpful to induce desired movements.

The proposed system is utilized to recognize the human motion. Large potential for applications in critical fields as well as for leisurely pleasures. Haptic devices must be smaller so that they are lighter, simpler and easier to use. Haptic technology allows interactivity in real-time with virtual objects. This is particularly relevant to manufacturing control systems that are required to control widely distributed devices in an environment that is prone to disruptions. With this model, control is achieved by the emergent behaviour of many simple, autonomous and co-operative entities (i.e., agents) that “decide locally not only how to act (as subroutines do), and what actions to take (as objects do), but also when to initiate their own activity”. Also, use diagrams for making proper understanding of robotic arm. Then discussed gaps in research and issues, its use as a guideline for future research work, at last give suggestions how we try to improve a robotic arm by working on effective algorithms and simulations. The objectives of this project has been achieved which was developing the hardware and software for an accelerometer controlled robotic arm.

The robotic arm has been developed successfully as the movement of the robot can be controlled precisely. This robotic arm control method is expected to overcome the problem such as placing or picking object that away from the user, pick and place hazardous object in a very fast and easy manner.

### Survey on Robotic Arm Controlling Technique:

The basic objective of this project is to develop a versatile and low-cost robotic arm which can be utilized for Pick and Place operation. Here controlling of the robot has been done by using servo drives and Arduino microcontroller. This robot is having 4 DOF and controlled by an android app with Bluetooth interfacing. The sizing process of a team of robots to be used in pick-and-place applications is a complicated process in that there are a high number of variables, often unknown, depending on the robot characteristics, the production environment, and the task logic assignment of the products to the robots.

This paper presents a practical method to size the number of robots required in a production line taking into consideration as many of the above variables as possible yet retaining relative simplicity. The idea at the basis of the method proposed is to use a simplified trajectory (from a mathematical point of view) and a constant travel speed of the end effector. Such speed ensures the execution of the task in the same time period as that which would be carried out by a robot in actual situations.

In this way, an accurate knowledge of the robot behaviour is unnecessary, and one can generalize the solution methodology to different robotic solutions and applications. The developed tool allows one to determine the number of robots required to satisfy certain production requirements in an industrial application in a systematic and easy to use approach by taking into account boundary conditions which would otherwise be impossible to do. The sizing tool can also estimate the performance of the system helping the designer to choose the optimal combination of the design variables. The behavior of complicated industrial pick-and-place systems can be simplified by introducing the definition of an average speed easily obtainable by a simple simulation of a single station of the production line with a particular type of robot.

As demonstrated in this work, the value obtained is reliable even if the distance and distribution of the products is out of the nominal data of the project. This crucial point allows one to develop a simplified model of a multi-robot scenario through which to realize a sizing tool. This type of robotic arm is famous for its characteristics like high speed, good accuracy; less maintenance and repeatability in pick and place operation which is required in assembly. This case study is concerned with design, manufacturing and analysis of mechanical structure of SCARA. The aim of this study is to provide Robotic arm as a learning material to Engineering colleges at lowest possible cost.

### Review on Design and Development of Robotic Arm Gen – I:

This research paper deals with a pick and place robot designed so that user is going to fill the liquid in bottle according to volume occupied in the bottle and after the bottle is filled robot will do pick and place operation by mechanical devices such as gripper and robotic arm. The robotic arm works on the principle of electrical input energy to perform some mechanical works effectively with the help of some automation and program-based operations.

The pick and place robotic arm consist of major hardware components such as strips & motors and arm gripper, switches, battery, piece of metal, and other discrete mechanical and electrical components. This project is designed for developing a pick and place robotic arm with a soft catching gripper. This soft catching gripper is used for safely handling an object carefully while catching and placing. The robotic arm consists of servo motor which is used for angular rotations of the arm for catching items (to hold items, to release, to rotate, to place). This servomotor used is works on the principle of Fleming‟s left-hand rule and is controlled using Arduino circuit board.

The designs are carried out on a low-cost robot platform for development of pick and place the things. There is establishment of both wireless communication between the mobile robot and the remote base station, and serial communication between the remote base station and the GUI application. This report presents the design and the development of robotic arm, which has the ability to perform simple tasks, such as light material handling. The robotic arm is designed and built from aircraft grade aluminium material where servo motors were used to perform arm movements. The design of the robotic arm limited to the four degrees of freedom.

The design of a Robotic arm has been complete. A prototype was built and confirmed functional. This system would make it easier for man to unrivalled the risk of handling suspicious objects which could be hazardous in its present environment and workplace. Complex and complicated duties would be achieved faster and more accurately with this design.

### Review Paper on Industrial Pick and Place Robotic Arm:

This project deals with designing the robotic arm which is to be used for unloading and loading the work piece on the lathe machine. The CAD model of robotic arm is made using CATIA V5 software and its simulation performed on Workspace Simulation Software. This will increase the total productivity of the machine where there is continuous operation and complete machine utilization. Use of Workspace LT software for designing the robotic components is very popular.

In the Arduino platform the signal sent from play station can be read on Arduino using built in function Psx.read() by including Psx.h header file during including the supporting files for execution. The receiver flag of the Arduino controller is monitored to detect any instruction is applied to the controller. Once the receiver flag becomes high it indicates a control signal is sent to the robot.

The next task is to decode the instruction been requested to perform. The signal been applied is read and stored in the variable called “DATA” further the algorithm searches for the opcode that executes when it is matched with the code stored in “DATA”. if data been read and stored in the variable is Psx.Down then all the dc motors re instructed to move in the reverse direction. Hence the chassis moves in reverse direction. Such eight conditions are programmed and depicted in the flowchart.

The pick and place robot so implemented is controlled using RF signal. The chassis is supported for the displacement of robotic arm by four Omni wheels. The robotic arm implemented has two degrees of freedom. The circuit powered up by 12V 1A battery fitted within the body of the chassis. This study deals with consideration of all parameters for designing the robotic arm. The proposed drive system for robotic arm is electric drive and the configuration is combination of polar and jointed arm configuration.

The proposed concept of pick and place robot using Arduino is implemented via RF play station. It is found that, the robot so implemented has the ability to locate itself to the location where the object to be lifted is available with the help of chassis and four dc motors. Further depending upon controlling action provided to servo motor it lifts the object and locates the same at required destination.

### Robotic Arm Control Using Arduino and Bluetooth Module:

This robotic arm is type of mechanical model arm, it is usually programmed, like of a human arm may be the sum total of mechanism or may be part of more complex robot. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or linear displacement. An industrial arm with six joints similarly to a human arm it has equivalent of a shoulder, elbow and a wrist. Typically, the shoulder is mounted on a stationary base structure rather than to a movable body. This type of robot has six degree of freedom, meaning it can pivot in six different ways. A human arm by comparison has seven-degree freedom. Like as we have our arm whose job is to move your hand from place to place.

Similarly, job of robotic arms is to move an object from one place to other that is what a pick and place robotic arm. Industrial robots are designed to do exactly in a controlled environment, over and over again. Arduino Nano microcontroller written in java language is programmed and servo motor control is provided. Thus, it is possible to perform the desired operations by means of elements located on the Arduino without any circuit construction other than the circuit where the servo motor inputs are located. For the mechanical part, the robot arm is drawn with solid works program and dimensions of the circuit construction other than the circuit where the servo motor inputs are located. For the mechanical part, robot arm is specified.

A 5v power supply is also preferred for the robot to work. Bluetooth module is used to communicate between two microcontrollers like Arduino or communicate with any device via Bluetooth. This module communicates with the help of USART at 9600 baud rates. The HC-05 has two operating modes, 1 is the data mode in which it can send and r5eceive data from other Bluetooth devices and the other is AT command mode where the default device setting can be changed. The L298N is a dual H-bridge motor driver which allows speed and direction control of two dc motors at the same time. The module can drive dc motors that have voltages between 5 and 35 volts with a peak current up to 2amps.

The driver module can drive two motors. The enabled terminals ENA and ENB are effective at high level. ENA and ENB pins are speed control pins for motor A and motor B, the enable A pin must be high to turn on the motor to drive motor to A direction say, clockwise, the pin input 1 must be high while pin input 2 must be low, to drive a motor to a direction say counter clockwise the pin input 1 must be low while pin input 2 must be high. Although we need to do is to apply signal to input and make motor to certain direction.

### Design Analysis & Implementation of a Robotic Arm on wheels – The Animator:

This research paper primarily focuses on mounting and implementation of pick and place robot on six wheeled drive chassis for making it compatible for both Industrial and Non-Industrial tasks. The robotic arm implemented has six degrees of freedom. As a modular design, changes can be made in robotic arm and end gripper as per required applications.

The robotic vehicle also consists of a storage area on a six wheeled drive chassis for picking and placing objects in a bulk, thus saving time in operation. Robotic arms, many areas are developable. Thanks to the robotic arms, many tasks are made easier and the resulting error level has been reduced to a minimum. For example; some pharmacy-based drug-giving robots and a projected robot arm have been developed. In addition to this, the ability to move the robot arm is further increased, and when the camera is placed in the finger area and the sensitivity is increased, it can be used in a wide range of applications from the medical sector to the automation systems.

With the robotic arms developed in this way, infecting the patient in the medical sector is minimized, while the human errors are minimized during the surgical intervention. Despite the fact that the robotic arm made by this project is of prototype quality, it has a quality that can be improved for more robotic systems. Besides these, robotic arm sector, which is open to development, will keep its importance in the future. The purpose of the project is to provide control of 4 axes moving robot arm design and this robot arm with a suitable microcontroller and Bluetooth module with android application.

The necessary theoretical and practical information for this purpose has been obtained and the necessary infrastructure has been established for the project. During the process of making and developing the project, a lot of theoretical knowledge has been transferred to the practice and it has been ensured that it is suitable for the purpose of the project.

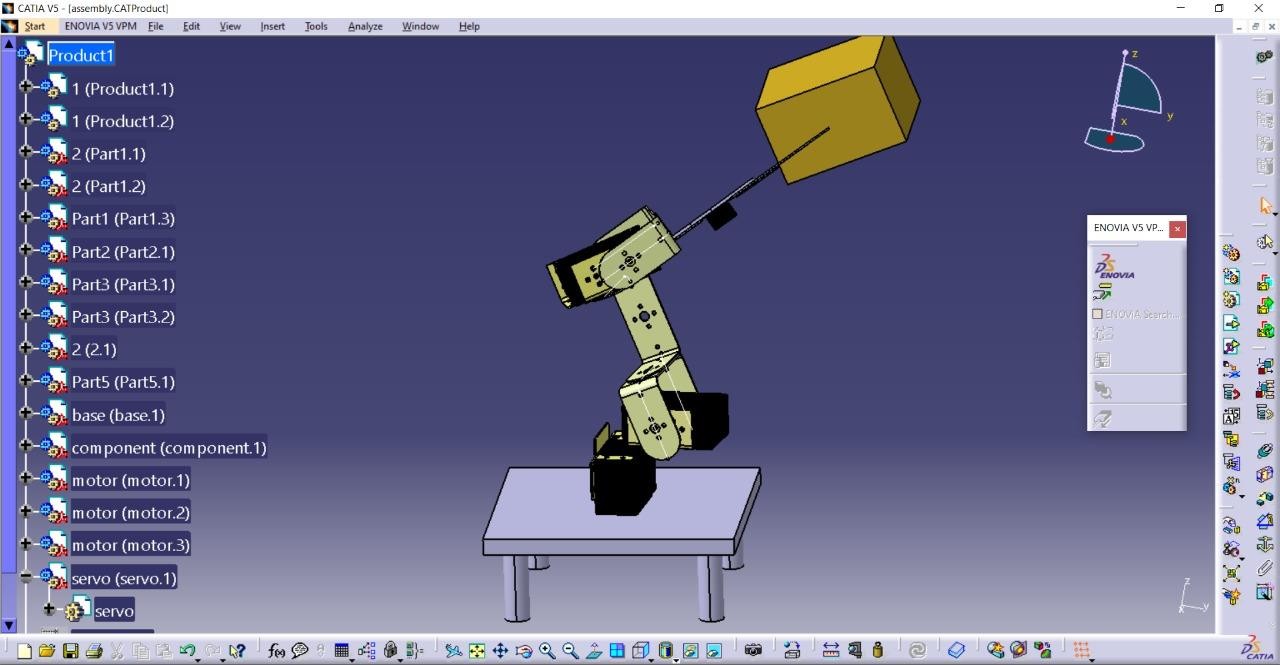
Through this research paper we got our basic idea how to do design components for our pick and place robotic manipulator and also how to assemble them. In this research paper concept of Six Wheel Drive Pick and Place Robot using Arduino is been discussed which helped us in the understanding of our project.

After reading all the research papers, we got serious information about the design, theory and programming for the manipulator. We also got the knowledge about various degree of freedom and principles in robotics.

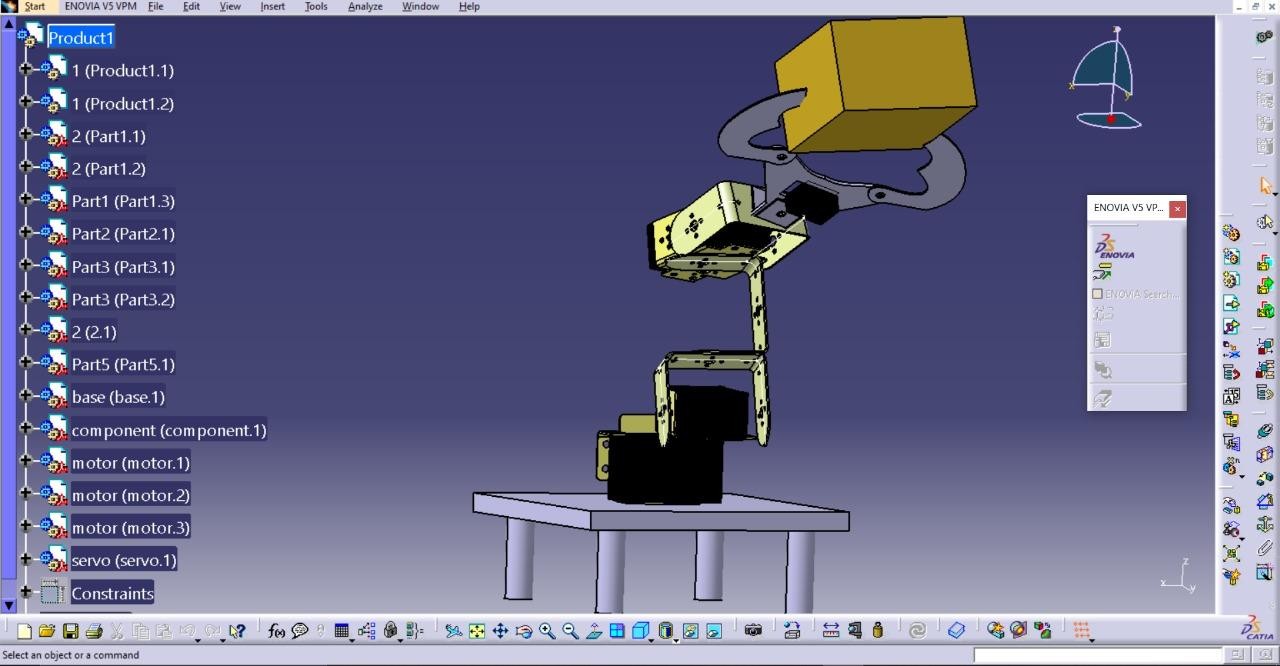
**CHAPTER - III**

1. **Design Scheme**

The most important aspect and backbone of this thesis is the mechanical design of the robotic arm. A robotic arm has certain design specifications and certain parameters are to be taken into consideration. Since, the design is an area related to thought, many varieties of designs come to the mind at the initial stages of the design. Everything might not be fruitful and the trial-and-error method cannot be trusted blindly. As earlier stated in the introductory chapter of this report, the robotic arm has **4 degrees of freedom** with the inclusion of the gripper. A CAD (Computer Aided Designing) model of a robotic arm structure was designed and analysed using CATIA and ANSYS software. The CAD model is shown in Figure below.



[Figure (A): CAD Model SV]



[Figure (B): CAD Model FV]

### Construction:

##### Functionality:

The arm is having the ability to lift, move, lower and release an object while closely mimicking the motion of the human arm with full extension. Any device that can perform the required motions to pick and place an object required would have met the requirements of this criterion. The choice of the number of the parts in this particular robotic arm is taken by comparing it with a human arm. We have the shoulder, elbow, arm, wrist and fingers do the job. This is the motivation for the choice of the number of parts. This robotic arm also has **4 parts and 4 joints** which are pretty much like the human hand.

##### Reliability:

The device is able to consistently pick up and place objects in a smooth manner i.e. the motion of the device is smooth enough to not drop the objects that are being lifted. Therefore, any device that can lift and move an object from one place to another without losing any grip would meet the criteria. After a detailed study, the choice of end effector is made. Since, this device is used for picking and placing blocks, the first common thought any mind would get is that a gripper would be used to pick up the block. So, we have enough motivation and data to use this technique.

##### Motion Range & Speed:

Like the human body the robots are constructed with the same joints between bones, here we have a constrained limit for the movement of the axis. In our design application, every particular axis has its own capacity of motion. The degree of movement of the robot is calibrated from the centre base of the axis. By this the speed in pick and place operation might vary, and this is occurred because each axis moves at different speeds. The complete motion of the operation is recorded in terms of degrees travelled per second.

##### Payload:

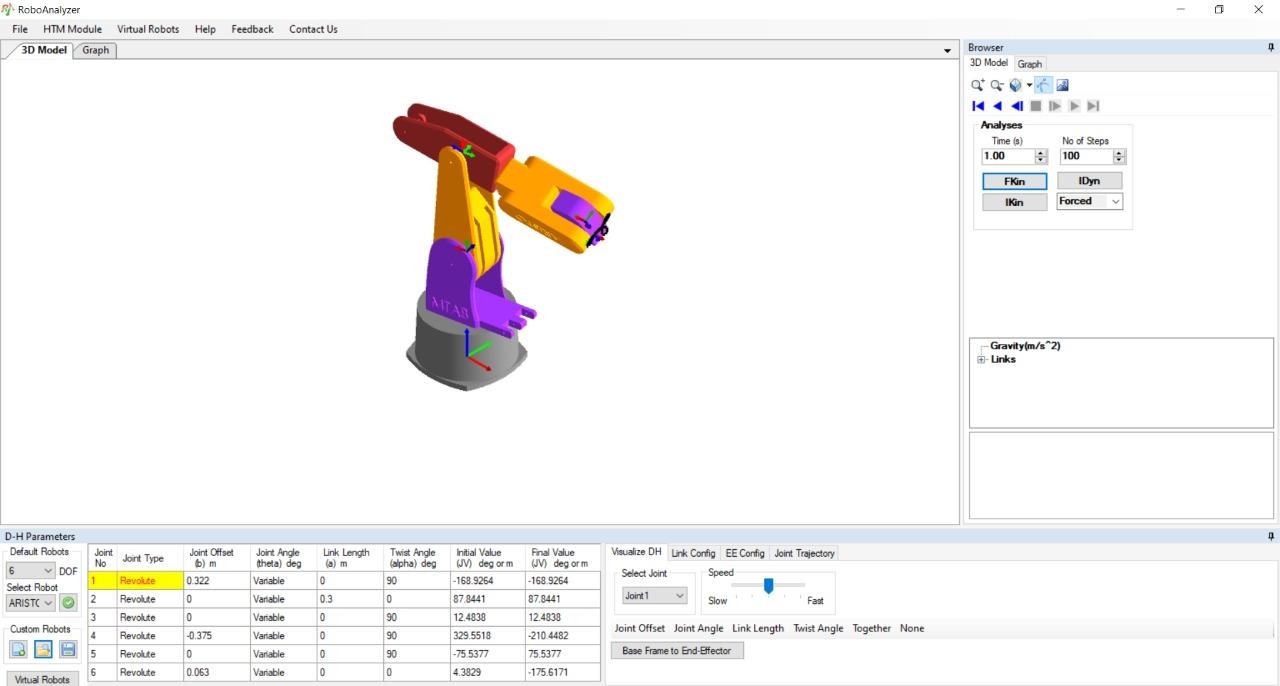
The limited weight of each robot is its payload. So, the critical specifications and tooling weights are sorted out to **100gms**. Since it is a prototype, lesser payload would be cost effective.

##### Reach:

In our articulated robot, we need to check the two extremities that is nothing but the V-reach and H-reach. Vertical reach is considered to know how high our robot can go in terms of height extension. Whereas the Horizontal reach is considered to know the distance of fully extended arm from base to wrist. Hence, we have a **V-reach of 350mm** and **H-reach of 320mm**.

##### Axes:

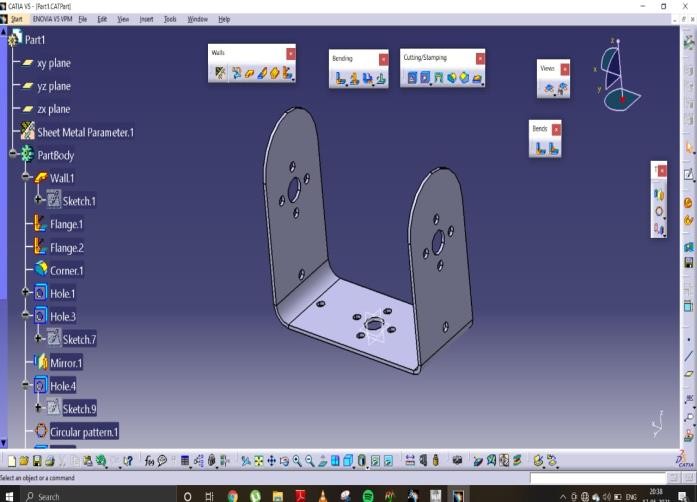
The distinctive segments of our robot are associated with mechanical joints that serve as an axis of movement. We have designed our articulated robot with **3-axis of movement**. Generally according to our knowledge industrial robots are designed to have 6-axis of movement, but the number and placement of robots just gives flexibility variation for each model.



[Figure (C): Robo-Analyzer Software]

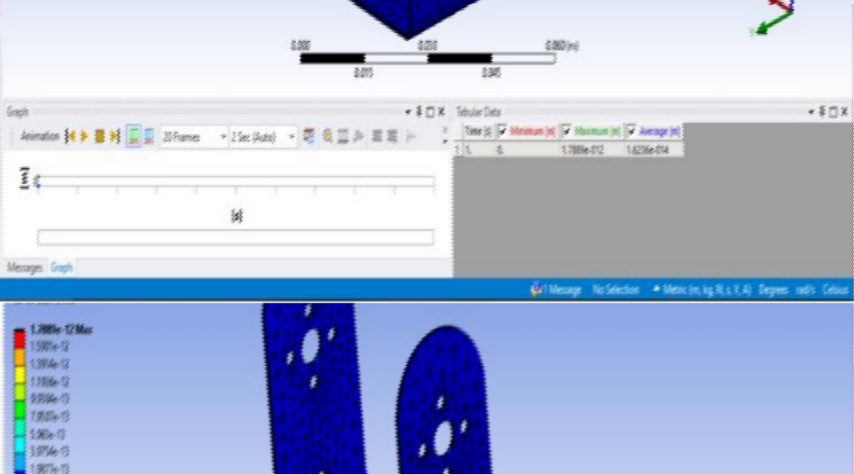
### Design Implementation:

* + 1. U shaped Aluminium Bracket

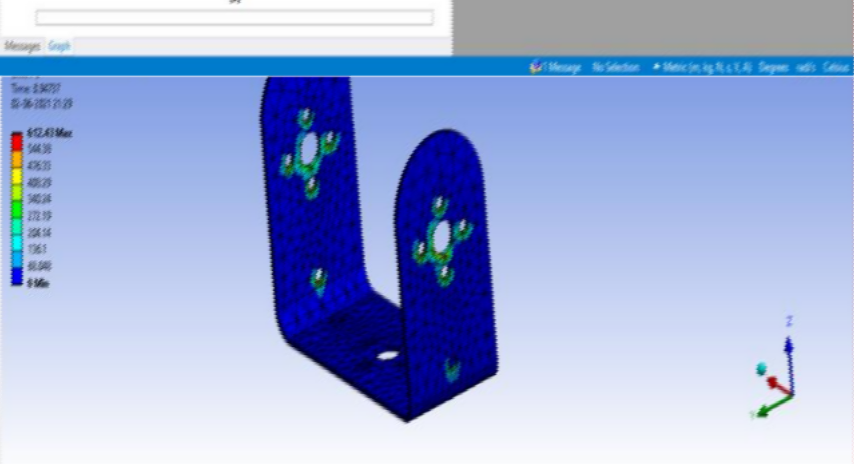


CAD Model of U - shaped bracket

Actual U – shaped Aluminium bracket

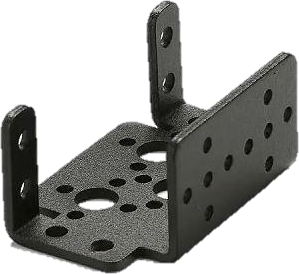
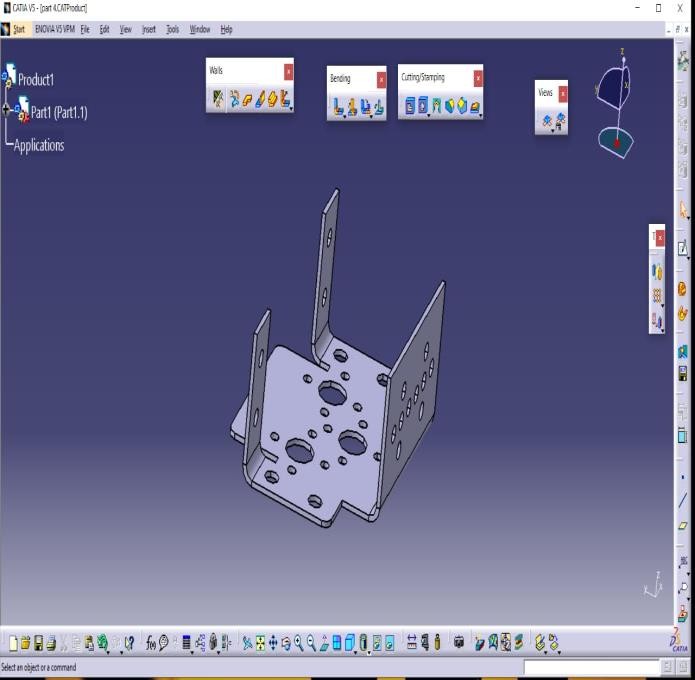


Deformation in the bracket



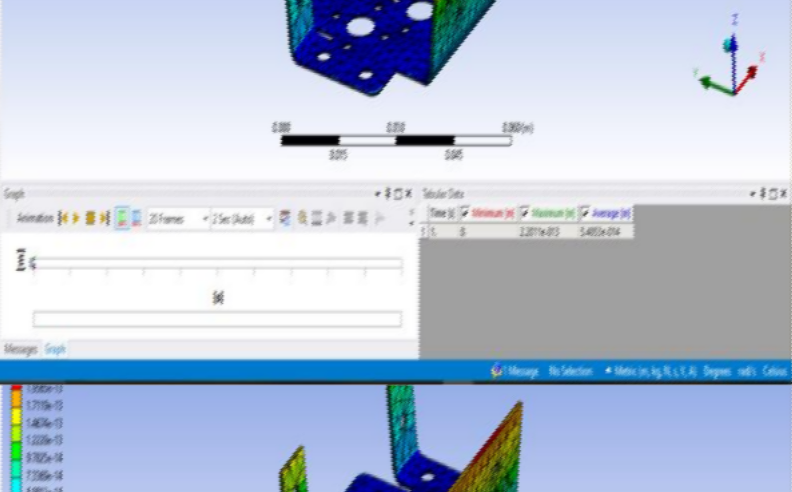
Stress in the bracket

* + 1. Multipurpose Aluminium Bracket

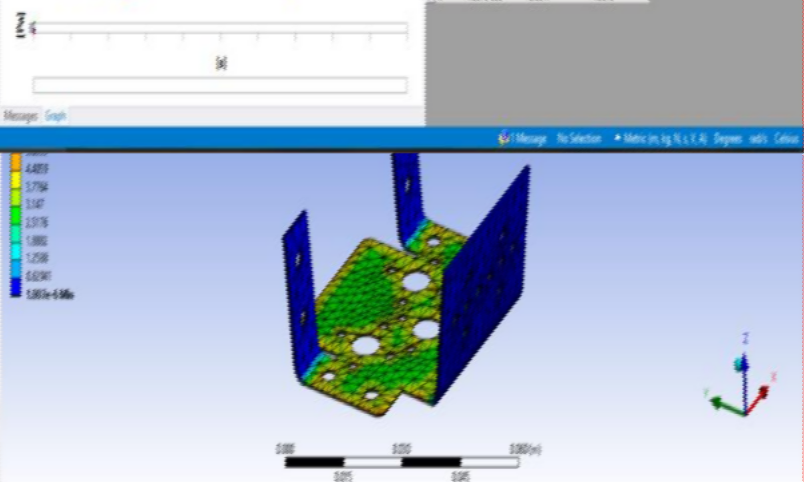


CAD Model of Multipurpose servo bracket

Actual Multipurpose Aluminium bracket

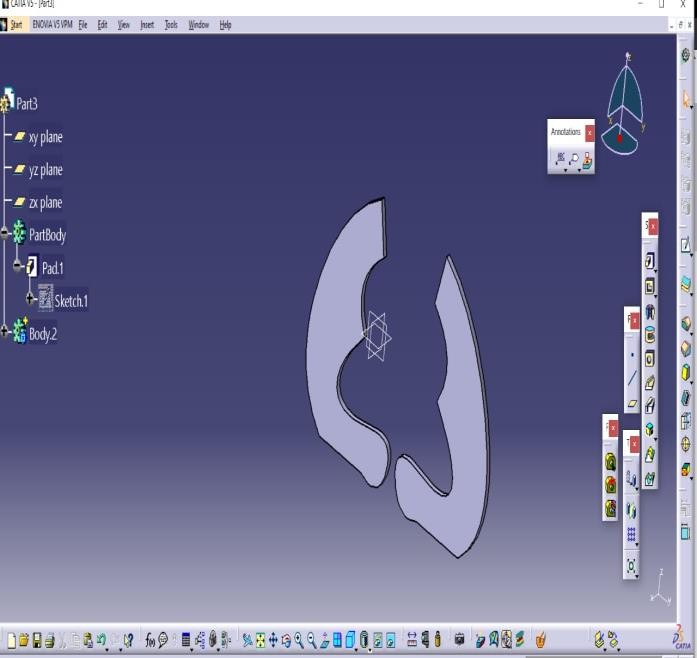


Deformation in Multipurpose servo bracket



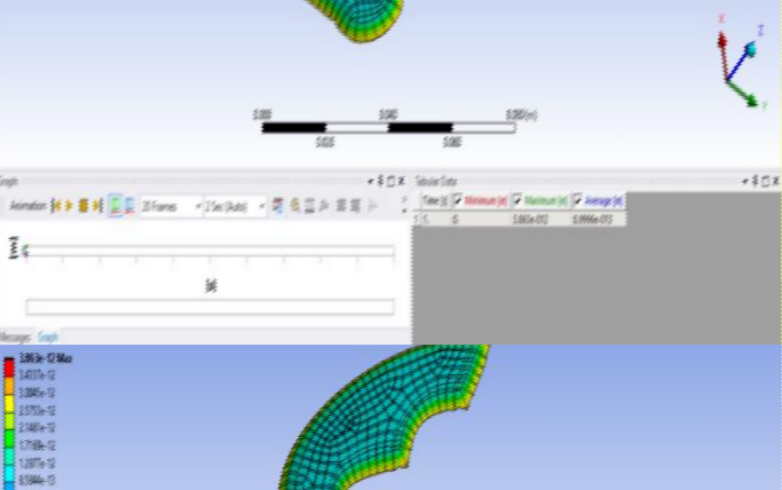
Stress in Multipurpose servo bracket

* + 1. Gripper Arm

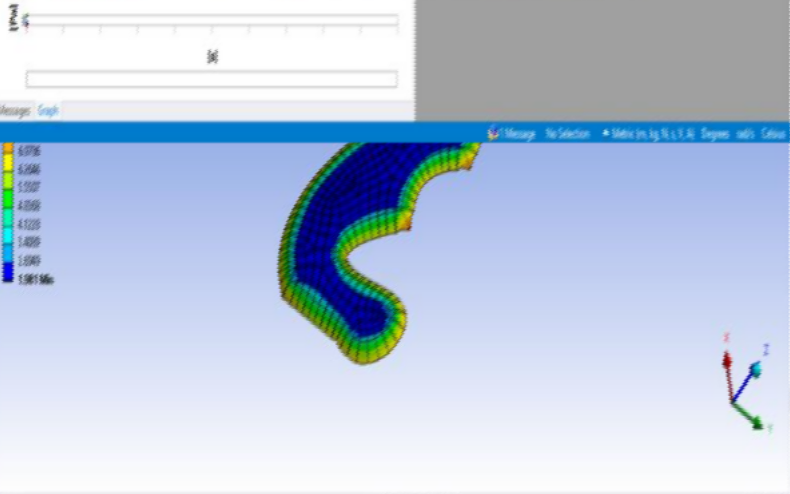


CAD Model of Gripper Arm

Actual Gripper Arm

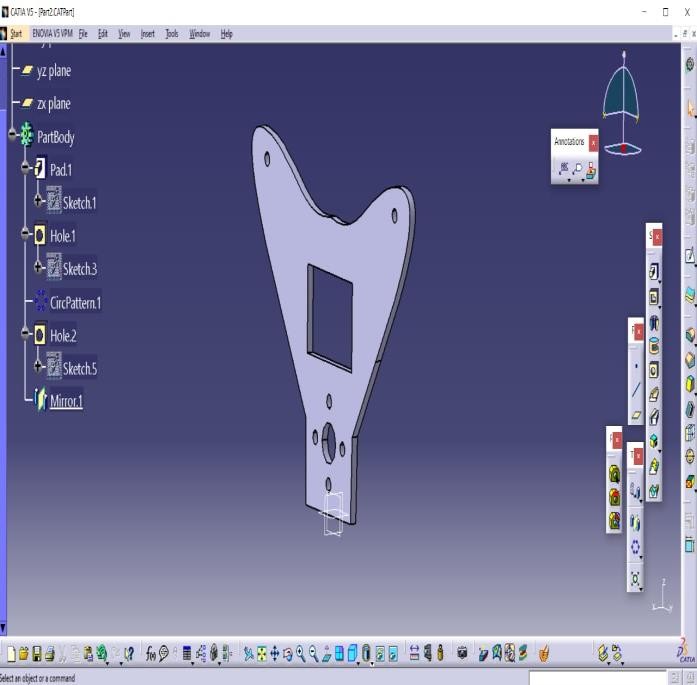


Deformation on Gripper Arm



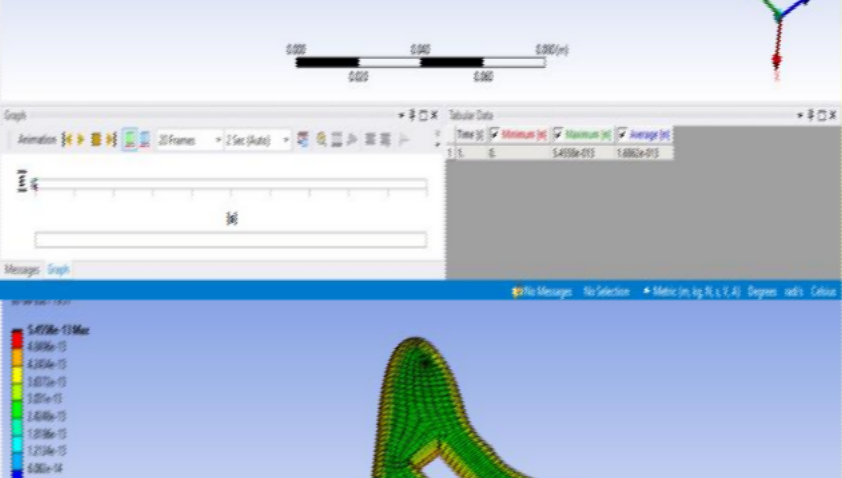
Stresses on Gripper Arm

* + 1. Gripper Base

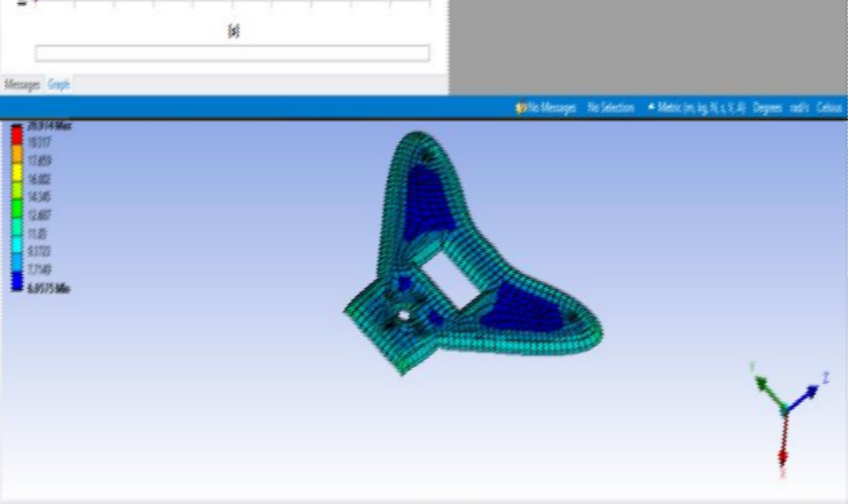


CAD Model of Gripper Base

Actual Gripper Base

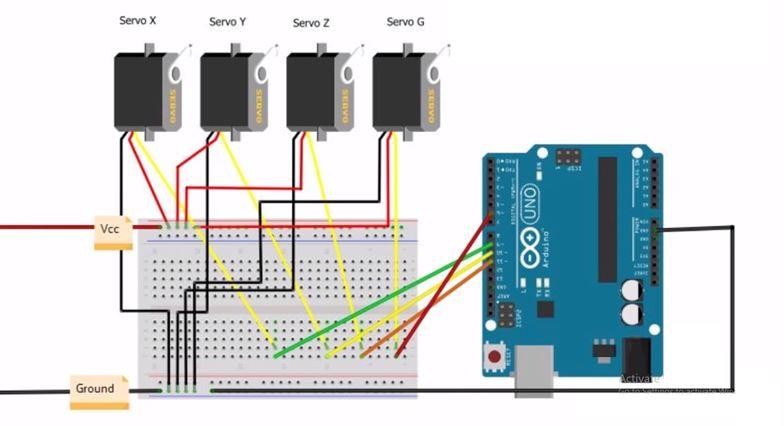


Deformation on Gripper Base



Stresses on Gripper Base

* 1. **Working System:**



[Figure (E): Arduino Circuit for the system]

1. **Arduino:**

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz quartz crystal, a USB connection, a power jack and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

#### Specifications:

|  |  |
| --- | --- |
| Microcontroller | ATmega328P |
| Operating Voltage | 5V |
| Input Voltage (limit) | 6-20V |
| Digital I/O Pins | 14 |
| PWM Digital I/O Pins | 6 |
| Analogue Input Pins | 6 |
| DC Current per I/O Pin | 20 mA |
| DC Current for 3.3V Pin | 50 mA |
| Flash Memory | 32 KB (ATmega328P) |

[Table (B): Arduino Specifications]

The Arduino Uno can be programmed with the (Arduino Software (IDE)).The ATmega328 on the Arduino Uno comes pre-programmed with a boot loader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol.

### Selection of wireless communication:

##### Bluetooth:

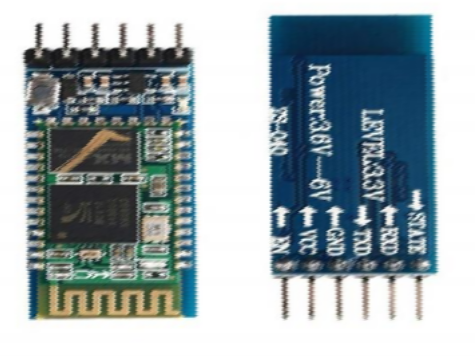
Bluetooth is a wireless communications protocol running at 2.4 GHz, with ISM band, suitable for forming personal area networks. It is designed for low power devices such as mobile phones. Bluetooth now comes as standard on the majority of mobile phones, and desktop computers. It can be easily fitted with a module to allow Bluetooth communication.

##### Bluetooth Module:

We have used the HC-05 Bluetooth module for our project. **The HC-05** is a very cool module which can add two-way (full-duplex) wireless functionality to your projects. You can use this module to communicate between two microcontrollers like Arduino or communicate with any device with Bluetooth functionality like a Phone or Laptop. There are many android applications that are already available which makes this process a lot easier. The module communicates with the help of USART at 9600 baud rate hence it is easy to interface with any microcontroller that supports USART. We can also configure the default values of the module by using the command mode.

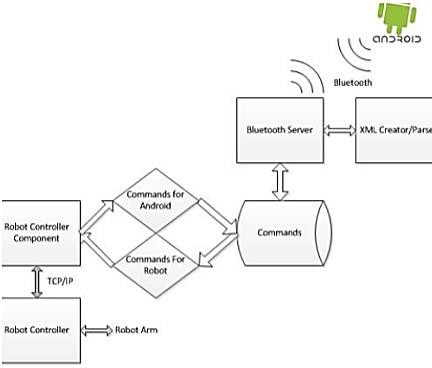
##### HC 05 Pin Structure:

* 1. KEY – Select Master or Slave; Slave by default.
  2. VCC – Power Suppy
  3. GND - Ground
  4. TXD – Transmitter Pin
  5. RXD – Receiver Pin
  6. STATE- Indicates whether the signal is sent or not.



[Figure (F): Bluetooth Module HC - 05]

### Application Connectivity:

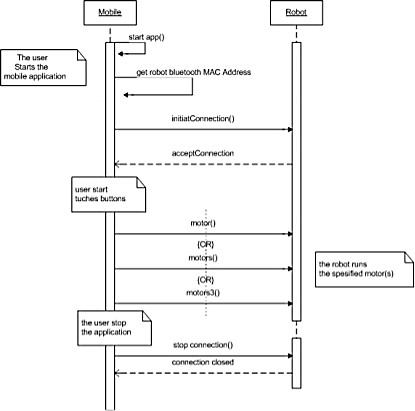


[Figure (G): Android Connectivity]

This project uses Bluetooth to connect and send direct commands from the mobile phone to control the robot based on direct Commands Communication Protocol. Above figure shows the typical sequence of events when a user runs the application.

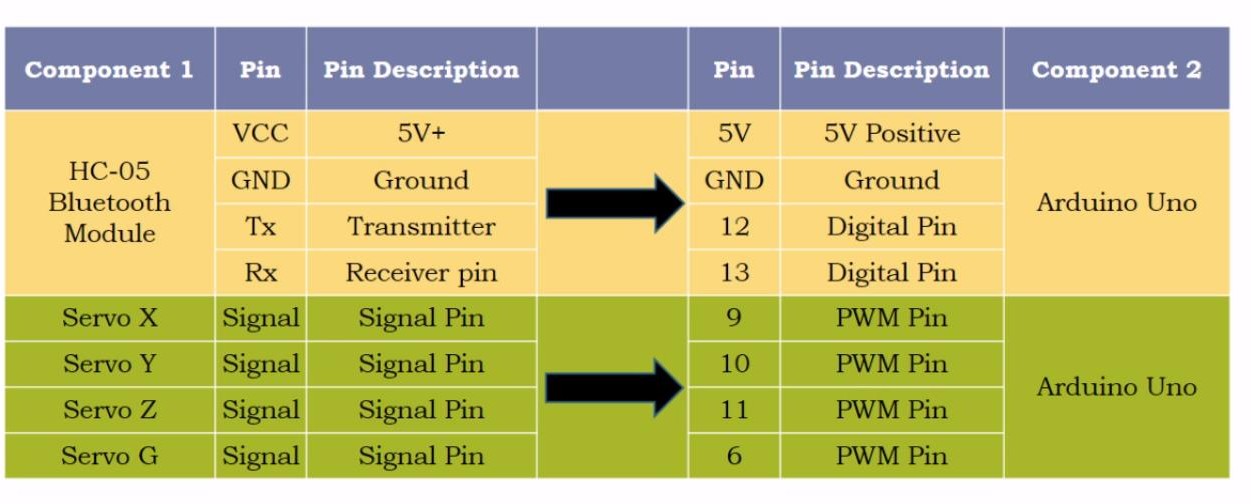
This sequence diagram assumes the user already has the software on his phone and the robot and it represents an abstract level of the interaction between the system components (mobile application and the robot). HC-05 embedded Bluetooth serial communication module has two work modes: order-response work mode and automatic connection work mode. HC-05 embedded

Bluetooth serial communication module has two work modes: order-response work mode and automatic connection work mode.



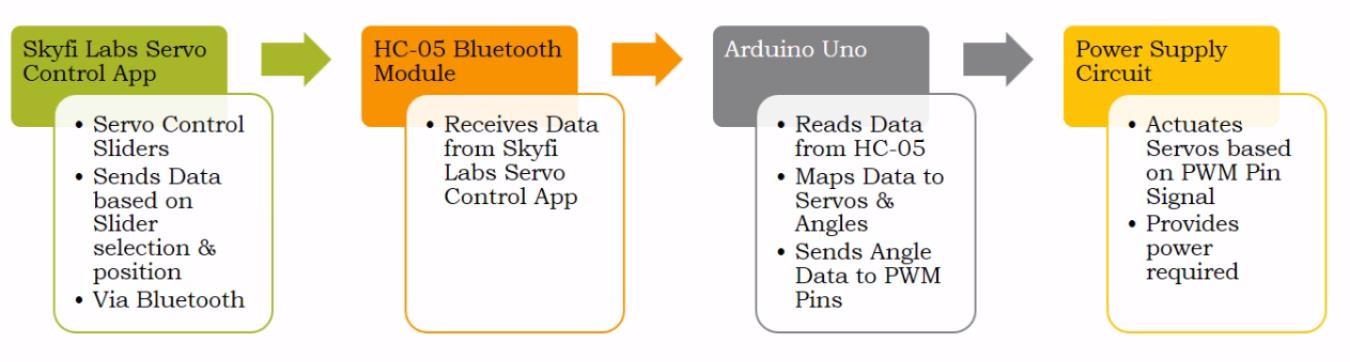
[Figure (H): Bluetooth Interface]

When the module is at the automatic connection work mode, it will follow the default way set lastly to transmit the data automatically. When the module is at the order-response work mode, user can send the AT command to the module to set the control parameters and sent control order. The work mode of module can be switched by controlling the module input level.



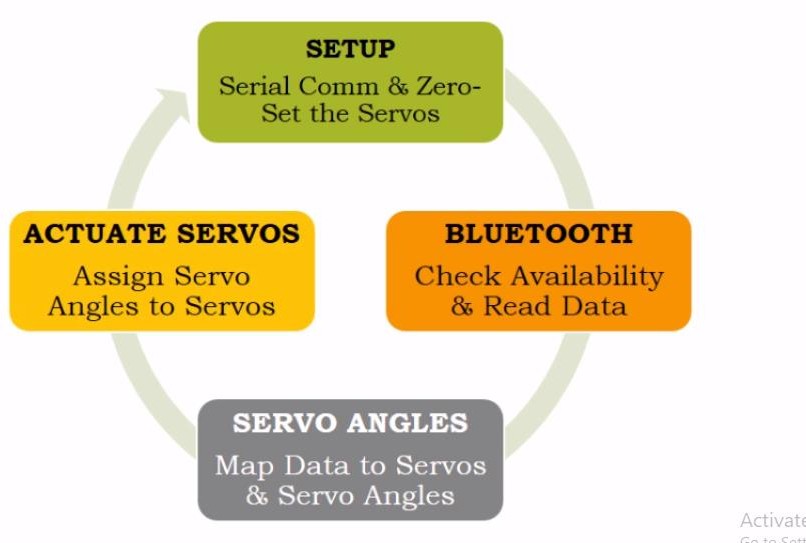
[Table (C): Connection Circuit]

The commands to the Bluetooth modem have to be sent as attention command. These commands are used for initial configuration devices such as baud rate specification, device address and modes of operation. Based on operation, two kinds of modes to be used, they are command mode and bypass mode. On command mode, it is command to locally connected Bluetooth device, while at bypass mode it should be a command to be executed on remotely connected Bluetooth device. The mobile application consists of many User Interfaces connected to each other, each interface specialized to control a specific functionality on the robot side, each button will send different command to the android client API that will process and execute the command.



[Chart (D): Control Process]

The Bluetooth server receives XML data from the Android phone. This data is then sent to the XML Service for parsing and then sent back to the server. The server then evaluates the message type. If the message is a command for the robot, the command is forwarded to the robot controller component and in turn forwarded to the robot controller for execution. If the message is a status update request, then a request is forwarded to the robot controller which sends the update data back to the server which then forwards the data back to the Android phone. The robot controller component maintains a queue of commands received from the phone to forward to the robot. The controller component also keeps a set of time stamped location and program data that is updated regularly, to be forwarded back to the phone upon request.



[Chart (E): Control Cycle]

### Motors:

##### Servo Motor: TowerPro MG996R:

Servo refers to an error sensing feedback control which is used to correct the performance of a system. Servo Motors are DC motors equipped with a servo mechanism for precise control of angular position. This continuous rotation motor has the ability to rotate continuously in 360 degrees. It makes this servo motor perfect for our manipulator.

##### Specifications:

|  |  |
| --- | --- |
| Operating Voltage | 4.8 - 6.0 |
| Operating Temp. Range | 0 to 55 deg. |
| Operating Speed (at 6.0 V) | 0.15sec/ 60 deg |
| Stall torque (at 4.8 V) | 9.4Kg-cm |
| Stall torque (at 6.0 V) | 11Kg-cm |
| Current Draw at idle | 10 MA |
| Weight | 55 gm. |

[Table (D): Servo MG996R Specification]

##### Servo Motor: TowerPro SG90 Mini:

The Servo Motor is a 180° rotation servo. It is a digital servo motor that receives and processes PWM signal faster and better. It equips sophisticated internal circuitry that provides good torque, holding power, and faster updates in response to external forces. It equips carbon fibre gears which make the servo motor much lighter than the same metal gear motor.

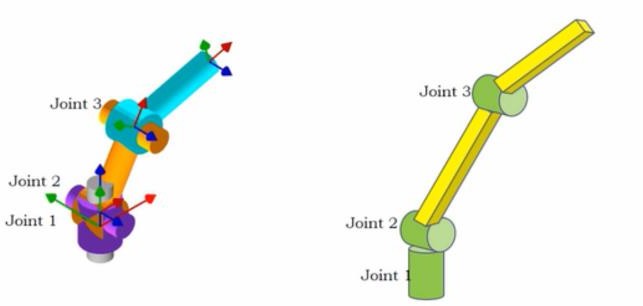
##### Specifications:

[Table (E): Servo SG90 Specification]

|  |  |
| --- | --- |
| Operating Voltage | 3.0 – 7.2 |
| Operating Temperature Range | 3.0 – 7.2 |
| Operating Speed (at 6.6 V) | 0.16sec/ 60 deg |
| Stall torque (at 4.8 V) | 1.2 Kg-cm |
| Stall torque (at 6.6 V) | 1.6 Kg-cm |
| Current Draw at idle | 10 MA |
| Weight | 9 gm. |

### Motor Selection:

##### Torque calculation:



[Figure (I): Line Diagram of manipulator]

The equations used in the calculator to determine the torque required at any given lifting joint (raising the arm vertically) in a robotic arm are presented here. Torque (T) is defined as a turning or twisting “force” and is calculated using the following relation:

**T = F x L (A)**

The force (F) acts at a length (L) from a pivot point. In a vertical plane, the force acting on an object (causing it to fall) is the acceleration due to gravity (g = 9.81m/s2) multiplied by its mass (m)**:**

##### F = m x g (B)

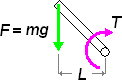
The force above is also considered the object's weight (W):

##### W = m x g (C)

The torque required to hold a mass at a given distance from a pivot is therefore:

##### T = m x g x L (D)

This can be found similarly by doing a torque balance about a point. Note that the length L is the PERPENDICULAR length from the pivot to the force.



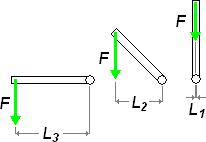
[Figure (J): Torsional force on joints]

### Σ T = 0 = F x L – T ……(E)

Therefore, replacing F with m\*g, we find the same equation above. This method is the more accurate way to find torque (using a torque balance).

##### m x g x L = TA (F)

Hence, in order to estimate the torque required at each joint, we must choose the worst-case scenario.

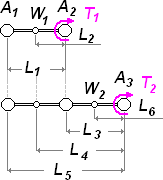
[Figure (K): Force on various joints]

In the above image, a link of length L is rotated clockwise. Only the perpendicular component of length between the pivot and the force is taken into account. We observe that this distance decreases from L3 to L1 (L1 being zero). Since the equation for torque is length (or distance) multiplied by the force, the greatest value will be obtained using L3, since F does not change. You can similarly rotate the link counter- clockwise and observe the same effect.

The weight of the object (the "load") being held, multiplied by the distance between its centre of mass and the pivot gives the torque required at the pivot. The tool takes into consideration that the links may have a significant weight (W1, W2) and assumes its centre of mass is located at roughly the centre of its length. The torques caused by these different masses must be added:

### T1 = L1 x A1 + 0.5 (L1 x W1) ……(G)

The length between its centre of mass and the pivot point is zero hence, when calculating the torque required by the actuator A3 its own mass is not considered. The torque required at the second joint must be re-calculated with new lengths, as shown below:

[Figure (L): Axial load on joints]

### T2 = L5 x A1 + L4 x W1 + L3 x A2 + L6 x W2 … (H)

Knowing that the link weight (W1, W2) is located in the centre (middle) of the lengths, and the distance between actuators (L1 and L3 as in the diagram above) we re-write the equation as:

##### T2 = (L1 + L3) x A1 + (0.5L1 + L3) x W1 + L3 x A2 + 0.5L3 x W2 ……(I)

The tool only requires that the user enter the lengths of each link, which would be L1 and L3 above so the equation is shown accordingly. The torques at each subsequent joint can be found similarly, by re- calculating the lengths between each weight and each new pivot point. The above equations only deal with the case where the robot arm is being held horizontally (not in motion)

For the arm to move from a rest position, acceleration is required. To solve for this added torque, it is known that the sum of torques acting at a pivot point is equal to the moment of inertia (I) multiplied by the angular acceleration (alpha):

##### T = I x α ………(J)

To calculate the extra torque required to move (i.e., create an angular acceleration) you would calculate the moment of inertia of the part from the end to the pivot using the equation:

##### I = m x (K)

This equation calculates the moment of inertia about the centre of mass. In the case of a robotic arm, the moment of inertia must take into consideration that the part is being rotated about a pivot point located a distance away from the centre of mass and a second term ( +mr ) needs to be added. For each joint, the moment of inertia is calculated by adding the products of each individual mass (mi) by the square of its respective length from the pivot (ri). Note that the equation for calculating the moment of inertia to consider for actuator N omits the mass of the actuator at the pivot point:

∑

**……………(L)**

In all cases considered here, „r‟ represents the distance from the centre of mass to the pivot. Since the moment of inertia varies tremendously from part to part, angular acceleration is not taken into consideration with the Robot Arm Torque Calculator. Instead, to correct for possible angular acceleration, a “safety factor” is used and set to 2 by default. As with all dynamic tools, inefficiencies in the actuators and joints themselves must also be taken into consideration. This way, the motor at each joint will be able to provide more than the required torque to keep the arm stationary. The required torque to accelerate the weight being support by an actuator from a static position can be calculated using the following relation:

**Σ TN = TN (HOLDING) + TN (MOTION) = I x α ……(M)**

Now,

L: length from pivot to pivot. M: link mass

A: Actuator (servo) mass.

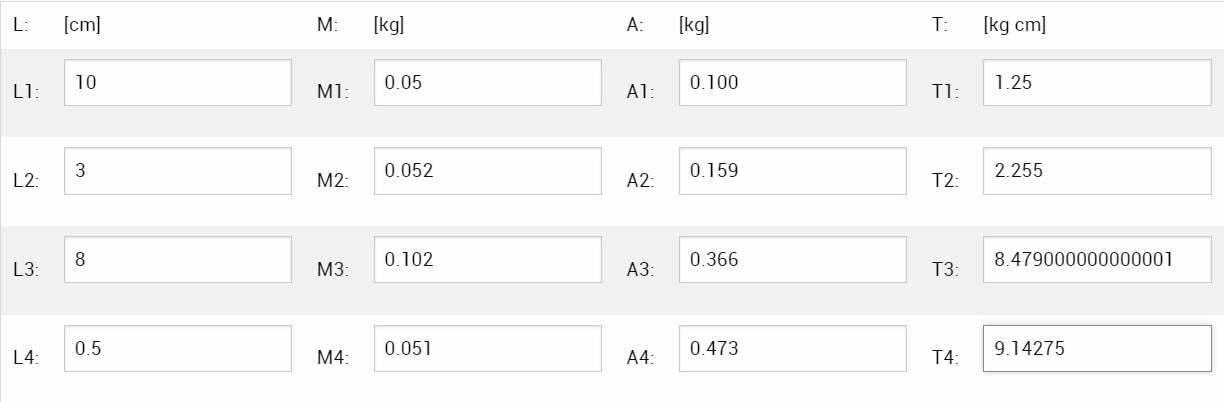
A1: can represent the load being lifted.

L1 = 10 cm = Gripper Length M1 = 0.05 kg

L2 = 3 cm M2 = 0.052 kg

L3 = 8 cm M3 = 0.102 kg

L4 = 0.5 cm M4 = 0.051 kg



[Table (F): Calculated torque]

A1 = 0.100 kg (Object weight)

A2 = 0.159 kg (gripper + gripper servo + object weight)

A3 = 0.366 kg (gripper + gripper servo + servo 1 + bracket + 2 u brackets + object weight)

A4 = 0.473 kg (gripper + gripper servo + servo 1 + bracket + 2 u brackets + servo 2 + bracket + object weight)

By calculations we get following torque T1 = 1.25 kg-cm

T2 = 2.55 kg-cm T3 = 8.479 kg-cm T4 = 9.142 kg-cm

### Hence, we used one TowerPro SG90 Mini Servo and three TowerPro Mg996R High Torque Metal Gear Servo Motors.

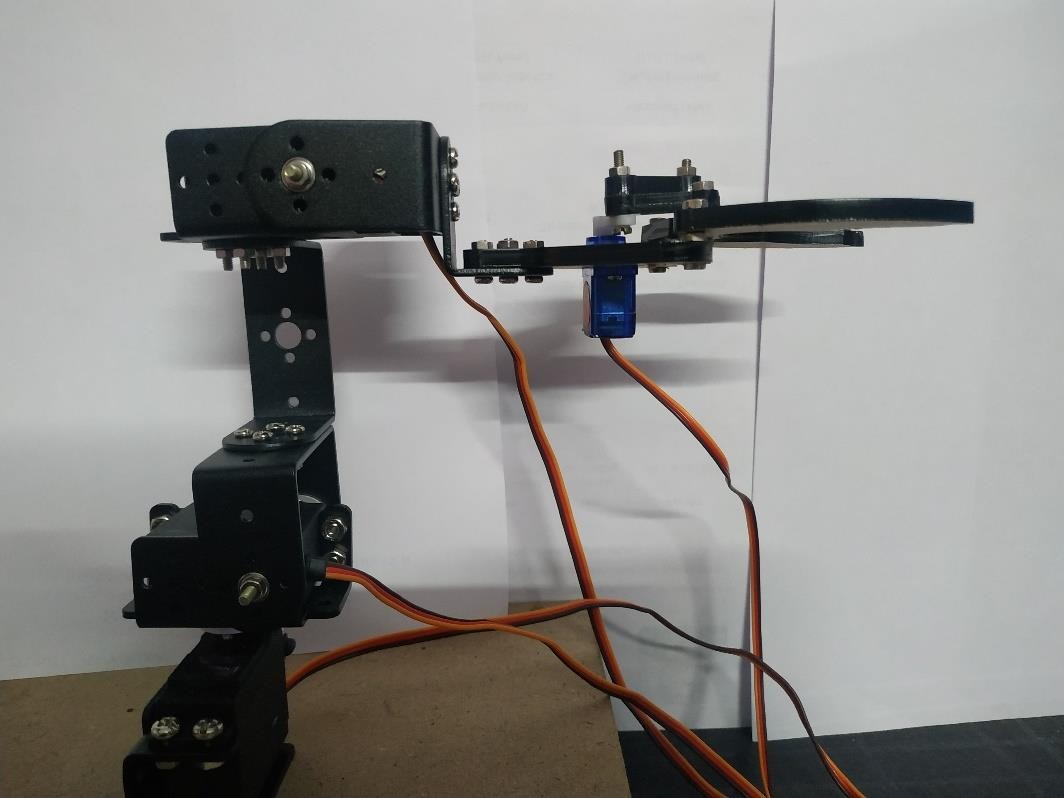


[Figure (M): Servo motors used]

### Actual Assembly of the System:



[Figure (N): Actual manipulator TV]



[Figure (O): Actual manipulator SV]

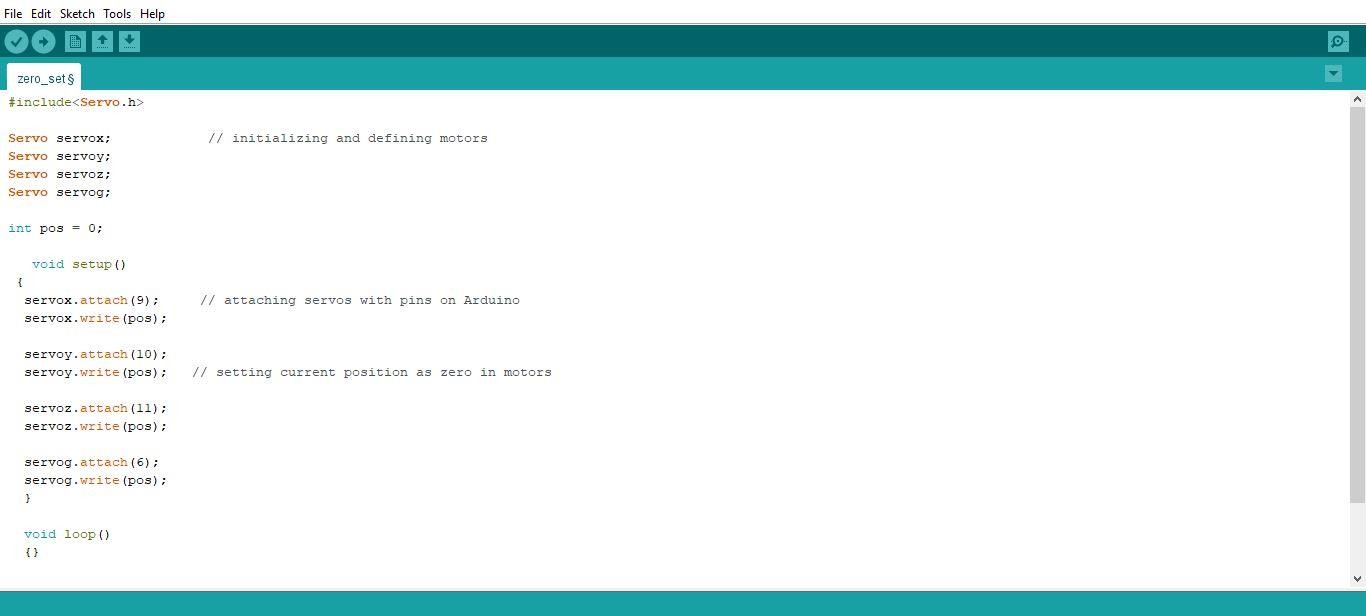
## CHAPTER - IV

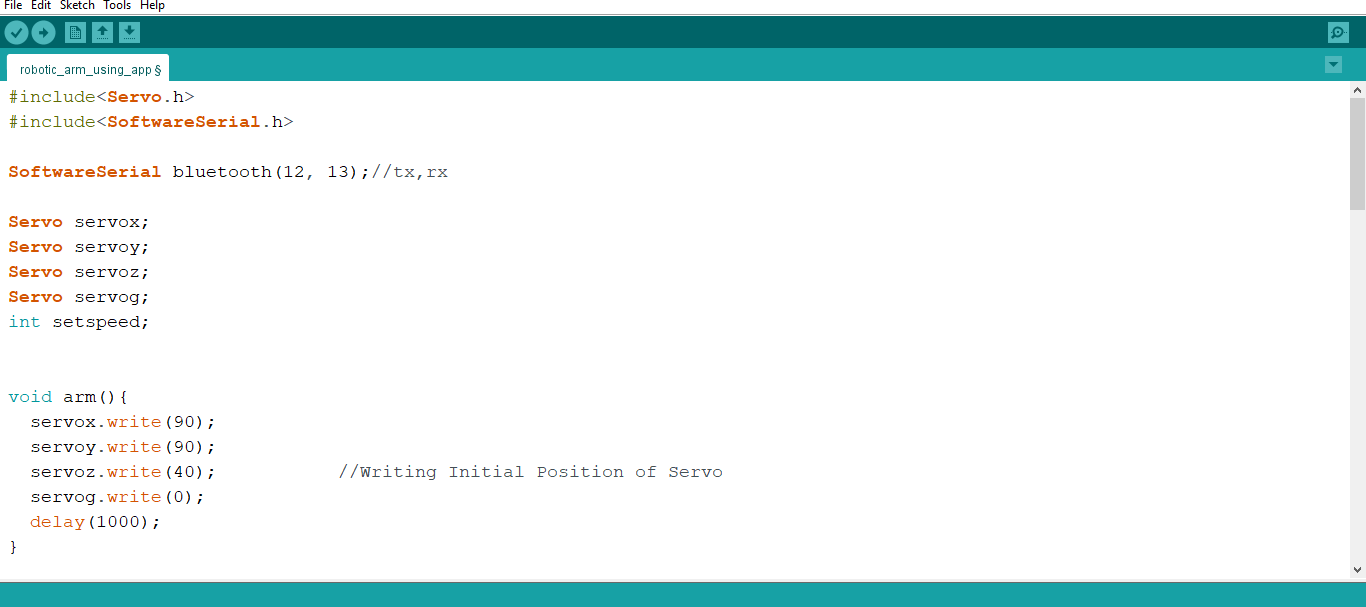
1. **Experimental Result**

#### Programming:

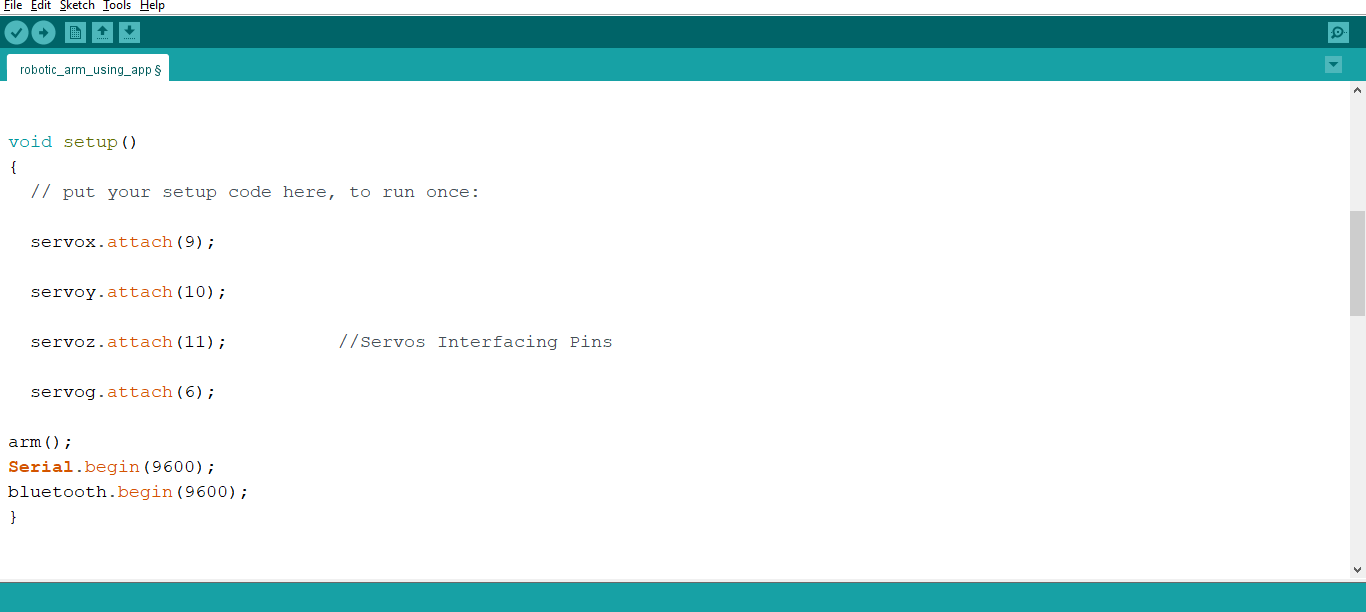
[Figure (P): All Arduino IDE Programs]

Zero postioning program for servo motors:

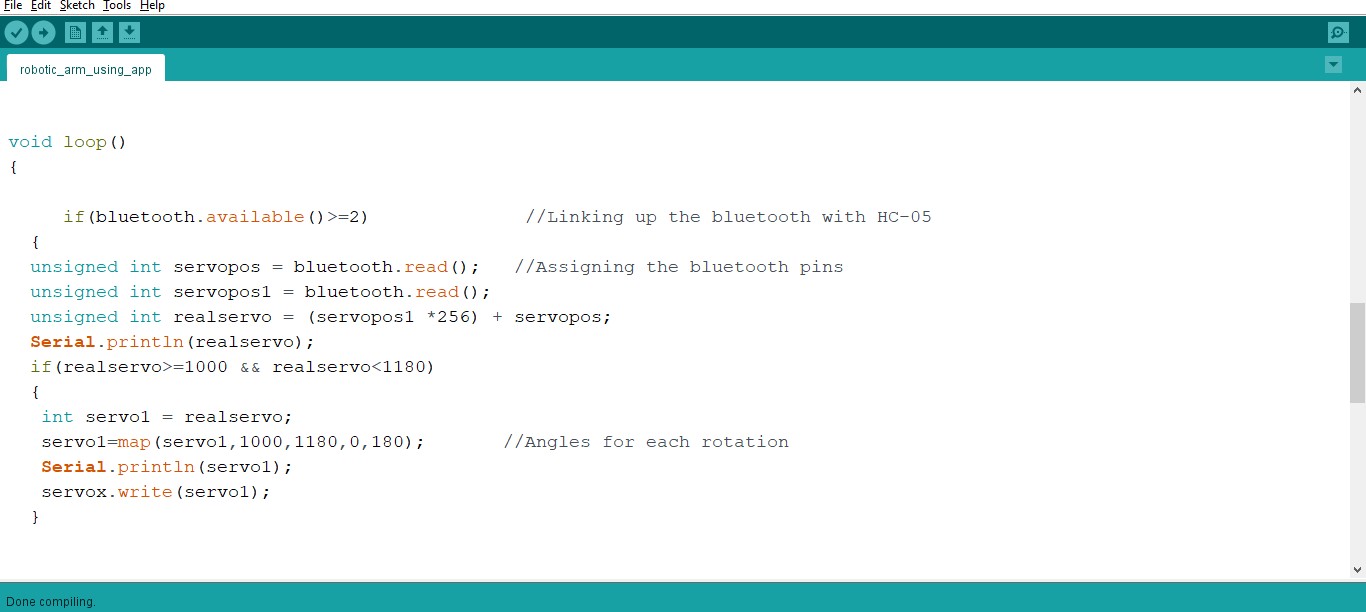


Program for Arduino setup

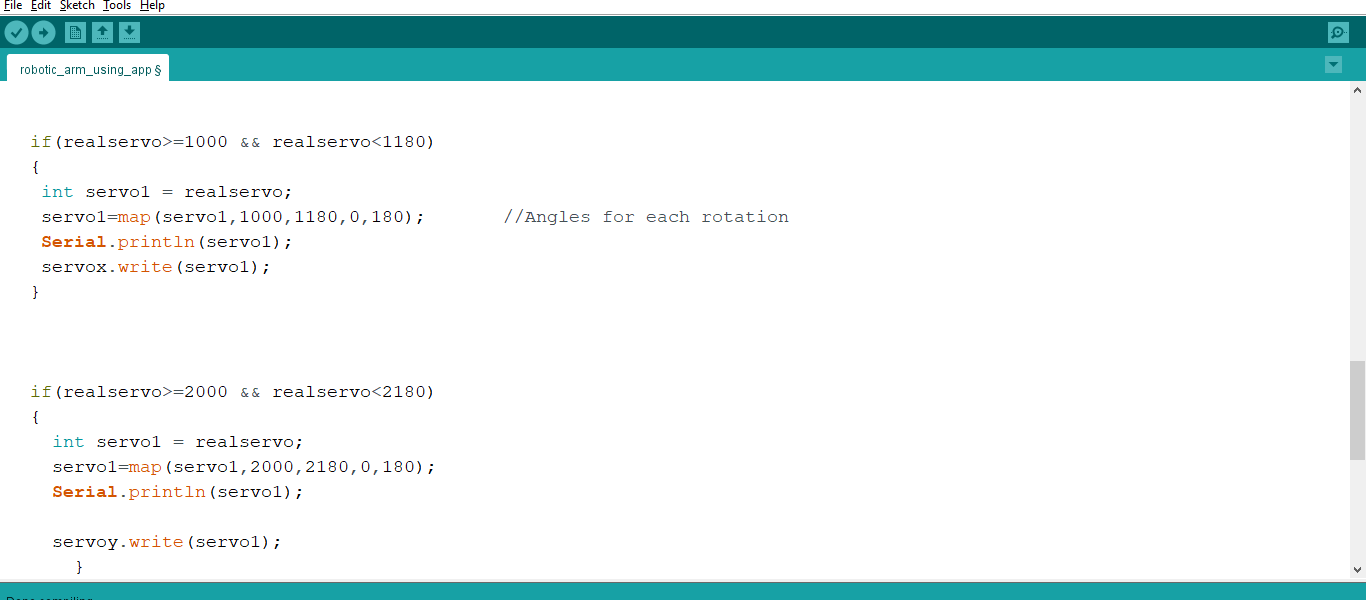
Defining all the directories and the motors:



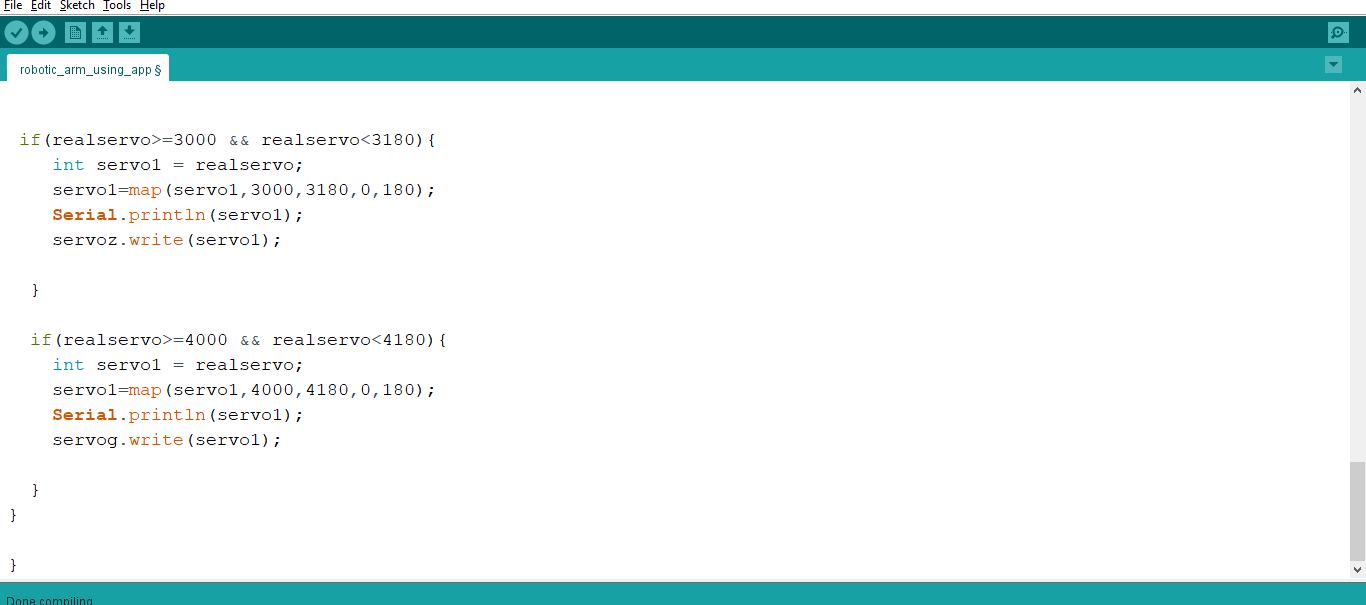
Initial setup for the input pins, Bluetooth connection:



Setting up angles for rotation of motors x and y:



Final part of program for motor z and gripper motor:



* 1. **Key details of the Robotic Manipulator:**

|  |  |  |
| --- | --- | --- |
| 1. | Support:  Material Dimensions  Weight | Wooden chassis 220 x 220 mm  100 gm. |
| 2. | Manipulator Base:  Material  Total Height Weight | Aluminium 45 mm  50 gm. |
| 3. | Link 1:  Material Total Height  Weight | Aluminium 50 mm  70 gm. |
| 4. | Arm:  Material  Total Length Weight | Aluminium 85 mm  90 gm. |
| 5. | Dexterity:  H – reach V -- reach | 320mm 350mm |
| 6. | Total Height of the Manipulator | 165 mm |
| 7. | Total weight of the Manipulator | 800 gm. |
| 8. | Max. payload on end effector | 50 gm. |
| 9. | Degree of Freedom | 4 |
| 10. | Motors used:  Servo Motor (11 kg-cm) Servo Motor (1.6 kg-cm) | 3  1 |

[Table (G): Manipulator Details]

1. **Cost Estimation**

**CHAPTER - V**

[Table (H): Pricing of material]

|  |  |  |  |
| --- | --- | --- | --- |
| **SR.NO.** | **ITEM NAME** | **QTY.** | **COST (RS.)** |
| 1. | High Torque Mg996 R Metal Gear  Digital Servo | 3 | 1800 |
| 2. | SG90 Servo – 9 gm. Mini | 1 | 119 |
| 3. | HC - 05 Bluetooth Module | 1 | 550 |
| 4. | Arduino UNO with USB Cable | 1 | 499 |
| 5. | USB Charger – 2.4A | 1 | 350 |
| 6. | Multipurpose Aluminium Standard  Servo Bracket | 3 | 357 |
| 7. | U Shape Aluminium Servo Bracket | 3 | 299 |
| 8. | L Shaped Interconnect Servo Bracket  Small | 1 | 79 |
| 9. | Gripper Arms | 1 | 399 |
| 10. | 1 Pin Jumper Wires- M/M (3 Different  colour set) | 10 | 65 |
| 11. | Metal Horn for Servo 25T | 3 | 270 |
| 12. | Metal Cup Micro Ball Bearing Small  Bearings 3 x 8 x 4 mm | 3 | 190 |
| 13. | Solder-less Breadboard(small) | 1 | 69 |
| 14. | Wire Stripper | 1 | 57 |
| 15. | Wooden Chassis- 22cm\*22cm | 1 | 99 |
| 16. | 1Pin Jumper Wires- M/M | 6 | 55 |
| 17. | 1 Pin Jumper Wires- M/F | 5 | 50 |
| 18. | Screw Driver (star) | 1 | 120 |
| 19. | Screw Driver(minus) | 1 | 120 |
| 20. | Servo Cable Extender | 1 | 39 |
|  |  | **TOTAL** | **₹ 5586/-** |

## CHAPTER - VI

1. **Concluding Remarks & Scope for the Future**
   1. **Concluding Remarks:**
2. The generation of the human-like manipulation motions has been implemented for the 4 degrees of freedom (DOF) arm of the humanoid robot.
3. The main reason to make the choice of designing a robotic arm was firstly to pick and place components in industry. Second, there is a space constraint we have in the industry.
4. The main task was to design a machine which fits in the environment and serves the purpose which has been achieved. But this is not the ultimate design.
5. We tried to cover all the aspects of design and structural analysis in our work. But there is still a large chance of upgrading the machine.
6. This system would make it easier for human beings to pick and place the risk of handling suspicious objects, which could be hazardous in its present environment and workplace.

##### Complex and complicated duties can be achieved faster and more accurately with this design.

* 1. **Scope for the Future:**

Although a good effort is put in building and analysing this system, this cannot be taken for granted. There are many other parameters on which the quality of a model is dependent on. The easiest way to design and analyse a robotic arm is described and explained in this document. We cannot say it is perfect. In fact, no design is perfect. It is all about how close you can get to perfection. This model needs to be optimized. We must have a detailed explanation on what effect could take place on what area of the robotic arm if a parameter is changed, especially design parameters like volume, thickness, material. Also, the cost study is needed to be performed in a more detailed way. After all, a good machine is also judged on how affordable it can be. There is always more room for innovation in any study. During this project, we came across many modern innovative automation techniques that today's world has developed. If given a chance to do this project again, we are very much interested in applying those techniques. One such technique is application of fluidic muscles. A fluidic muscle is an artificial version of human muscle. Not only this, many other techniques are applicable for this kind of machine.

##### With all these additions, the machine gets upgraded into a super machine with ultimate application of automation.

**CHAPTER - VII**

1. **References:**
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2. Design, Analysis and Implementation of a Robotic Arm- The Animator by Md. Anisur Rahman1, Alimul Haque Khan, Dr. Tofayel Ahmed3 Md. Mohsin Sajjad Volume-02, Issue-10, pp-298-307
3. Designing a Robotic Arm for Moving and Sorting Scraps at Pacific Can, Beijing, China by Mohamad Alblaihess ,William Farrar,Fernando Gonzalez, Yifan Shao.
4. Nikesh. R. Vange, Atul .V. Nar, Dhananjay .B. Surve, Anita. P. Trimukhe, Manisha .M. Patil, Rajesh

.A. Patil, Object Sorting Robotic Arm Based on Color Sensing Mechanism , International Journal of Emerging Technology and Advanced Engineering , (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 5, Issue 5, May 2015)

### Papers from Conference Proceedings :

1. “Survey of Robotic Arm and Parameters” Conference Paper · January 2016

* 1. **Reference Books:**

1. “Industrial Robotics”, M P Groover, Tata McGraw Hill
2. Er. R.K.Rajput, “Robotics and Industrial Automation‟, S. Chand Publications, 2014.