PICK AND PLACE ROBOTIC ARM FOR THE ELDERLY & DISABLED

Report submitted to the SASTRA Deemed to be University
as the requirement of the course

MEC300/MCT300 MINI PROJECT

Submitted by

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May 2023

SCHOOL OF MECHANICAL ENGINEERING
THANJAVUR - 613401

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Bonafide Certificate

This is to certify that the report titled "**Pick & Place Robotic Arm For The Elderly & Disabled**" submitted as a requirement for the course, **MEC300/MCT300 Mini-Project** for B.Tech. Mechanical Engineering & B.Tech. Mechatronics programme, is a bonafide certificate of the work done by **Mr. Jamalapuram Praharshith Kashyap (Reg No: 124009054), Mr. Annadanam Satvik (Reg no: 124009118) & Ms. Ruchi Gupta (Reg No: 124012036)** during the Academic Year 2022-23, in the School of Mechanical Engineering, under my supervision.

Signature of the Project Supervisor : 16/05/2023

Name with Affiliation : **Dr. C. Ramprasadh, Professor**

Date : **16-05-2023**

Mini-Project Viva-voce conducted on :

Examiner 1 **Examiner 2**

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Declaration

We declare that the report "**Robotic Arm For The Elderly & Disabled**" submitted by us is an original work done by us under the guidance of **Dr. C. Ramprasadh, Senior Professor, School of Mechanical Engineering, SASTRA Deemed to be University** during the even semester of the Academic Year 2022-23, in the **School of Mechanical Engineering**. The work is original and wherever we have used materials from other sources, we have given due credit and cited them in the text of the report. This report has not formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title to any candidate of any University.

Signature of the Candidates:

Name of the Candidates:
Jamalapuram Praharshith Kashyap (Reg No: 124009054)
Annadanam Satvik (Reg No: 124009118)
Ruchi Gupta (Reg No: 124012036)

Date: 17-05-2022

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Nomenclature

Abbreviation	Full Form
DoF	Degrees of Freedom
IIoT	Industrial Internet of Things
MND	Motor Neuron Disease
PLA	Polylactic Acid
ROS	Robotic Operating System
Rviz	Robotic Visualization
D-H Parameters	Denavit-Hartenberg Parameters

Special Notations (Symbols)	Meaning
a_i	Link length [Link Parameters]
α_i	Link twist [Link Parameters]
d_i	Joint displacement [Joint Parameters]
θ_i	Joint angle [Joint Parameters]

Abstract

Robotics is currently a growing trend in digital media as well as in technology applications across a number of important industries. Robotic applications and other robotic features have grown since the Industrial Revolution 3.0. Our industrial efficiency and the caliber of our products have grown enormously since the introduction of manipulator kinds of robots. A manipulator is, by definition, a device used in robotics to move objects without the user making any direct physical contact. Robotic arms with a certain degree of freedom are used to do this; each arm is unique and created for a particular application or function. Designing a Pick & Place Robotic Manipulator that can be operated by voice recognition is the major goal of this project work. It is proposed that the manipulator be designed using ROS, Gazebo, and Robotics Theory. The project's initial strategy is to simulate the manipulator in Gazebo before subsequently designing and implementing it physically.

Specific Contributions:

- **124009054:**
    - Numerical analysis of 4 Degrees of Freedom using Inverse & Forward Kinematics.
    - Mini Project Report making.
- **124009118:**
    - CAD Designing of the 6 DoF Manipulator.
    - Voice Recognition feature addition.
- **124012036:**
    - Numerical analysis of 6 Degree of Freedom using Inverse & Forward Kinematics.
    - Literature Research.

Specific Learnings:

- **124009054:**
    - Inverse & Forward Kinematics.
    - Literature review & summarizing for report.
- **124009118:**
    - ROS, Gazebo & Alexa for voice recognition.
    - Analytical Analysis of Forward & Inverse Kinematics using VSCode.
- **124012036:**
    - Inverse & Forward Kinematics.
    - ROS and Gazebo functioning.

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CHAPTER 1

<u>INTRODUCTION</u>

1.1 ROBOTS

Robots have been a crucial part of our day to day lives in the current present. A robot by definition is:

- *"Robot, any automatically operated machine that replaces human effort, though it may not resemble human beings in appearance or perform functions in a humanlike manner"* - Britannica

  Or

- "*A robot is a machine—especially one programmable by a computer—capable of carrying out a complex series of actions automatically.*" - Wikipedia

Robots have always been a big part of human history, be it in respect to Mythologies or Science Fiction or even Science. The idea of a machine that could think like a human and reduce the strain on its creators, the humans, has been a route to shape what Robots are in the present. Many cultures around the world had legends that gave rise to the concept of automata. Ancient engineers and creators from cultures like Ancient China, Ancient Greece, and Ptolemaic Egypt strove to build self-contained devices, some of which resembled humans and animals. Early examples of automata include Archytas' artificial doves, Mozi and Lu Ban's artificial birds, Hero of Alexandria's "speaking" automaton, Philo of Byzantium's washstand automaton, and Lie Zi's tale of a human automaton.

Especially with the rapid development in the fields of IIoT & Industry 4.0, Robots and Robotics have taken up a notch in their respective domains as well. There still are ongoing attempts to integrate certain aspects of technological ease from software to hardware.

Robots have also helped humans, not just in the industrial sector, but medical & domestic aspects as well. It is safe to predict cybernetic enhancements of the human body using advanced robotic parts might not be just a fantasy anymore.

1.2 MOTOR NEURON ISSUES

Neurodegeneration is premature damage and dying of motor neurons. This is a rare disease that leads to a loss of a lot of motor activities in our body. Usually it starts off with a weakened grip or weakened breathing patterns. Which is usually an early sign of a worsening condition inside the body.

Motor Neuron Issues are not bound by any age, and that’s what makes it all the more deadlier to deal with than any other neurological diseases. This detrimentation can happen regardless of what age a person might be in.

Motor Neurons usually carry the following duties:

- Gripping
- Walking
- Speaking
- Swallowing
- Breathing

Thus the premature ending of these neurons can be lethal to a person’s stability both physically and mentally. 20% of MND cases are genetic causes, this is one of the known causes of the disease. People with a family history of MND will make about half of all genetic cases. Those with no family history will account for the other half of genetic cases.

The likelihood of inheriting MND can also rise if frontotemporal dementia runs in the family. The gene's error has an impact on the cells' capacity for survival and normal function. There is a possibility that you could put your child at risk for having MND if you have a hereditary type of the disease. Numerous variables, including age, can influence the likelihood that they will develop the illness.

There is no cure to this condition as of now yet, just specialized treatment to slow down the progression of the disease in the body.

1.3 IoT & VOICE ASSISTANTS

Voice Assistants are the softwares that carry out tasks which are given out through voice commands. One such voice assistant is Alexa which is a multipurpose voice assistant that serves from daily simple tasks to direct a complex robotic arm using voice commands and voice recognition. Alexa is also connected through IoT inside a workspace which makes it all the more easier to communicate with and connect with, from anywhere in the world.

1.4 MOTIVATION

The motivation to choose this as our mini project after observing elderly and disabled people, specifically the ones with motor neuron issues who struggle to have a strong grip over physical objects. It is aimed to design a redundant manipulator bio-inspired by an elephant's trunk with more than or equal to 6 degrees of freedom to freely move and pick items flexibly.

CHAPTER 2

OBJECTIVES

- ➔ To design a 6 degree of freedom end manipulator robotic arm using forward kinematics
- ➔ To design and fabricate a 4 degree of freedom end manipulator robotic arm using 3D printed parts integrated with servo motors.
- ➔ To integrate Alexa's voice recognition into the 4 dof system

CHAPTER 3

METHODOLOGY

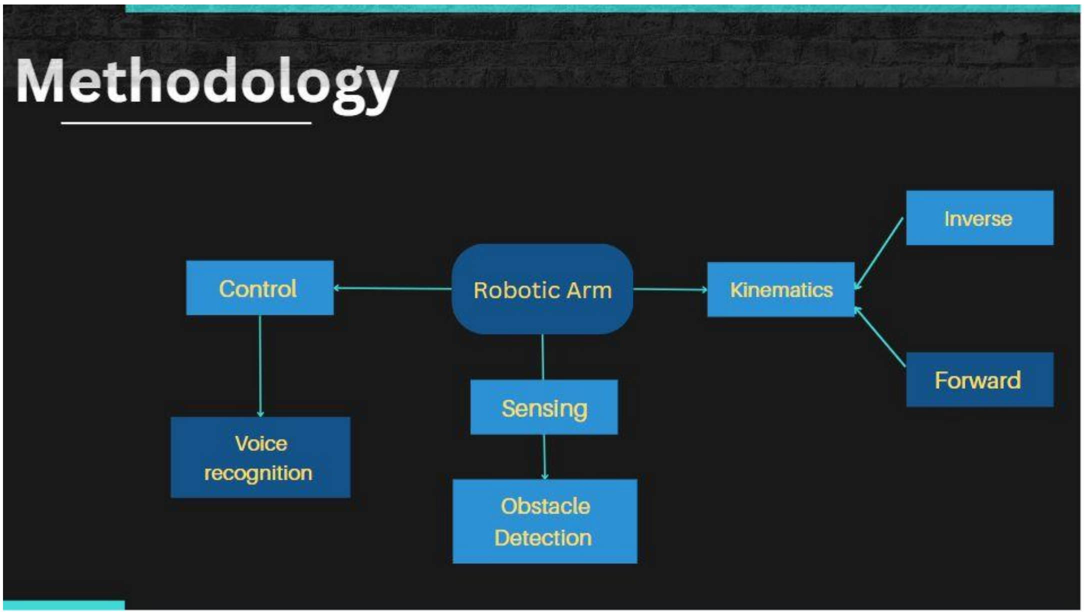


Fig.3.0 Methodology Flowchart

3.1 KINEMATICS

Coming up next we're put into thought in the structure procedure. Electrical actuators DC servo are picked rather than pressure driven and pneumatic actuators due to the little power necessity and its light weight which is reasonable for this plan. Materials utilized for the creation were privately sourced from accessible materials. The materials which will be utilized for the structure will be light in weight to decrease the weight focus on the base and the shoulder. A continuous path controller was chosen (Arduino was used). The torque is completely adjusted by the inertia of the electric motors.

3.1.1 FORWARD KINEMATICS

- Forward kinematics is a term used in robot kinematics to describe the process of using a robot's kinematic equations to determine the position of the end-effector given provided values for the joint parameters. Robotics, video games, and animation all employ the robot's kinematics equations. Inverse kinematics is the procedure that computes the joint parameters necessary to move an end-effector to a specific position.

3.1.2 DENAVIT-HARTENBERG(D-H) NOTATION

The definition of a controller with four joint-interface parameters for each connection and a precise methodology for appointing right-gave orthonormal arrange outlines, one to each connection in an open kinematic chain, was proposed by Denavit &Hartenberg ,so is known as Denavit - Hartenberg (D-H) notation.

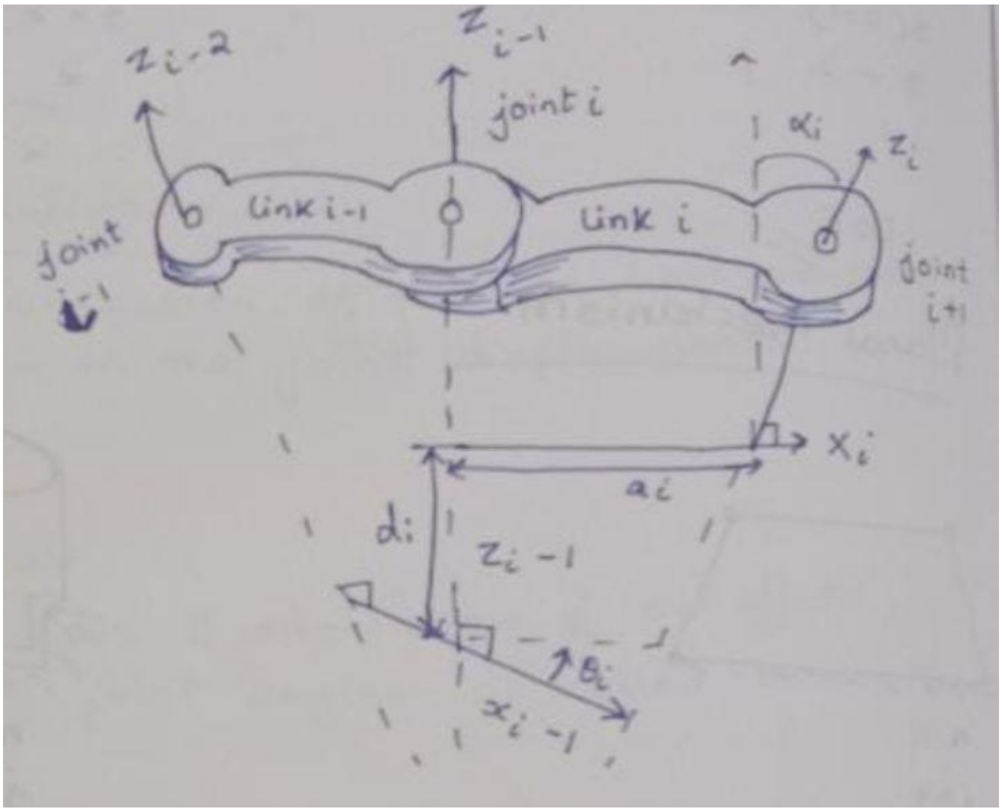
A frame{i} is assigned to link i as follows:

i.TheZi -1 lies along the axis of motion of the ith joint.
ii.The Xi pivot is normal to the Zi-1 axis, and pointing far from it.
iii.The Yi axis completes the right – handed coordinate system as required.

The DH representation of a rigid link depends on four geometric parameters associated with each links. These four parameters completely describe any revolute or prismatic joint as follows:

I. Connection length (ai) – separate estimated along xi hub from the purpose of convergence of xi pivot with zi1 hub to the cause of edge {i}.
Ii. Link twist (αi) – angle between zi-1 and z axes measured about xi-axis in the right hand sense.
Iii. Joint distance(di) - distance measured along zi-1 axis from the origin of frame {i-1} to intersection of xi axis with the zi-1 axis.
Iv. Joint angle (θi) – angle between xi-1 and xi axes measured about the zi-1 axis in the right hand sense.

Fig.3.1.2.1 Mathematical model of a manipulator



The transformation matrix for a link **i** is described as follows:

$$A_i = \begin{bmatrix} \cos\theta i & -\sin\theta i \cos\alpha i & \sin\theta i \sin\alpha i & \alpha i \cos\theta i \\ \sin\theta i & \cos\theta i \cos\alpha i & -\cos\theta i \sin\alpha i & \alpha i \sin\theta i \\ 0 & \sin\alpha i & \cos\alpha i & \mathrm{d}i \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

A_1 is the transformation matrix T_1^0:

$$T_1^0 = \begin{bmatrix} \cos\theta 1 & -\sin\theta 1 \cos\alpha 1 & \sin\theta 1 \sin\alpha 1 & \alpha 1 \cos\theta 1 \\ \sin\theta 1 & \cos\theta 1 \cos\alpha 1 & -\cos\theta 1 \sin\alpha 1 & \alpha 1 \sin\theta 1 \\ 0 & \sin\alpha 1 & \cos\alpha 1 & d1 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

and $\alpha = 90$, so T_1^0 will be as follows:

$$T_1^0 = \begin{bmatrix} \cos\theta 1 & 0 & \sin\theta 1 & \alpha 1\cos\theta 1 \\ \sin\theta 1 & 0 & -\cos\theta 1 & \alpha 1\sin\theta 1 \\ 0 & 1 & 0 & d1 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

For A2:

$$T_2^1 = \begin{bmatrix} \cos\theta 2 & -\sin\theta 2 & 0 & \alpha 2\cos\theta 2 \\ \sin\theta 2 & \cos\theta 2 & 0 & \alpha 2\sin\theta 2 \\ 0 & 0 & 1 & d2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For A3:

$$T_3^2 = \begin{bmatrix} \cos\theta 3 & 0 & \sin\theta 3 & \alpha 3\cos\theta 3 \\ \sin\theta 3 & 0 & -\cos\theta 3 & \alpha 3\sin\theta 3 \\ 0 & 1 & 0 & d3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For A4:

$$T_4^3 = \begin{bmatrix} \cos\theta 4 & 0 & -\sin\theta 4 & \alpha 4\cos\theta 4 \\ \sin\theta 4 & 0 & \cos\theta 4 & \alpha 4\sin\theta 4 \\ 0 & -1 & 0 & d4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For A5:

$$T_5^4 = \begin{bmatrix} \cos\theta 5 & 0 & \sin\theta 5 & \alpha 5 \ \cos\theta 5 \\ \sin\theta 5 & 0 & -\cos\theta 5 & \alpha 5 \ \sin\theta 5 \\ 0 & 1 & 0 & d5 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For A6:

$$T_6^5 = \begin{bmatrix} \cos\theta 6 & -\sin\theta 6 & 0 & \alpha 6 \ \cos\theta 6 \\ \sin\theta 6 & \cos\theta 6 & 0 & \alpha 6 \ \sin\theta 6 \\ 0 & 0 & 1 & d6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{T^0{}_6 = T^0{}_1}\ \boldsymbol{x}\ \mathbf{T^1{}_2}\ \boldsymbol{x}\ \mathbf{T^2{}_3}\ \boldsymbol{x}\ \mathbf{T^3{}_4}\ \boldsymbol{x}\ \mathbf{T^4{}_5}\ \boldsymbol{x}\ \mathbf{T^5{}_6}$$

$T^0{}_6$ gives the Forward Kinematic equation.

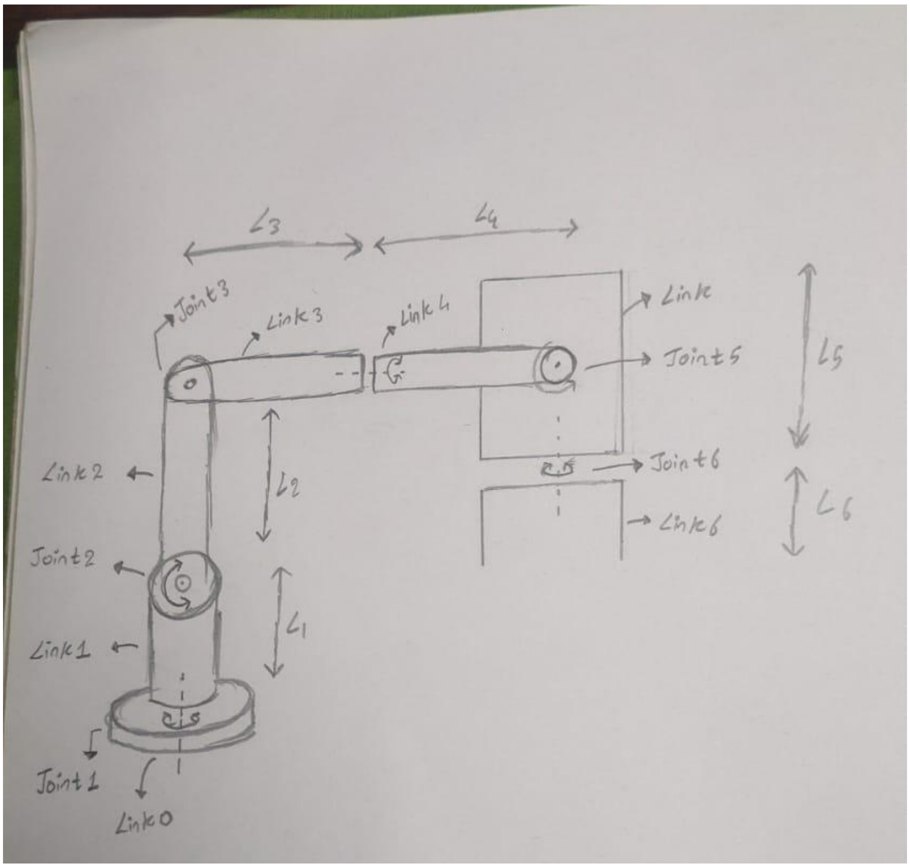


Fig.3.1.2.2. Representation of Links & Joints of 6 DoF

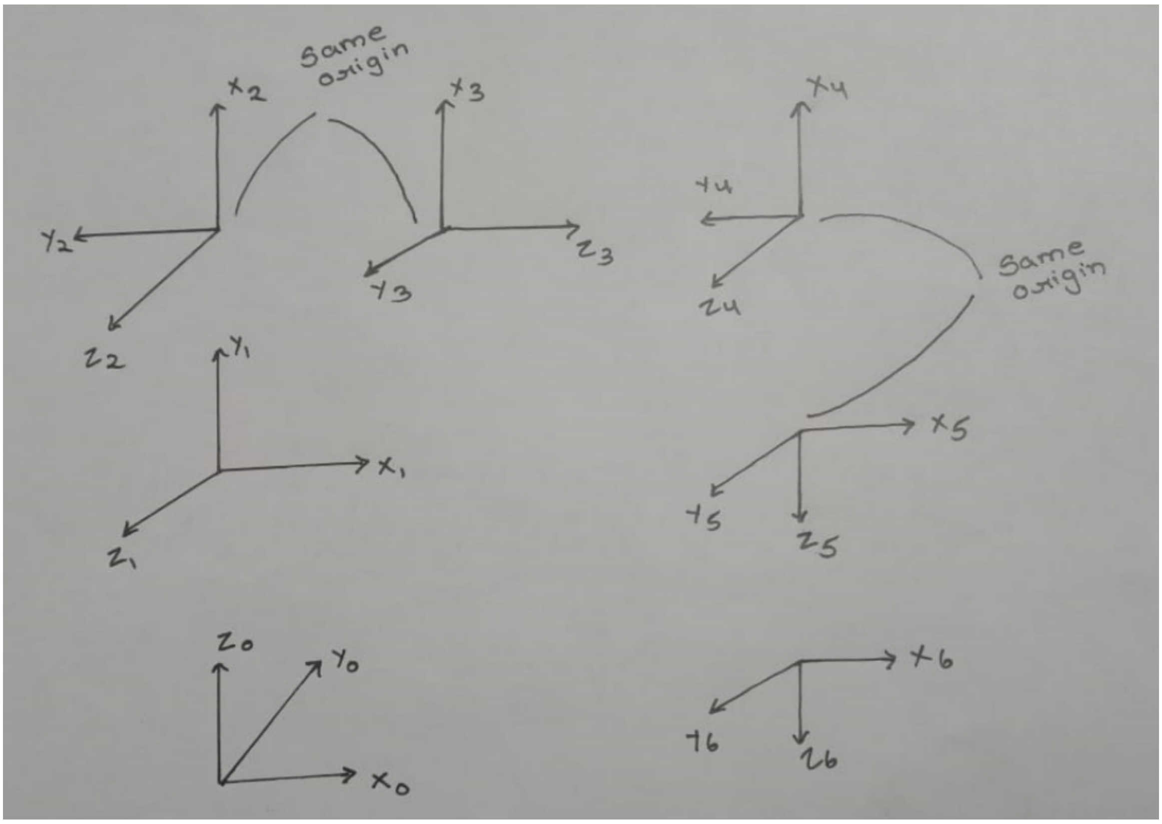


Fig.3.1.2.3 - Frames of 6 DoF

D-H Parameters

Link i	a_i	α_i	d_i	θ_i	Joint variable
1	0	90	L_1	θ_1	θ_1
2	L_2	0	0	$90+\theta_2$	θ_2
3	0	90	D	θ_3	θ_3
4	0	-90	L_3+L_4	θ_4	θ_4
5	0	90	0	$90+\theta_5$	θ_5
6	0	0	L_5+L_6	θ_6	θ_6

Table 3.1.2.4. D-H Parameters of 6 DoF

3.2 Design of the Manipulators

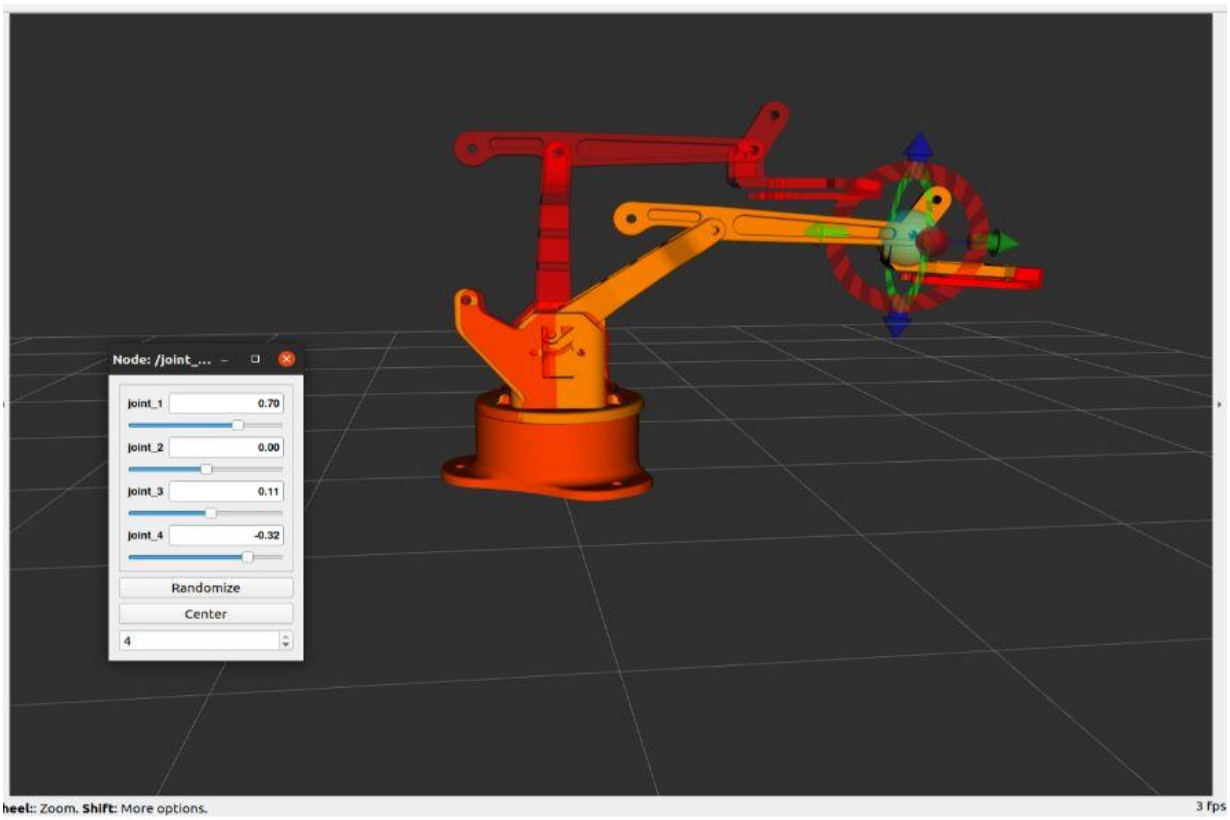


Fig.3.2.1. 4 DoF CAD Design.

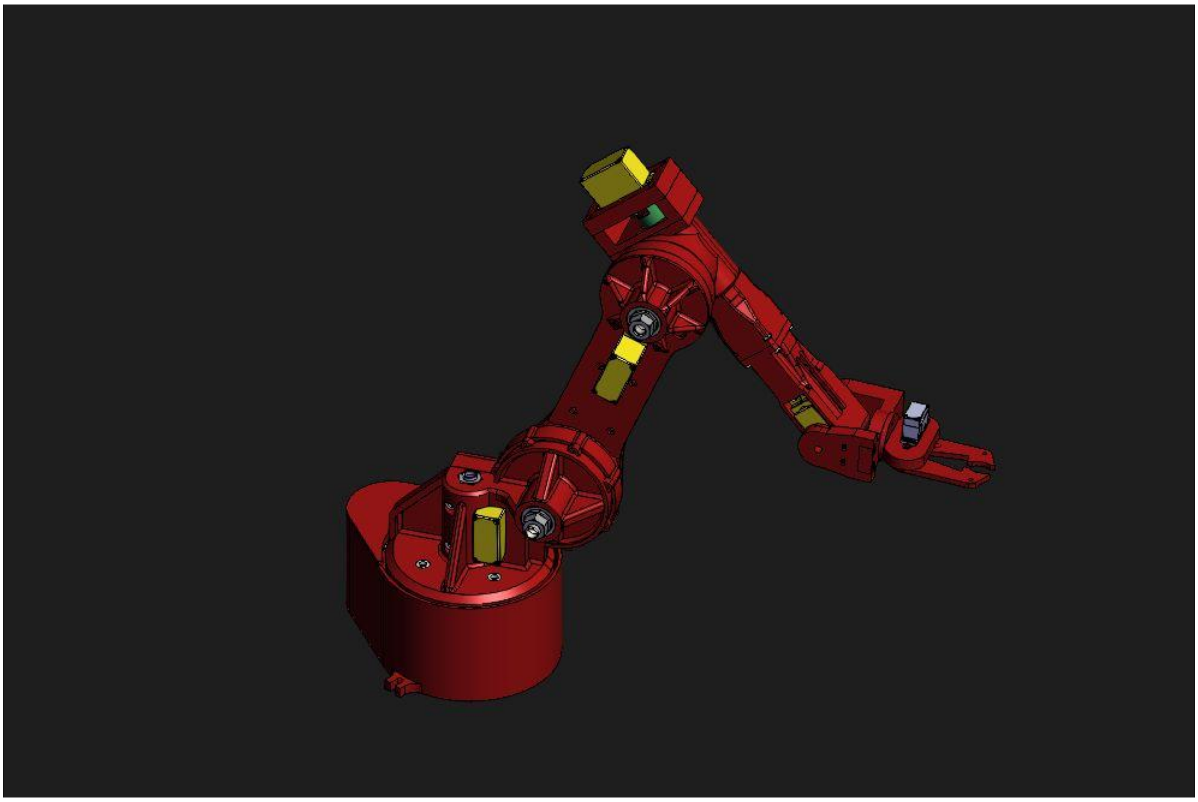


Fig.3.2.2. 6 DoF CAD Design.

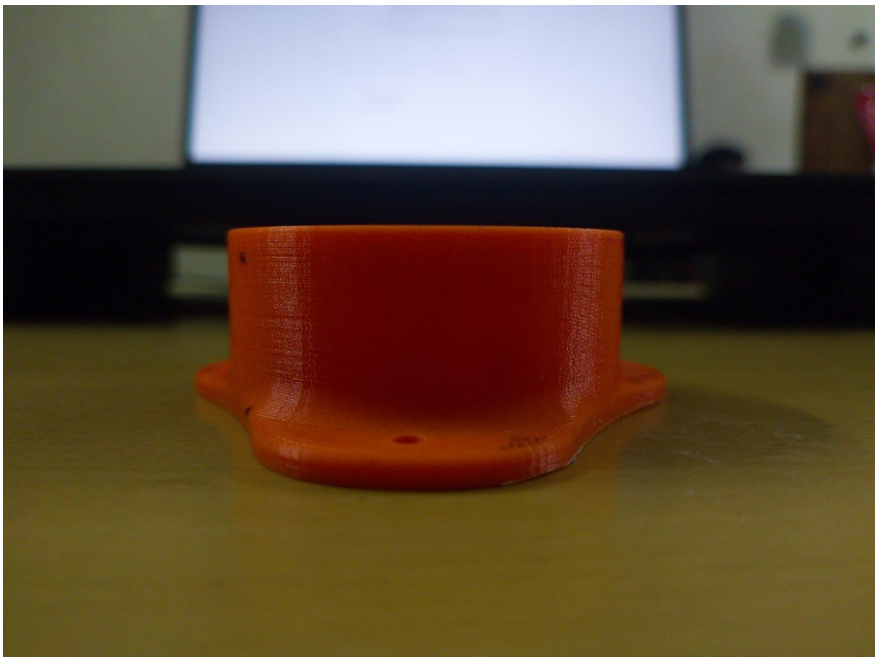
3.3 3D Printing

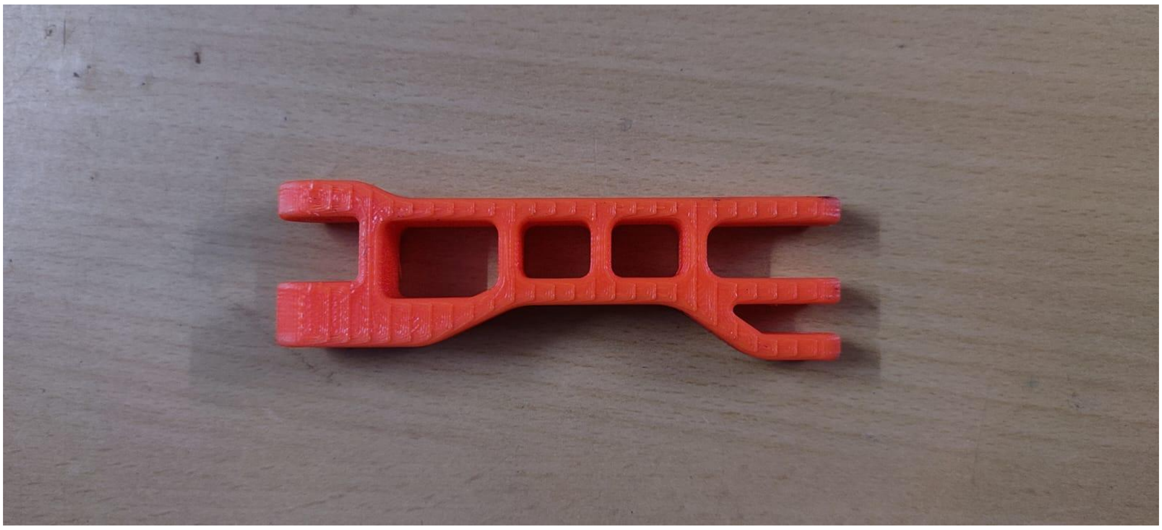
3.3.1 Materials

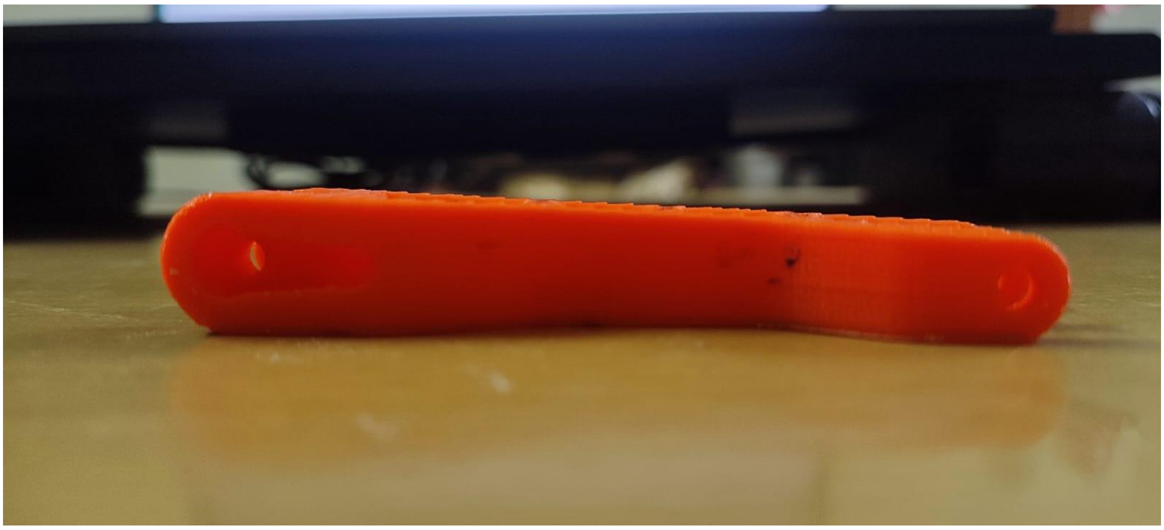
- For the 3D printing of the 4 DoF end manipulator, it was proposed to use Polylactic Acid polymer for the economic value and strength of the model that carries a minimum weight of 2.5 kgs.
- Polylactic Acid or PLA is a dehydrated polymer with Lactic Acid as its base: $[–C(CH_3)HC(=O)O–]_n$. It is also an organic material that could be a healthier alternative.

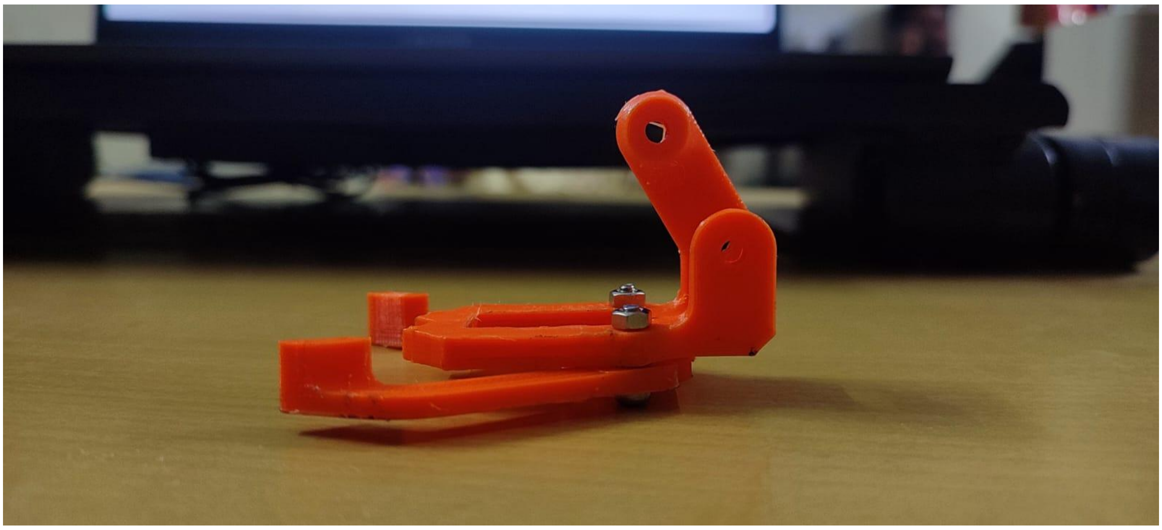
3.3.2 Parts

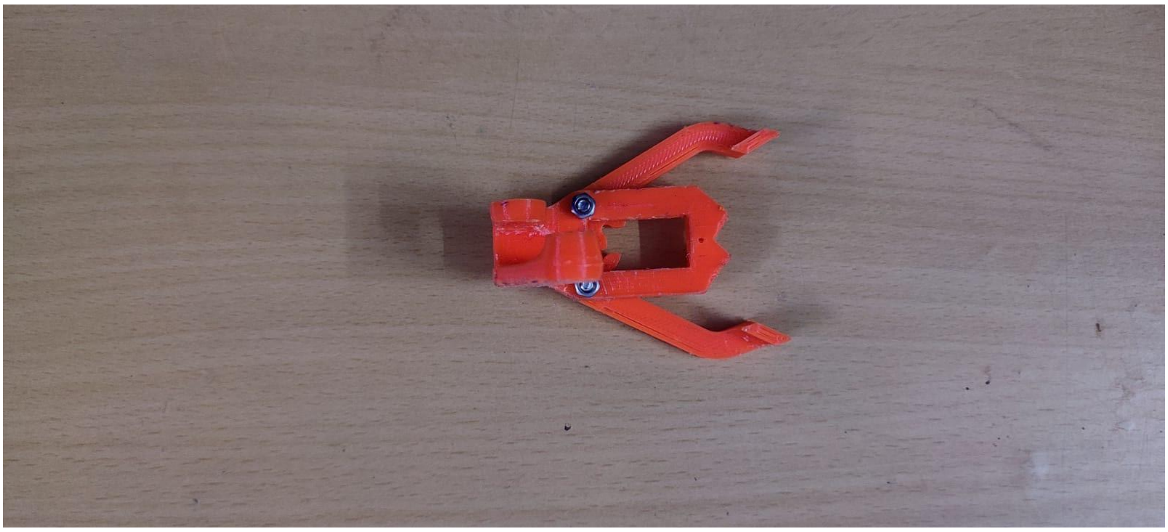
- The following figures are the pictures taken of the 3D printed parts that were fabricated using PLA at ASK II:

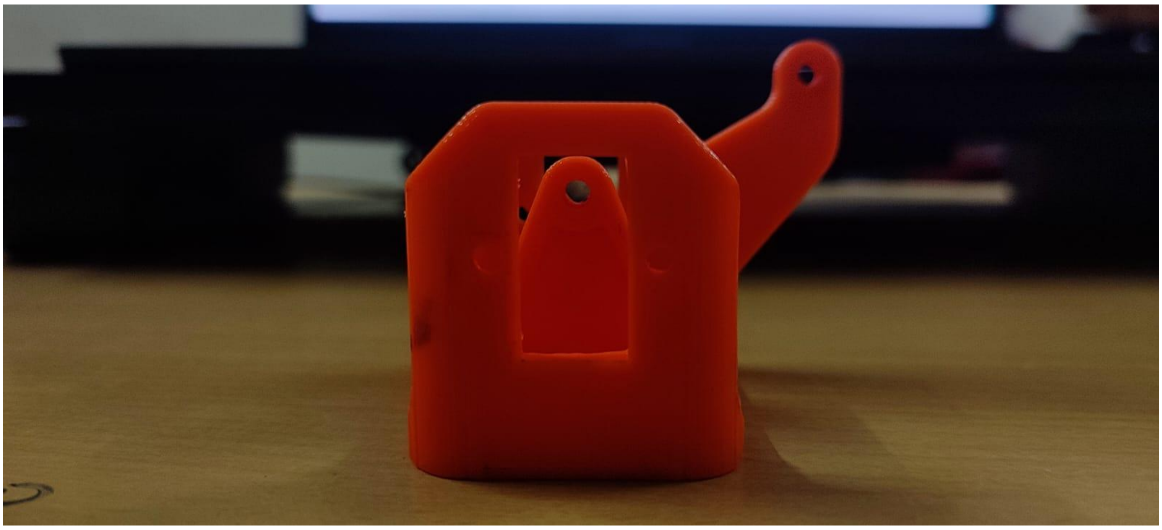


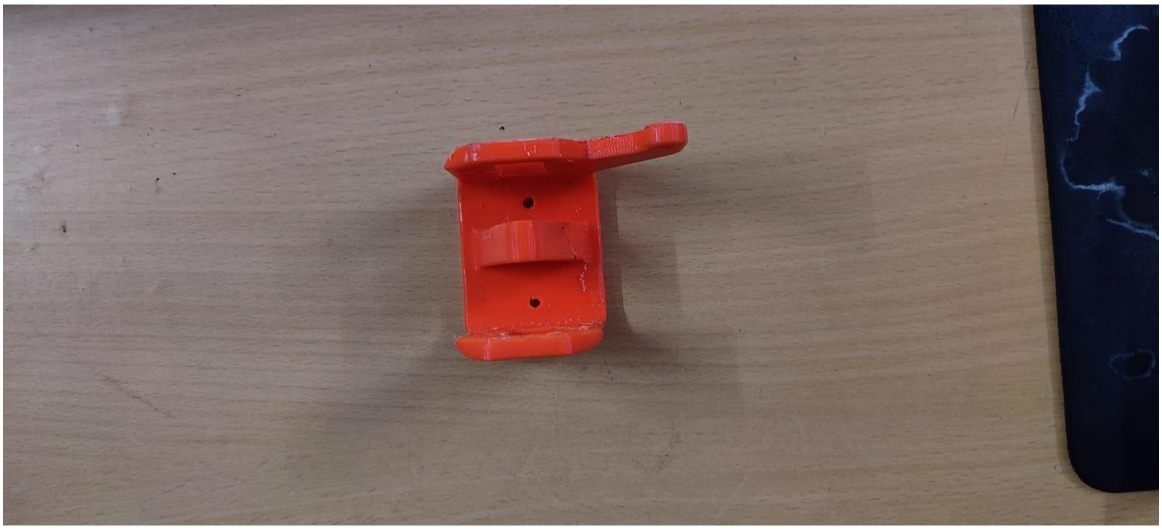


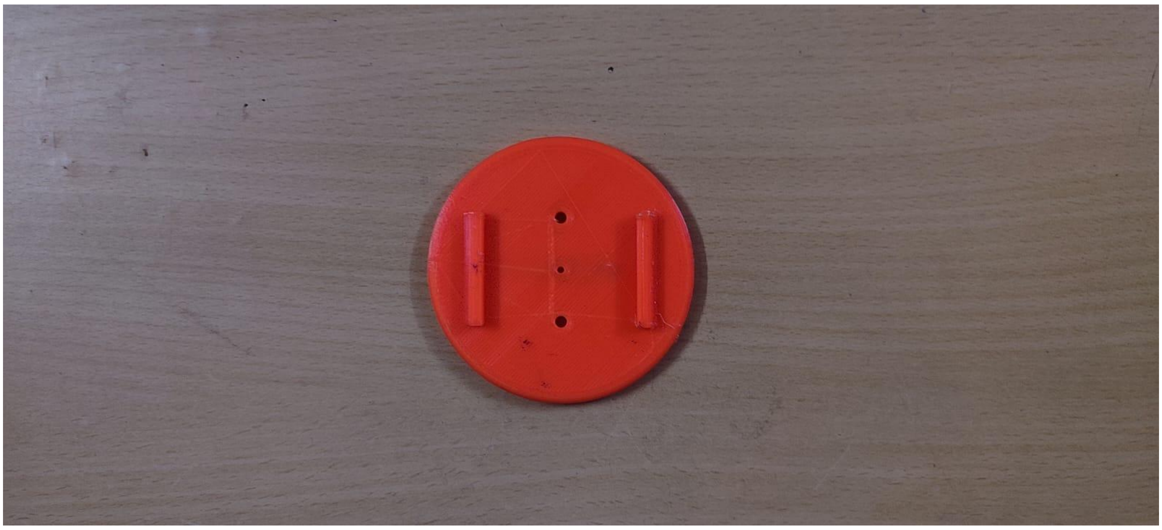












3.4 Actuators

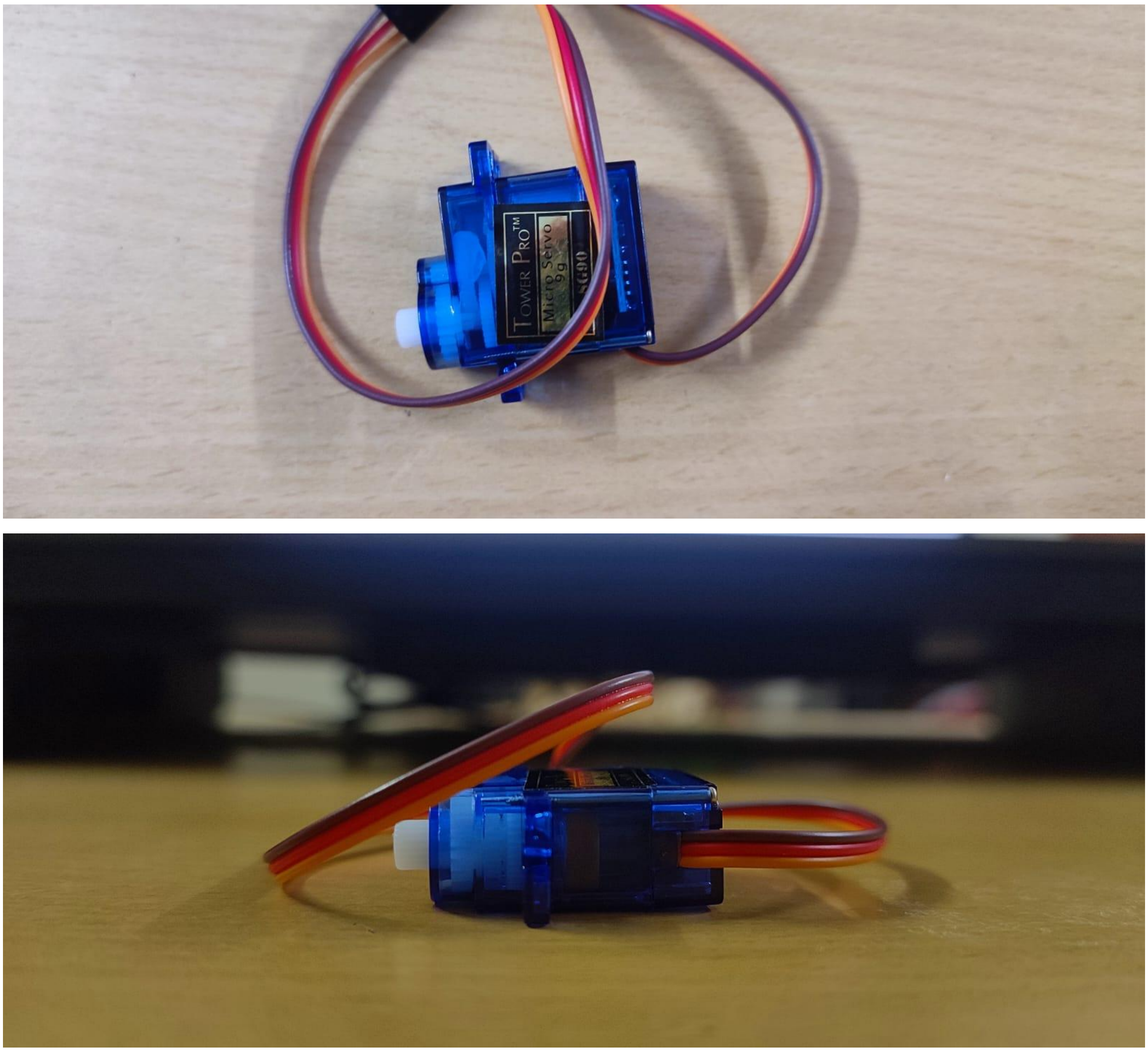
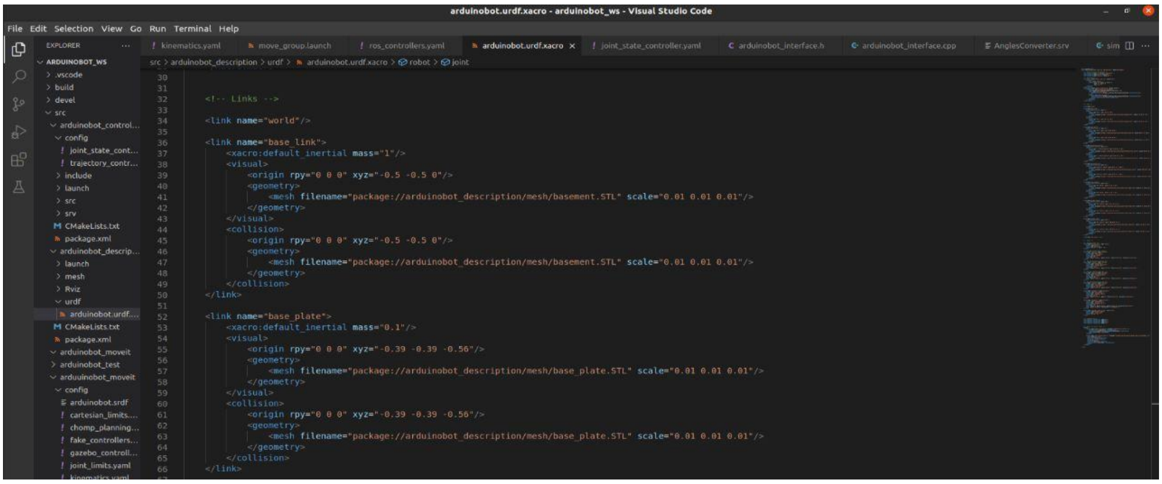
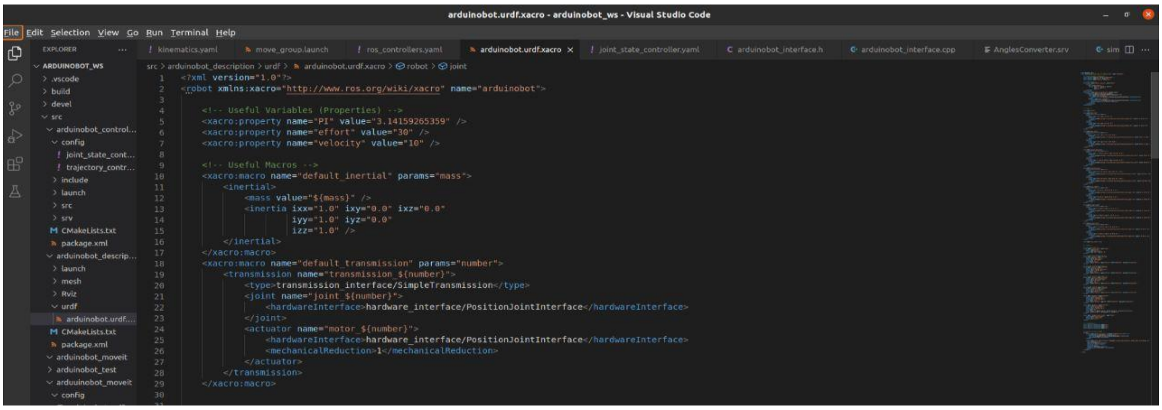
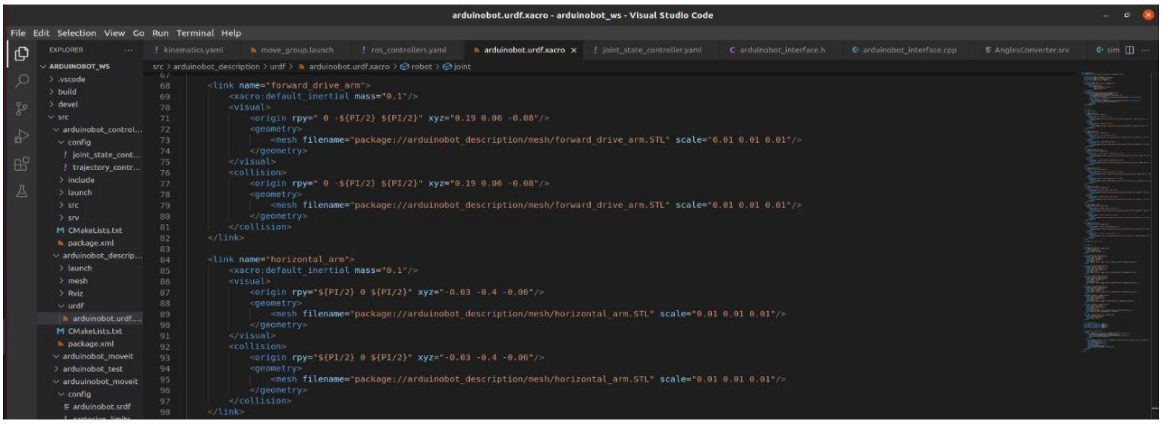


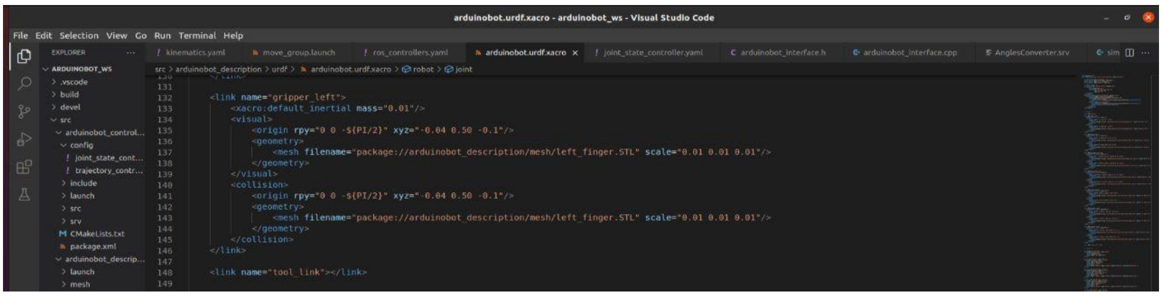
Fig.3.4.1. SG90 Micro Servo Motor 9G

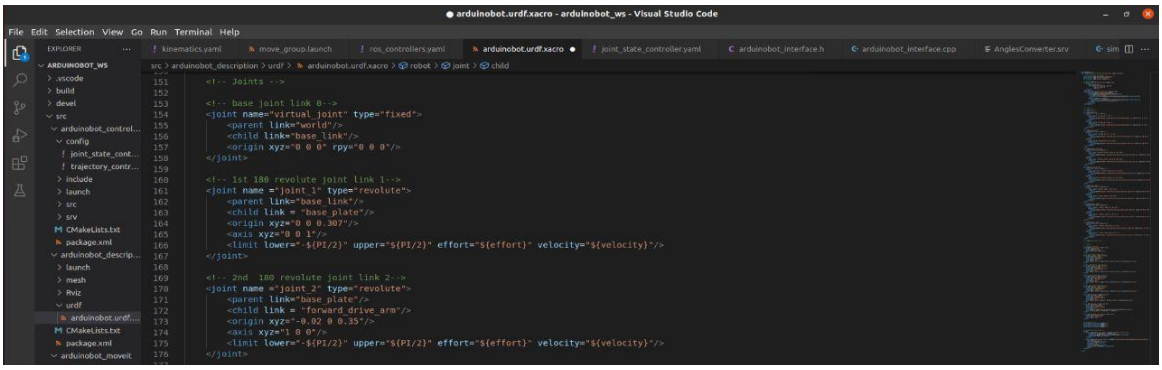
3.5 Gazebo & ROS







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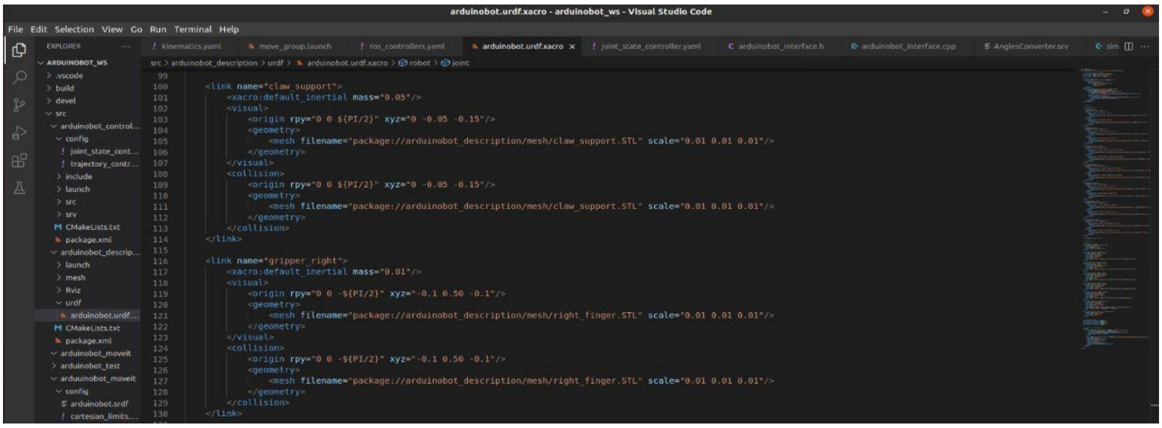
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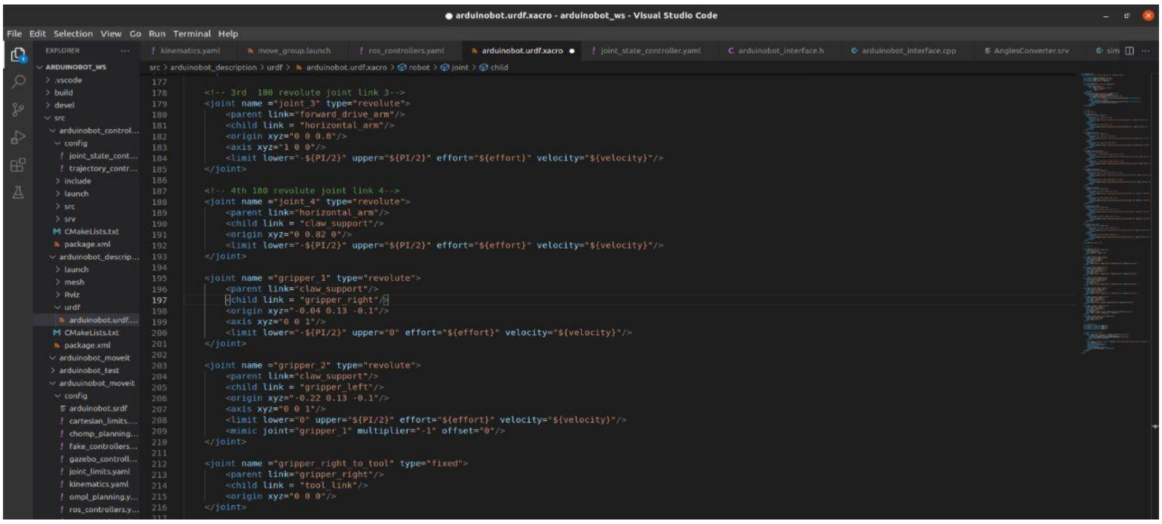
arduinobot.urdf.xacro - arduinobot_ws - Visual Studio Code
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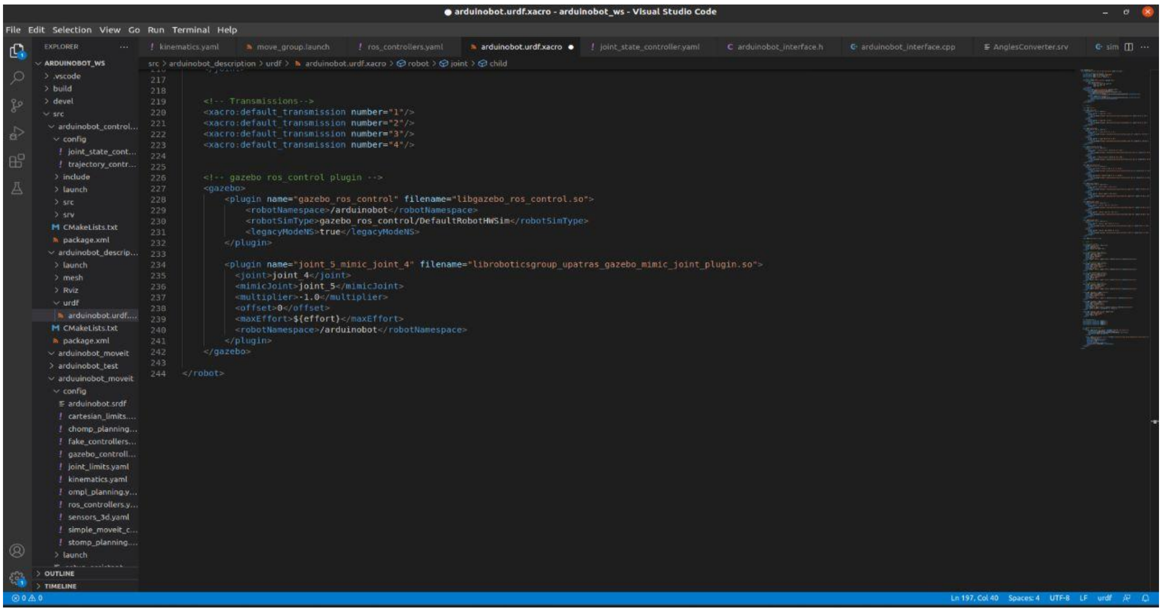
</joint>
<joint name ="gripper_right_to_tool" type="fixed">
<parent link="gripper_right"/>
<child link = "tool_link"/>
<origin xyz="0 0 0"/>
</joint>


arduinobot.urdf.xacro - arduinobot_ws - Visual Studio Code
src > arduinobot_description > urdf > arduinobot.urdf.xacro > robot > joint > child
<!-- Transmissions-->
<xacro:default_transmission number="1"/>
<xacro:default_transmission number="2"/>
<xacro:default_transmission number="3"/>
<xacro:default_transmission number="4"/>
<!-- gazebo ros_control plugin -->
<gazebo>
<plugin name="gazebo_ros_control" filename="libgazebo_ros_control.so">
<robotNamespace>/arduinobot</robotNamespace>
<robotSimType>gazebo_ros_control/DefaultRobotHWSim</robotSimType>
<legacyModeNS>true</legacyModeNS>
</plugin>
<plugin name="joint_5_mimic_joint_4" filename="libroboticsgroup_upatras_gazebo_mimic_joint_plugin.so">
<joint>joint_4</joint>
<mimicJoint>joint_5</mimicJoint>
<multiplier>-1.0</multiplier>
<offset>0</offset>
<maxEffort>${effort}</maxEffort>
<robotNamespace>/arduinobot</robotNamespace>
</plugin>
</gazebo>
</robot>

3.6 Voice Recognition using Alexa

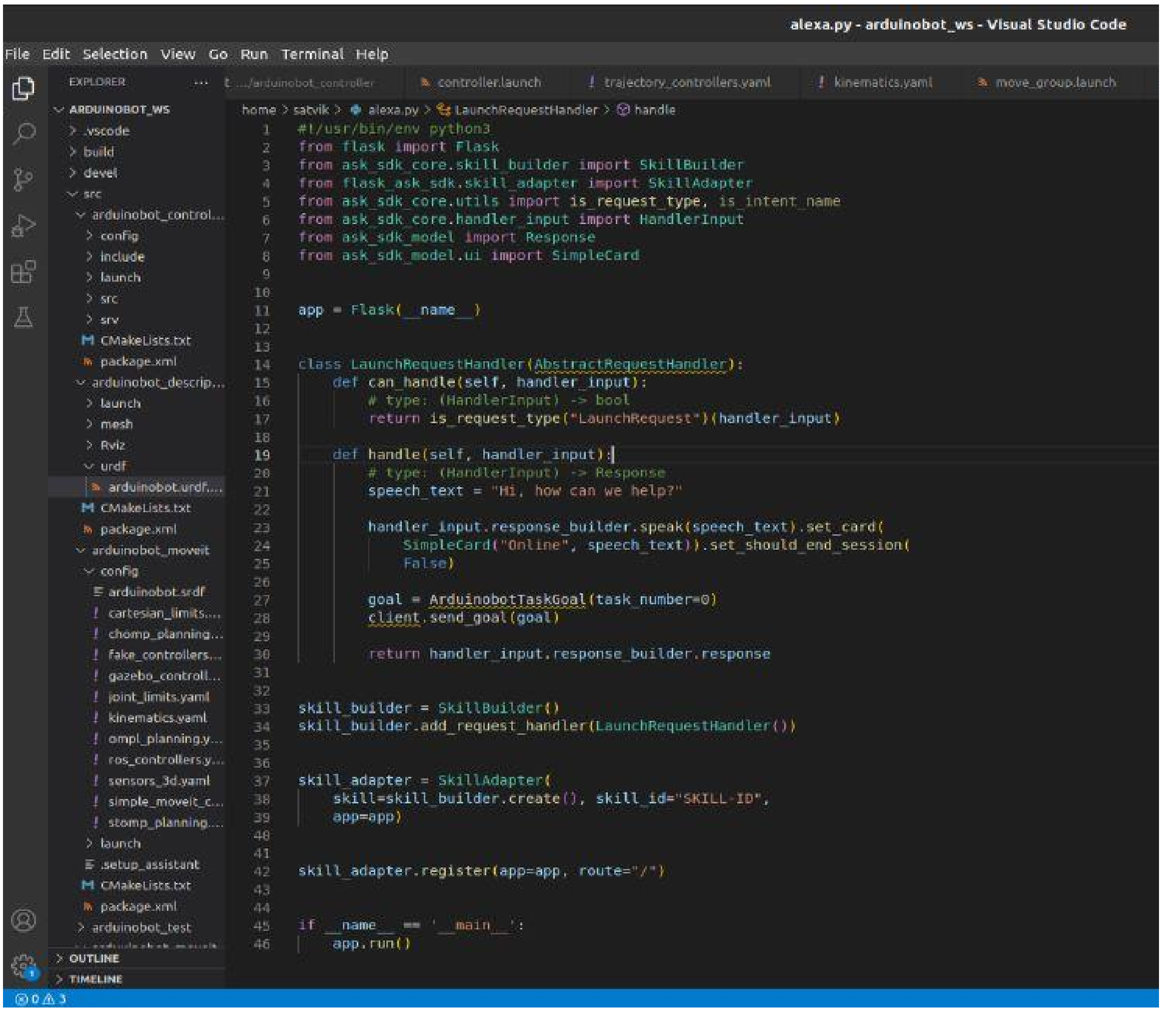


Fig.3.6.1. Code running behind Alexa for Voice Recognition.

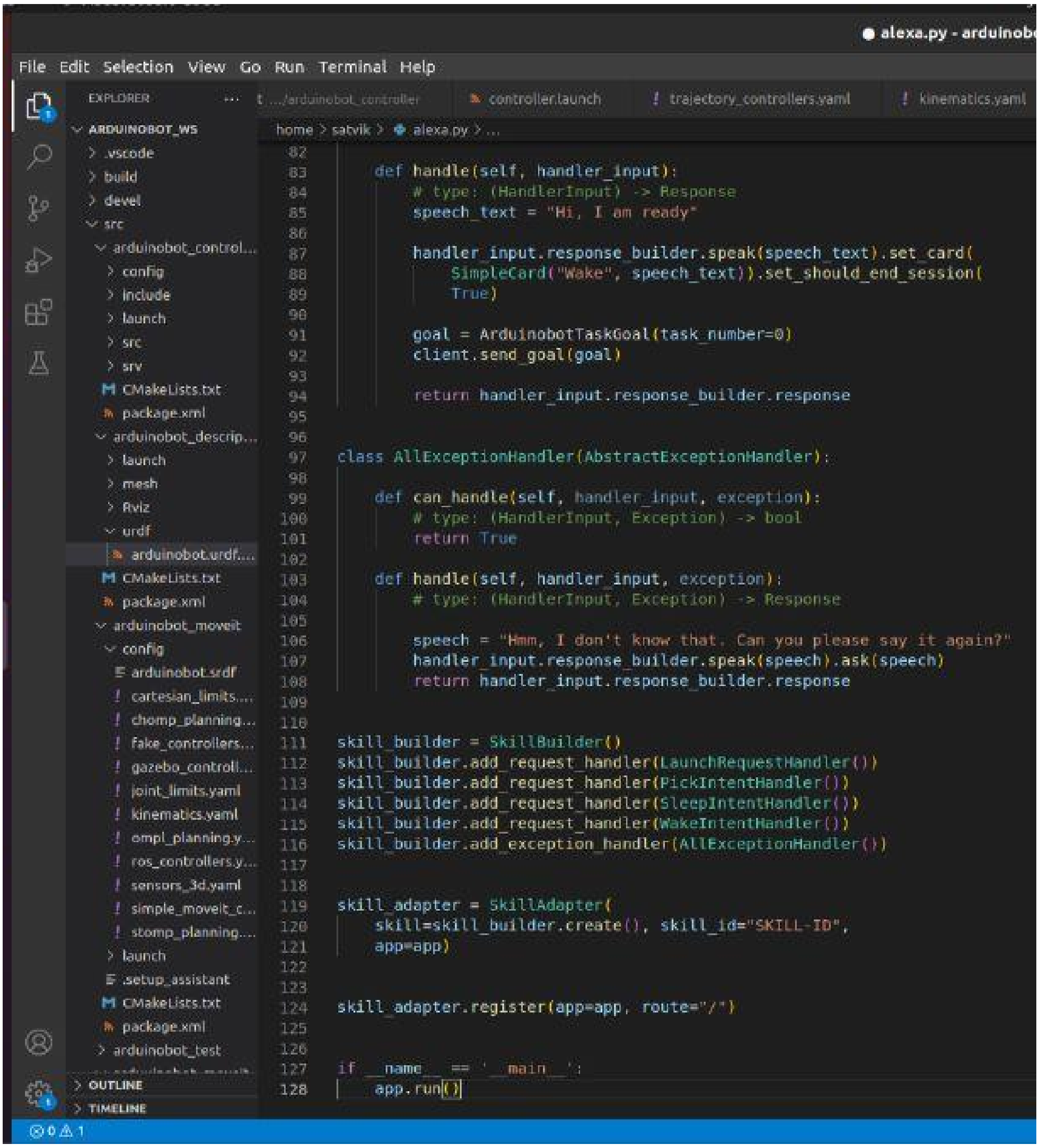


Fig.3.6.2. Voice Interaction Model with Alexa.

CHAPTER 4

RESULTS & DISCUSSIONS

4.4 Working Designs

The following screenshots show the working designs of the 4 DoF End Manipulator on simulation:

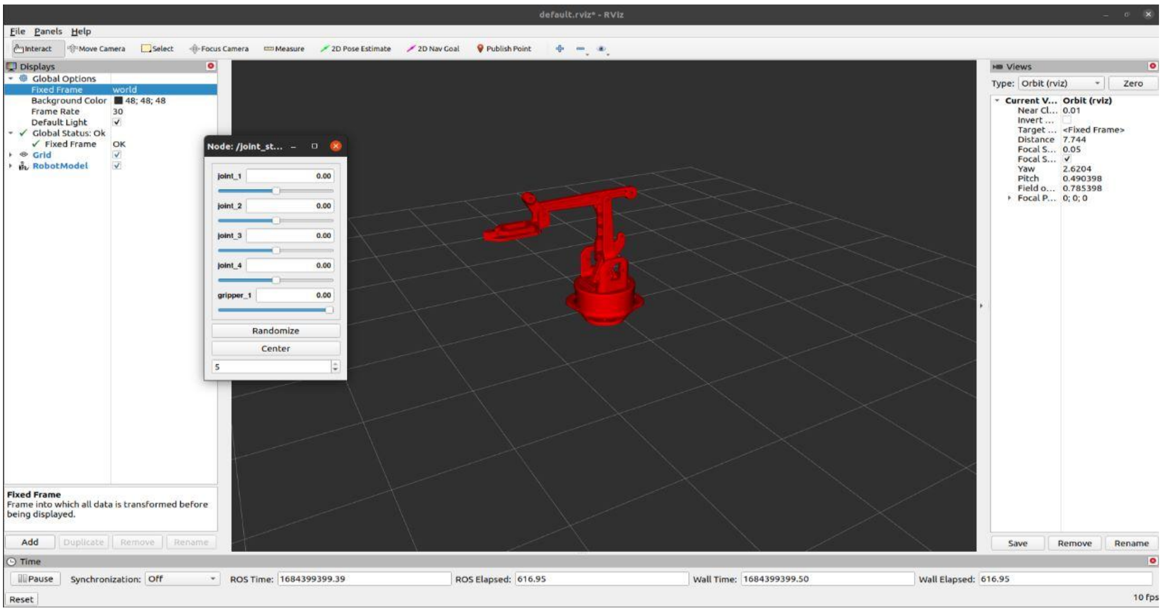


Fig.4.4.1. 4 DoF Home Position

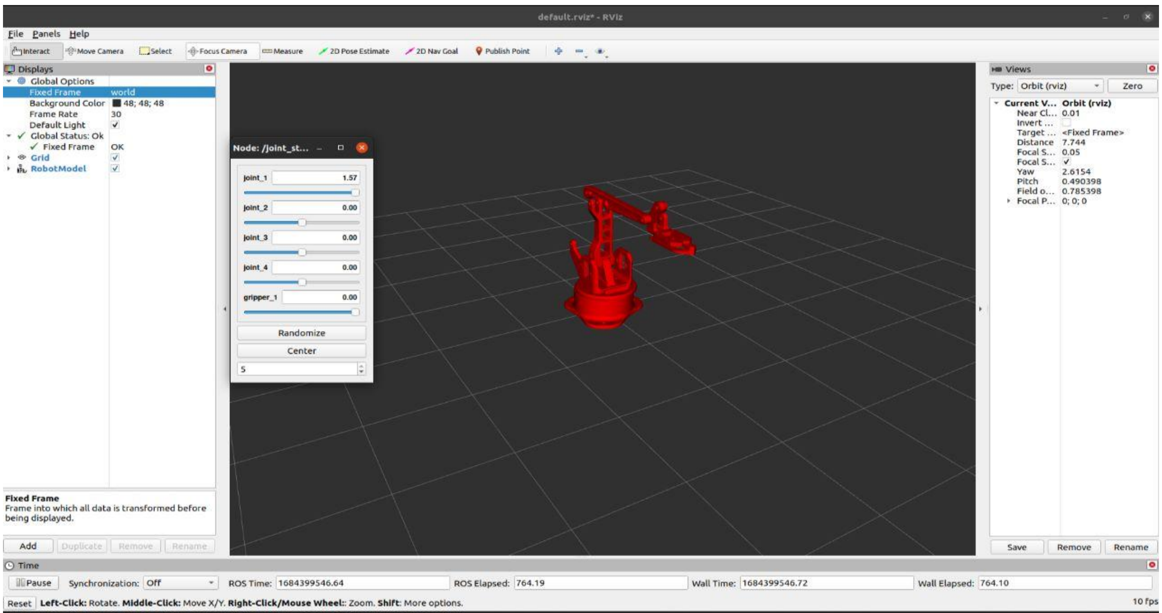


Fig.4.4.2. 4 DoF - Joint 1 180 degree movement

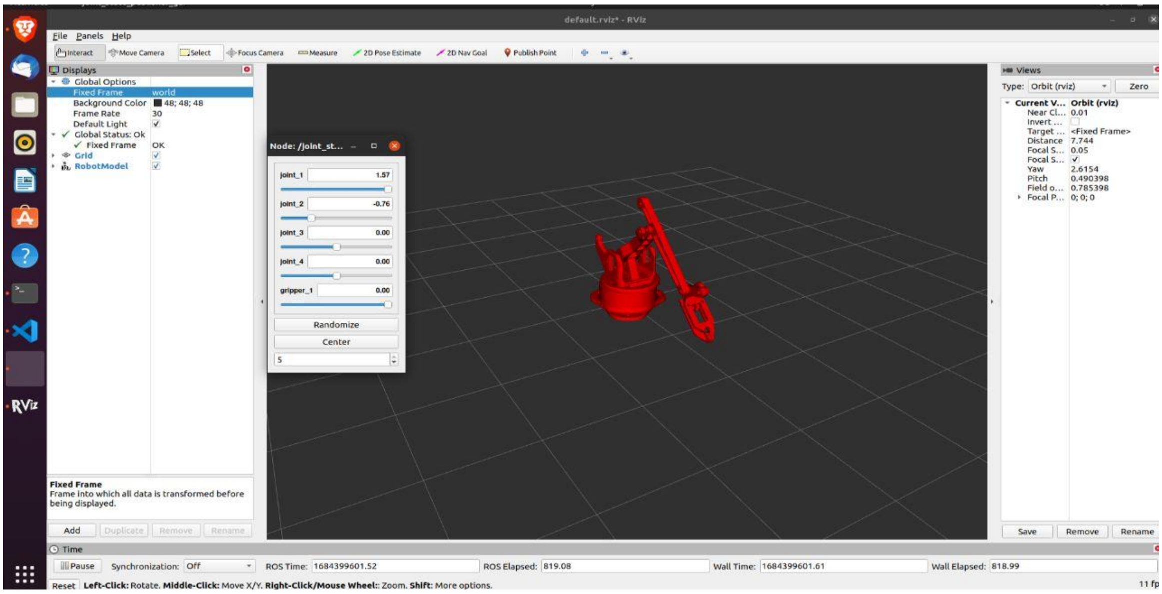


Fig.4.4.3. 4 DoF - Joint 2 - bending to pick up objects

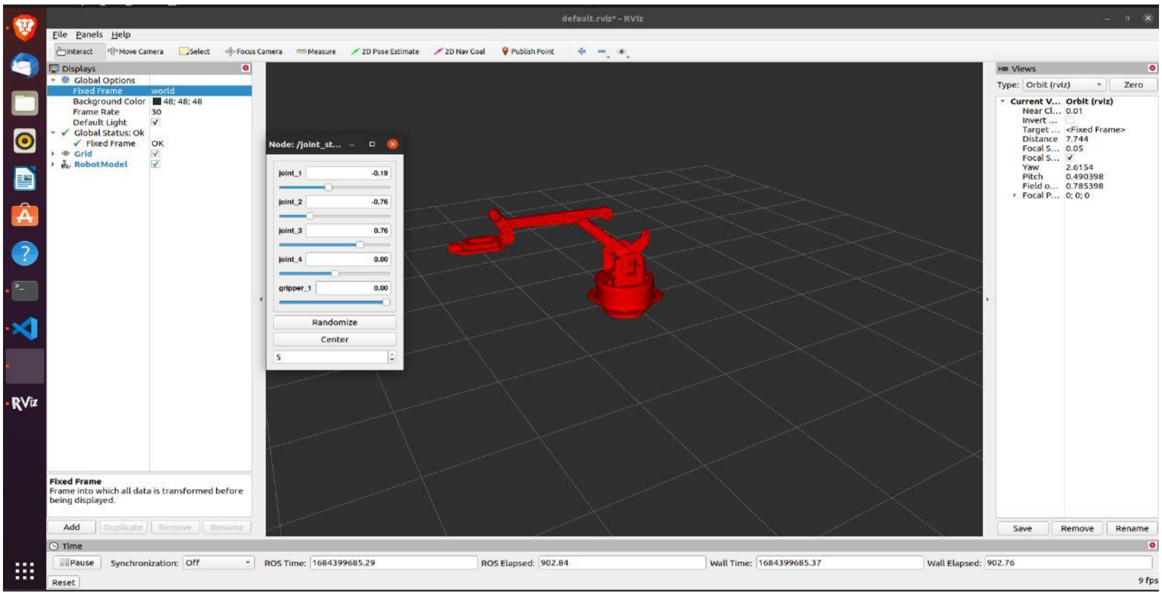


Fig. 4.4.4. 4 DoF - Joint 3 - Placing Objects

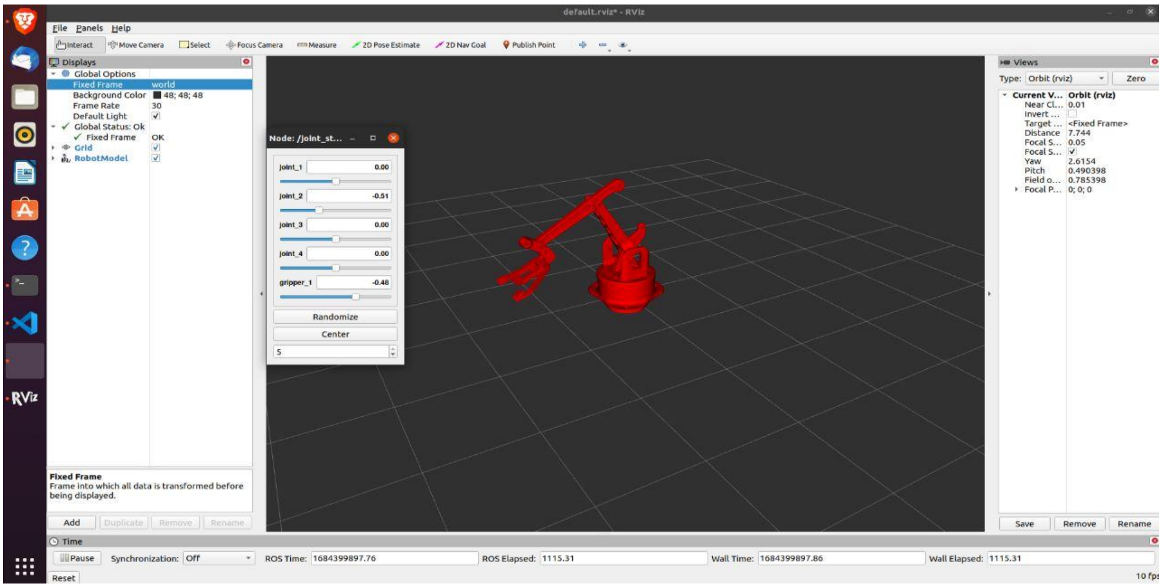


Fig.4.4.5. 4 DoF - Joint 4 - Movement

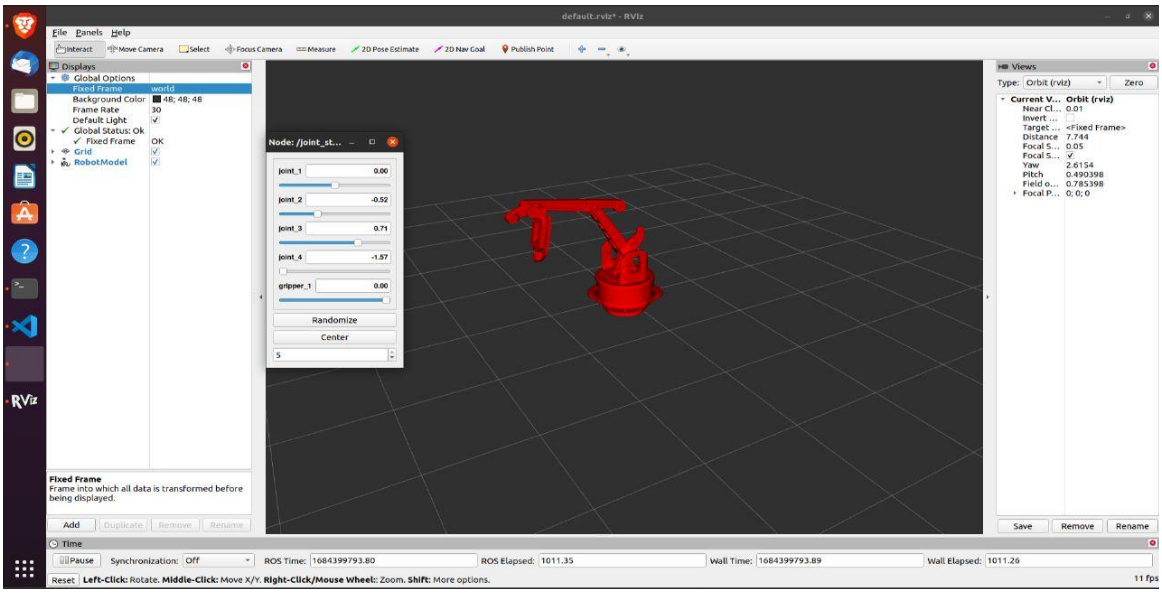


Fig.4.4.6. 4 DoF - Joint 4 - Dropping object.

CHAPTER 5

CONCLUSIONS & FURTHER WORK

5.1 CONCLUSION

The robotic arm's design and construction have been successfully finished. Solidworks is used to generate the robotic arm's line diagram. The manipulator's design has been identified. For various loads, the torque acting at each joint is determined. On the basis of the torque, the power is predicted. Depending on the required torque, the servo is chosen for each joint. Microsoft's C++ programming language is being used to construct the robotic arm's servo controller and control software. The pick-and-place robot was used in the studies, and the outcomes were quite pleasing. The joints can be powered by motors with higher torque ratings to keep the robotic arm in place even when there is no electric supply. The robotic arm can implement object recognition and collision avoidance by adding proximity sensors.

5.2 FURTHER WORK

For further work, We have looked into possibly applying the design in industrial applications and reduce the costs to build and maintain an end effector manipulator. This could delve into slight economical debate on how good 3D printed materials are at holding and working with heavier materials.

The robot so programmed for pick and place operation can be made versatile and more efficient by providing the feedback and making it work on its own than any human interventions. It can be made possible by an image processing tool interfaced with this Arduino. The features that can be added on to improve its efficiency, make it operate on its own thought without any human intervention are line follower, wall hugger, obstacle avoider, metal detector, bomb diffuser etc.

CHAPTER 6

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CHAPTER 7

APPENDIX

7.1 DUPLICHECKER PLAGIARISM TEST REPORT