Prototype of Humanoid Arm and Neck

A PROJECT REPORT

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In

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By

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CERTIFICATE

This is to certify that the project titled **PROTOTYPE OF HUMANOID ARM AND NECK** is a record of the bonafide work done by **SHILPITHA GANDLA** (179403049) submitted in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology (B.Tech) in **(Mechatronics)** of Manipal University Jaipur, during the academic year 2018-19.

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ABSTRACT

Traditionally robots were used for industrial and automation purposes, but in the recent days the need for robots has been changed from industrial automation to human assistance. The project, titled Prototype of Humanoid Arm and Neck is based on this concept of use of human friendly robots, for assisting in human activities. The objective of this project is to make a humanoid arm with 5DOF and controlled by arduino and other controllers.

The arm is designed and 3d printed. Then the kinematic analysis of the robot arm is done, followed by the analysis and testing of components to be used in the assembling the humanoid arm. The robot arm is plotted in MATLAB. The result of this arm is to be able to come into different positions as it is controlled by arduino and other controllers.

Key words:
Humanoid Robot, Kinematic analysis, DOF (Degree of freedom), Forward Kinematics, Robotics, MATLAB, Simulink.

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Chapter 1: INTRODUCTION

1.1 Introduction:

Humanoid robots are robots that resemble human structure. The shape of the robot body is built to resemble human body structure. Humanoids can perform tasks like humans in human environments. They are mainly made for the purpose of research, space exploration, military and assisting in environments like hospitals and offices. They are also used for interaction with humans and experimental purposes. Many humanoids are made for domestic purposes as well like assisting in household chores and to work in restaurants etc.

IIIRPD, Institute for Industrial Interdisciplinary Research and Product Development, has provided me the opportunity of carrying forward an internship on embedded systems and robotics. IIIRPD is a startup company in the field of robotics and 3D printing, based in Hyderabad. The major project in this internship is "Prototype of humanoid arm and neck".

The project involves the kinematic analysis and prototype of humanoid robot arm. The MATLAB simulation for the robot is done as well. The area of project work is embedded systems and IoT in robotics. Embedded system is an integrated system as it combines hardware and software. It comprises of intelligent computing devices such as smartphones, smart watches, smart home devices, medical equipment, security alarms, IoT products, etc. It is used for performing a specific function. It uses microcontrollers or microprocessors to perform a single task.

1.2 Motivation:

The traditional robots are typically used for industrial uses and automation. The need for robots has recently been changed from industrial automation to human-friendly robot systems. Robots are now required to assist in human activities in human environments like offices, homes and hospitals. To achieve these demands, many humanoid robots have been designed in the past few years.

The robotic arm is found to be used in different sectors of the industries, for example in pick and place of objects in factories, in surgeries in hospitals etc. The humanoid robot has many advantages like robotic arms help in improving the production capacity of companies; humanoid robots are mechanical and do not require breaks or fall sick unlike humans. In addition, they also work faster and more efficiently. They work with accuracy and precision. Humanoid robots can perform tasks that are dull, dirty or dangerous for humans to perform. They can improve the working conditions of a workplace.

Domestic robots or human friendly robots like humanoids have been purchased by different sectors. The sales of human-friendly or domestic robots have boosted in the past few years and will continue to grow in the coming years.

Figure 1 shows the sales of domestic robots in the years 2018 and 2019. It also shows the potential growth in sales in the upcoming years. It can be implemented that the use of domestic robots has been increasing with time.

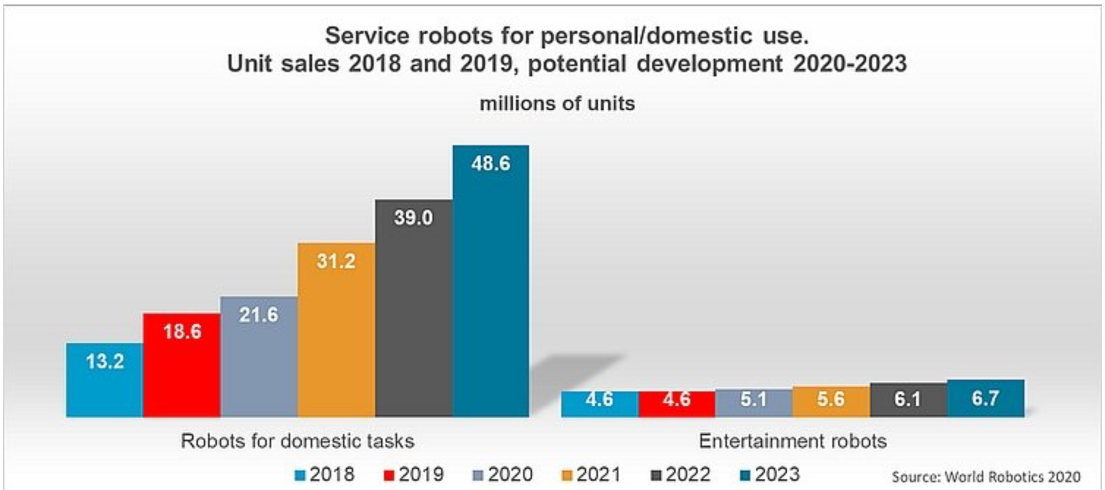


Figure 1: Sales of domestic robots [1]

The main motivation of this project is to make humanoid robot arms; each arm has 5 DOF along with a head of 1 DOF. This will be mounted on a metal body with a mobile base.

The aim of the project is to study the forward kinematics of the robotic arm and make it perform different tasks and to simulate it in MATLAB. The joints of the arm will be able to move to different angles to form a particular position of the arm.

1.3 Objectives of the project:

The main motive of the internship is to learn the various concepts in IOT and Robotics and to work on various IOT and Robotics projects on different controllers like Arduino and ESP32.

The major project in this internship is a prototype of a humanoid robot arm and neck. The arm and neck can move to form different positions of the humanoid robot.

The objective of the above project can be decomposed into 4 smaller learning objectives:

1.3.1 Forward kinematics of robotic arm:

Study the forward kinematics of a 5 DOF robotic arm and understand the mathematical logics behind the performance of the robotic arm.

1.3.2 Design and Structure:

Design the parts of the arm on Solidworks and 3D print them. Analyze the structural design to mount it on a metal body.

1.3.3 Controllers and coding:

Understand the concept of controllers like Arduino and esp32 and code for the arm to move to different positions.

1.3.4 MATLAB simulation:

In MATLAB, plot the 5R robot along with animation for forward kinematics visualization.

The aim of this project is to create a humanoid robot which can perform various tasks.

1.4 Organization of report:

The work schedule of the project was divided into 4 months. The monthly work done is as shown below:

1.4.1 Feb 2021

- Study the Arduino and esp32.
- Work on small projects on arduino and esp32 like hand sanitizer dispenser and 4 wheel mobile robot to understand the concepts.

1.3.2 Mar 2021

- Study the forward kinematics of robotic arm and humanoid robot
- Study on servo motors
- Work on the robotic arm with arduino.

1.3.3 Apr 2021

- Work on robotic arm with esp32
- Work on Bluetooth module and interface it with arduino and esp32

1.3.4 May 2021

- Interface the arms and neck with the entire body
- Complete movement of the humanoid robot
- MATLAB simulation for forward kinematics visualization of 5 DOF robot.

Chapter 2: Background Material

2.1 Conceptual Overview:

2.1.1 Kinematic analysis:

The forward kinematics is done to calculate the transformation matrix that describes the position and orientation of the end effector of the robot with respect to the base of the robot. The resultant total transformation matrix describes the relation between the end effector and base of the robot.

The kinematic analysis is done by the Denavit-Hartenberg convention method. This method is proposed by Jacques Denavit and Richard Hartenberg. This method is developed to create a general theory to describe an articulated sequence of joints. The DH notation is particularly applicable for robots that are serial link manipulators or have the same mechanism.

In serial link manipulators, each joint is attached, via a link, to the previous joint. The links are rigid, each joint move: either revolute or prismatic. Every joint connects two links and every link connects two joins except the first and last links. The first link is the base of the robot, considered as the 0^{th} link, which does not move. The last link is the end effector. If the robot has N joints, then it will have N+1 links including the base or 0^{th} link.

Each joint in the robot has 4 parameters. There are 4 parameters of the DH table- a_i, α_i, θ_i, d_i parameters, where i is the joint number. Here, i has a range from 0 to 5. The 0^{th} position is the base frame, hence there are 6 positions.

Table 1 lists the description of each parameter of the DH table.

a_i	Link length	Distance from z_{i-1} to z_i measured along x_i
α_i	Link twist	Angle from z_{i-1} to z_i measured about x_i
θ_i	Joint angle	Distance from x_{i-1} to x_i measured along z_i
d_i	Link offset	Angle from x_{i-1} to x_i measured about z_i

Table 1: DH parameters description

The first step of DH convention method is to assign the coordinate frames of robot arm to each joint, starting from the base of the robot. A universal frame with the 3 axes is taken as reference. The z axis is the axis about rotation of each joint of the arm. Using right hand rule, x axis and y axis are assigned for each joint. The frames of the robot are assigned. Figure 2 shows the coordinate frame assignments to joints.

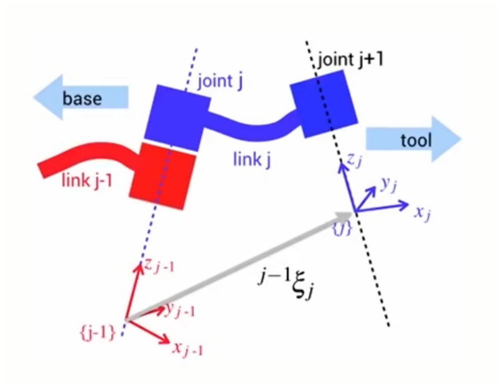


Figure 2: Coordinate frame assignment [2]

Using the frame assignments, the parameters of the DH table are filled. The Denavit- Hartenberg parameters table is used to find the forward kinematic equation.

Using parameters from the table, transformation matrix of each joint is found. The transformation matrix is denoted by A which is given by the equation:

$$A=Rot_z(\theta_i)Tran_z(d_i)Tran_x(a_i)Rot_x(\alpha_i)$$

Transformation matrix is given by,

$$A_n=\begin{pmatrix} Cos\theta_n & -Sin\theta_n Cos\alpha_n & Sin\theta_n Sin\alpha_n & a_n Cos\theta_n \\ Sin\theta_n & Cos\theta_n Cos\alpha_n & -Cos\theta_n Sin\alpha_n & a_n Sin\theta_n \\ 0 & Sin\alpha_n & Cos\alpha_n & d_n \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Since the arm is 5 DOF arm, 5 transformation matrices are found with the corresponding parameters from the DH table.

R_{th} is total transformation matrix. It is given by, $R_{th}=A_1.A_2.A_3.A_4.A_5$. Forward kinematic equation is given by P_x, P_y and P_z.

$P_x= a_n Cos\theta_n$

$P_y= a_n Sin\theta_n$

$P_z= d_n$

2.1.2 *Arduino:*

The project uses the Arduino Mega board. The Arduino Mega 2560 board is a microcontroller board, based on the Atmega2560. It has 54 digital input and output pins out of which 14 are PWM pins. It has 16 analog pins and 4 UARTs. In addition it has 16MHz crystal oscillator, a USB connection, a power jack, an ICSP header and reset button.

The study of the arduino mega board is done. First small projects like automatic hand sanitizer dispenser and a 4 wheel mobile robot are made to understand the concept of Arduino.

The code is written in embedded C in the Arduino IDE software. The testing of each servo motor to read the angles is done. The instruction *servo.read* is used to find the angles of each servo motor. The instruction *servo.write* is used to assign an angle for the servo motors.

2.1.3 Testing mechanical components:

The mechanical components used for the movement of the arm are dc servo motors. Five servo motors are used for each arm so that each of the 5 parts can move in different direction. Servo motors are used because the angles can be controlled. Each position of the arm requires different angles of each servo motors. It will be coded accordingly.

Most robots and humanoids use stepper motors to contain the weight of the material. Servo motors are used in 3D printed or small robots or humanoids. They are used as a high performing alternative to stepper motors. Servo motors work on the principle of Pulse Width Modulation which is its angles of rotation is controlled by the pulse modulation given to its control pin. Servo motor is made of a DC motor with a variable resistor or potentiometer.

2.1.4 MATLAB Simulation:

MATLAB stands for Matrix Laboratory. It is a programming and numeric control platform. It is used for a wide range of applications in different industries. MATLAB and Simulink are used in robotics for designing and simulation. It is used to verify every aspect of robot system or autonomous system.

The robot can be plotted in MATLAB based on its DH parameters. It is plotted for the visualization of forward kinematics of the 5 DOF robot arm. The coding is done to receive a resultant plot that runs continuously till it reaches the number of points assigned. Figure 3 shows the plotting of a 2R robot arm.

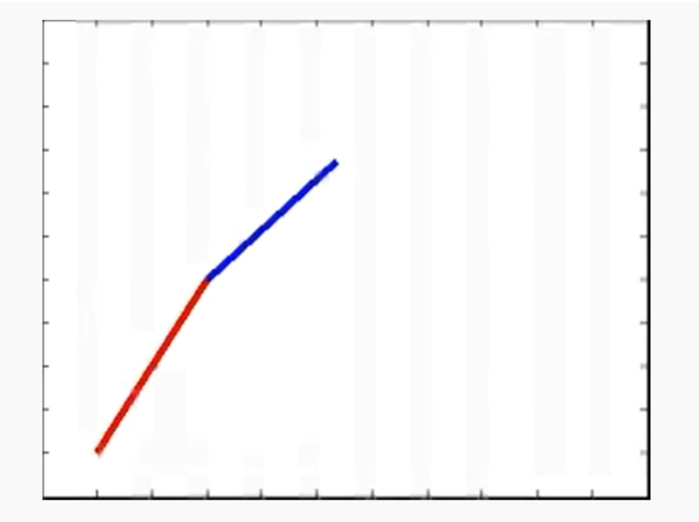


Figure 3: Plot of 2R arm [3]

2.2 Technologies Involved:

The different technologies used in the implementation of the project are as follows:

2.2.1 Design and Structure:

The virtual model of the arm was designed and developed used Solidworks environment. Solidworks is a solid modeling, computer aided design and computer aided engineering program. Solidworks is a platform to develop mechatronics systems from start to end. It allows you to design parts for a mechanical or mechatronics system.

2.2.2 Fabrication:

After being designed on Solidworks platform, the model is then fabricated. The fabrication is done by 3D printing. The 3D printer used is Creality Ender-3 3D printer. This is done by importing the *.STL* file into CURA software which is supported by the 3D printer. The material used to 3D print the parts is PLA. 3D printing is a technique that constructs 3D parts from a CAD design or a digital 3D model for any mechanical or mechatronics system.

2.2.3 Controlling:

The controller used is Arduino Mega 2650 Board. The software to develop the code is Arduino IDE. The circuit is interfaced to the computer using the ATMEGA 2650 controller board.

2.2.4 Simulation:

The simulation of the arm is done on MATLAB. MATLAB is a software portal used for robotics to design and simulate the robots. It is used for plotting the robot which continuously runs for the given number of points on the axis.

2.3 Literature Survey:

The development in technology has increased the development of humanoid robotic arms due to its efficiency and functionality in different industries. Many humanoid robots have already been made in the past.

The literature survey of some humanoid robots and 3D printed robots has been done to understand the variation of the DOFs in a robot.

A few of the various robotic arms that are designed and printed have been discussed and reviewed.

2.3.1 Reachy robotic arm:

Reachy is a 3d printed robotic arm which resembles a human arm is used as a test bed for human- robot control activities such as in surgeries etc. Reachy was invented with the motive of providing researchers with a robotic platform for which they can test and control interfaces and strategies that would be employed to drive a robotic arm.

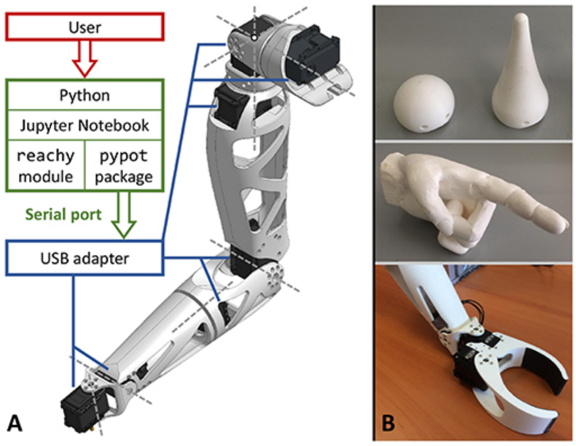


Figure 4: Reachy in standard version [4]

2.3.2 *TUAT/ Karlsruhe humanoid hand:*

Various robotic arms are designed with different degrees of freedom. This humanoid hand is made with 8 degrees of freedom. The 8 DOF robotic arm is more efficient for performing human like activities. This arm made by the department of mechatronics from Ho Chi Minh University of technology in Vietnam has also been designed for the fingers part of the arm to make it more human-like. Each of the fingers has an additional 4 degrees of freedom. This arm completely works as a human arm.

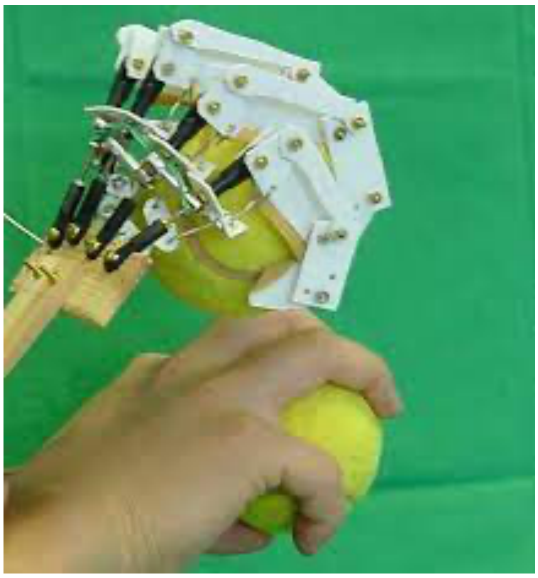


Figure 5: TUAT/ Karlsruhe humanoid hand [5]

2.3.3 *ARMAR humanoid robot:*

ARMAR is a humanoid robot. Its arm consists of 7 DOF from the wrist to shoulder. The applicability of this robot is to generate human-like manipulation and movement. The concept of redundancy has been introduced in this project. The ARMAR robot is designed on the basis of reduction of workspace of the arm. It also has the analytical description of the redundancy of the robotic arm. ARMAR project was created in order to perform human-like manipulation motions from object trajectories.

Figure 6: ARMAR Robot [6]

Many more humanoid robots have been created in the past years which consist of different DOFs. The different arms have been made with varying DOFs. All these are analyzed to understand the suitability of DOF for the project.

Table 2 lists the comparisons of various humanoid robots based on DOF in arm, neck and torso along with the year and by who the robots were created.

Sl.no	Robot	Year	Created by	Arm DOF	Torso DOF	Neck DOF
1	ASIMO	2000	Honda	7	2	3
2	PEPPER	2014	Softbank Robotics	5	2	2
3	WALKER	2019	UBTECH	7	2	1
4	NAO	2008	Softbank Robotics	6	1	2
5	ROMEO	2009	Softbank Robotics	7	3	2
6	T-HR3	2017	Toyota	7	3	1
7	SURENA ROBOTS	2010	Iranian University of Tehran	7	1	2
8	ROBO-THESPIAN	2004	Engineered Arts	7	2	3
9	ROBONAUT 2	2011	NASA	7	1	3
10	VALKYRIE	2013	NASA	7	3	3
11	NEXTAGE	2009	Kawada Robotics	6	1	2
12	ARMAR	2017	Karlsruhe Institute of Technology	8	1	2

13	OCEAN 1	2016	Stanford Robotics lab	7	4	2
14	ATLAS	2013	Boston Dynamics	6	3	1
15	PETMAN	2009	Boston Dynamics	6	3	2

Table 2: List of Humanoid Robots

From table 2, it can be found that most of the humanoid robots have 7 DOF in their arms which is an ideal number as the human arm also has 7 DOF. This project is a simplified version of the humanoid robots and hence it has 5 DOF which is the essential joints of the arm.

Some robot arms have been 3d printed. Table 3 lists the 3d printed robotic arms along with its DOFs

Sl.no	Robot arm	DOF	Supported by
1	UFactoryuArm	4	Arduino, raspberry pi
2	Thor	6	Arduino mega
3	Little arm	3	Arduino UNO
4	MeArm	4	Arduino, raspberry pi
5	Zotrax robotic arm	5	Arduino
6	BCN3D Moveo	4	Arduino
7	Roboteurs RBX1 Remix	6	Raspberry pi
8	EEZYbotARM MK2	4	Arduino, raspberry pi
9	Little arm V3	4	Arduino Nano
10	OWI Robotic Arm Edge	4	Raspberry pi

Table 3: 3D printed robotic arms

From the table above, it can be implemented that most of the 3D printed arms have 4 DOF. This is because 3D printed arms are light-weight and contain only a small number of degrees of freedom. It can also be implemented that most 3D printed arms use Arduino as their controller.

From the above literature survey, it can be concluded that the prototype of humanoid arm can be 3D printed with 5 DOF.

Chapter 3: Methodology:

3.1 Methodology adopted:

Firstly, to get hands on grip and knowledge of the arduino and esp32, different small projects are worked on the controllers. For example, automatic hand sanitizer dispenser and 4 wheel mobile robot. The hand sanitizer dispenser is made with different controllers and sensors, first IR sensor and 555 timer then ultrasonic sensor and arduino then esp32.

A keen study of the different types of motors is done to analyze which motor is best suited for the robotic arm. A study on the forward kinematics is done for a 5 DOF robotic arm is done.

A pick and place robotic arm model is made with servo motors and 3D printed parts. It is mounted on a 4 wheel mobile robot. This robot moves around as it is controlled by a Bluetooth module. It will also pick up and place objects. This is done to understand how a robotic arm works and creates a basic idea of the humanoid.

The parts of the arm are designed and 3D printed. They are fixed with servo motors, one for each part. Coding for the parts is done accordingly for different positions. The project is modified with different controllers and components. The simulation of the arm is done on MATLAB by plotting it for understanding the forward kinematics of the robot arm. It is plotted based on its DH parameters that are found during the kinematic analysis of the arm. The result is a continuously running plot of the arm.

3.2 Functional Partitioning:

The project can be divided into 4 parts:

3.2.1 The design and structure of the arm:

The two arms are symmetrical; therefore the design for both the arms will be same. The degree of freedom for the arm is 5. There are 5 parts on the arm, from the shoulder to the hand. These parts are designed on Solidworks and then 3D printed. They are then fixed to the metal body.

3.2.2 Mechanical components:

The mechanical components used for the movement of the arm are servo motors. Five servo motors are used for each arm so that each of the 5 parts can move in different direction. Servo motors are used because the angles can be controlled. Each position of the arm requires different angles of each servo motors. It will be coded accordingly.

3.2.3 Electronic components:

Electronic components are nothing but the controller and the different modules used. At first arduino is used, then later esp32. This is a prototype of the robotic arm so the controller that is more efficient is used for the actual robot.

3.2.4 Coding:

The code for running and controlling the angles of the servo motors is written in such a way that it is controlled in the serial monitor. As an instruction is given, which in this case is a letter for each position, the arm will move in the required directions to come to that particular position.

3.2.5 MATLAB Simulation:

The robot arm is plotted on MATLAB using Simulink. This is done to visualize the forward kinematics of the 5 DOF arm. The result of the plot is the arm continuously running for each of the link's theta values.

Additionally, the neck of the humanoid is also worked on. The neck will move from left to right, making the humanoid to look left and right. It will use 1 servo motor and it will be mounted on top of the metal body.

3.3 Tools required:

3.3.1 Hardware:

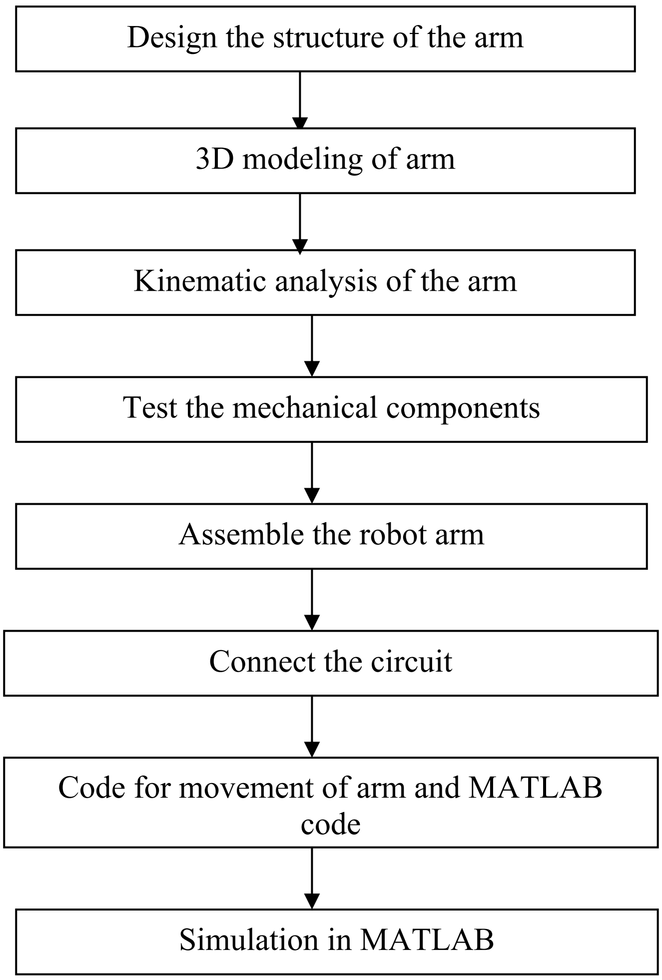
3D printers, servo motors, metal body, controllers like arduino and esp32, bread board, etc.

3.3.2 Software:

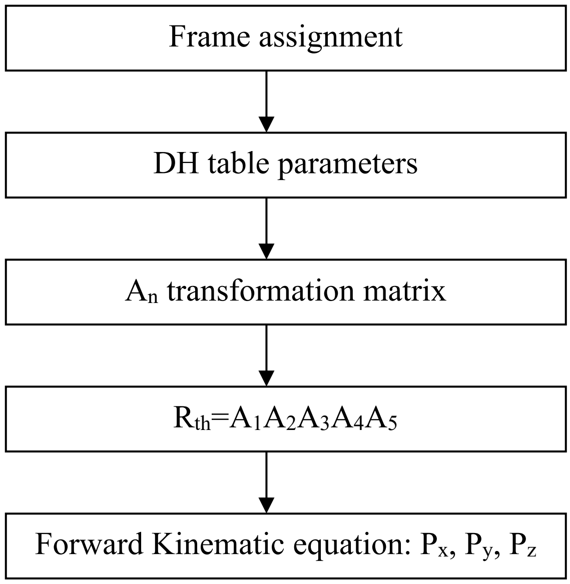
Soldiworks-3D printing, Arduino ide and esp libraries, MATLAB Simulink

3.4 Block diagram:

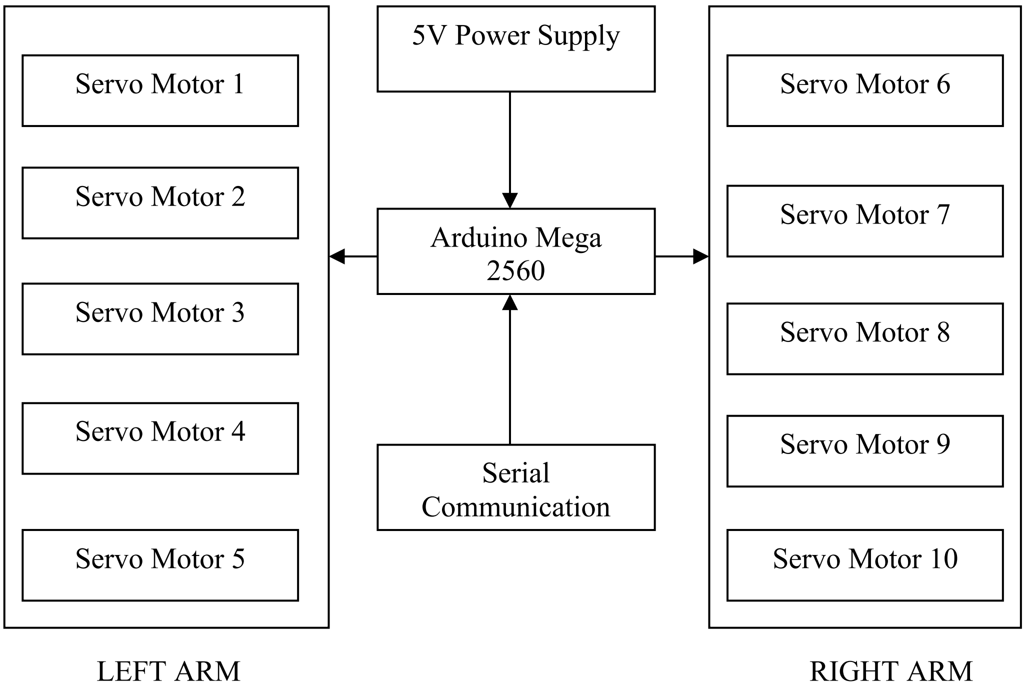
3.4.1 Steps from beginning to end result:



3.4.2 Kinematic analysis:



3.4.3 Electronic control circuit:



3.5 Circuit layout and Assembly:

Each arm has 5 DOF hence, 5 servo motors for each arm. 10 servo motors are connected to the arduino mega 2650 board for both the robot arms. Additionally 1 servo motor is also connected for the neck. The below pictures show the different connections to implement the project.

Figure 7 shows the connection of a servo motor to the arduino board.

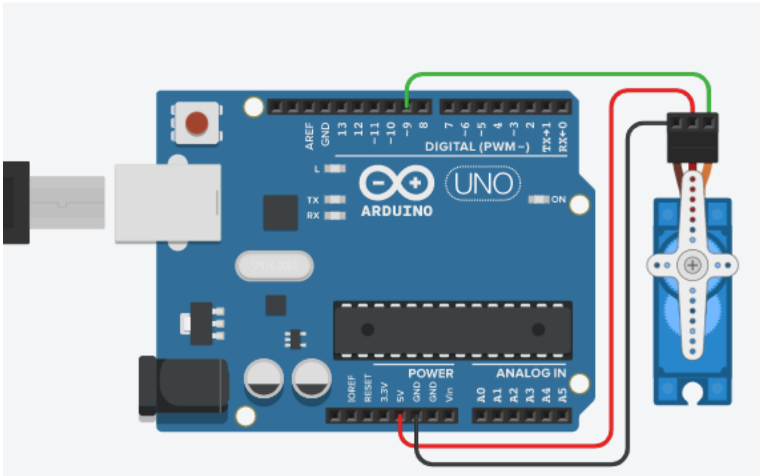


Figure 7: Servo motor connected to arduino [7]

Figure 8 shows the electronic control circuit board connected to the humanoid robot.

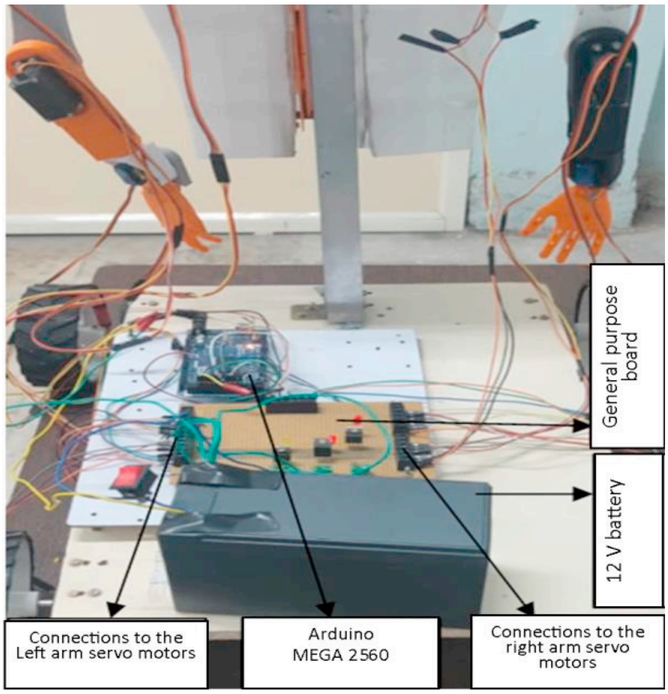


Figure 8: Electronic connection to humanoid

The servo motors are attached to the digital pins of the Arduino mega board. The 5V pin is connected to the v_{cc} of the servo. The ground pin is also connected. For 10 servo motors, the connections are made using bread board.

The assembly of the robot arm is shown in the figure 9 below.

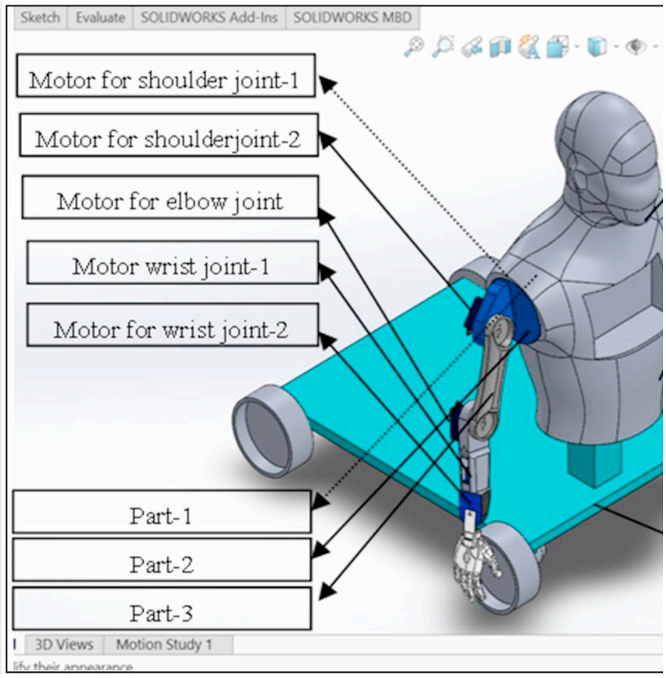


Figure 9: Assembly of robot arm

The range of motion for each joint is shown is tabulated in the below table 4:

Arm	Shoulder Joint		Elbow Joint	Wrist Joint	
Joint	1	2	3	4	5
Angle(deg)	-90 to 90	0 to 180	-90 to 90	-75 to 75	-75 to 75

Table 4: Range of motion for arm

Chapter 4: Implementation:

4.1 Target Specifications:

This project involves the keen study of forward kinematics of a 5 DOF robotic arm that performs various tasks.

This arm will be able to be in "Hi" position and various other positions. The project also involves controlling the neck of the humanoid.

The controllers used will be arduino and esp32, accordingly the most efficient controller will be used in the humanoid. It will be initially controlled by serial monitor and then later it will work on Bluetooth module and voice control.

The left arm will be worked on and tested. The right arm is symmetrical and hence only a few changes will be made to the right arm.

After coding for the movement of the arm, the MATLAB simulation for the forward kinematics of the 5DOF robot arm is done. The arm is plotted on the basis of its DH parameters.

4.2 Kinematic analysis:

The first step of kinematic analysis is the coordinate frame assignment. As shown in figure 9, the frames of the robot arm are assigned from the base of the robot to the end effector of the robot arm. The z axis is the axis of rotation. The x axis is found by the right hand rule. In the below figure 10, the frames of each joint is shown.

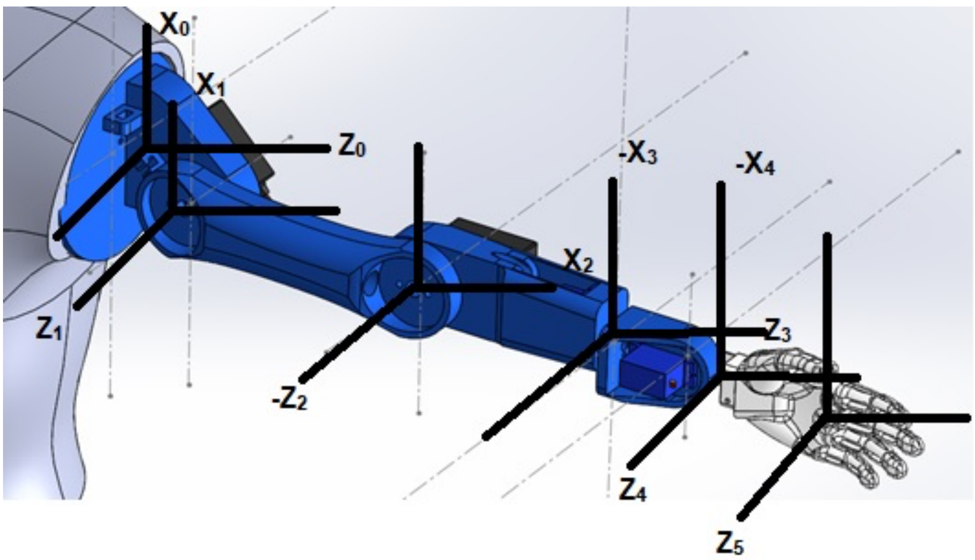


Figure 10: Frame assignment of arm

Using Solidworks, we can find the lengths from one joint to another as shown in the below figure 11. The link lengths of the arm are used in the DH table and hence used in the calculation of the transformation matrix.

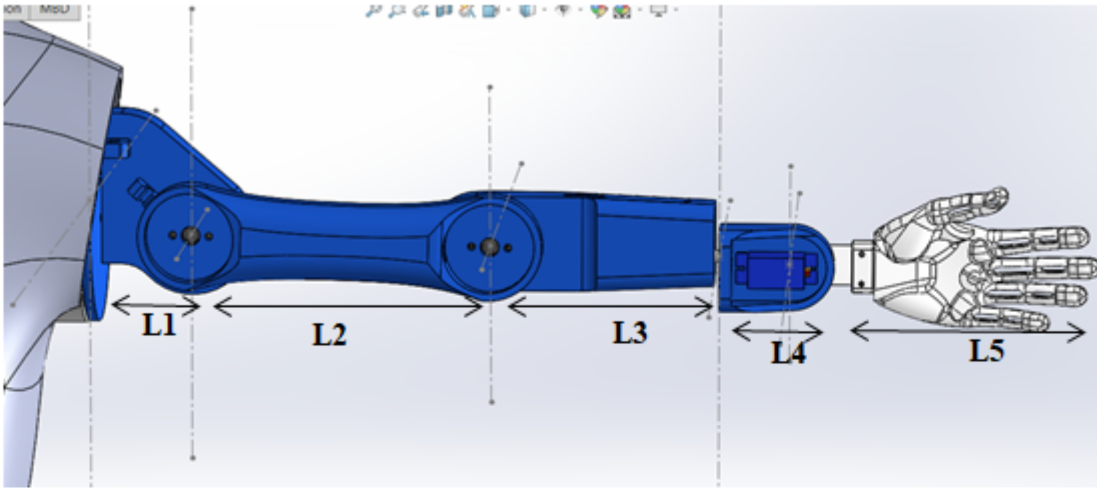


Figure 11: Link Lengths of arm

L1=41mm;
L2=120mm;
L3=92mm;
L4=28mm;
L5=120mm

Using the frame assignments from figure 8, we can find the Denavit-Hartenberg table. Table 5 lists the DH parameters of the humanoid arm.

Link	a_i	α_i	d_i	θ_i
0-1	0	90º	L1	0º
1-2	L2	0º	0	-90º
2-3	0	90º	0	90º
3-4	0	90º	L3+L4	0º
4-5	L5	0º	0	90º

Table 5: DH table of robot arm

From the DH table, the transformation matrix for each joint is found, using the above formula for A_n.

$$A1=\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 41 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A2=\begin{pmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & -120 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A3=\begin{pmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A4=\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 120 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A5=\begin{pmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 120 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

The total transformation matrix (Rth) is given by the post multiplication of each of the single transformation matrix.

Rth=A1.A2.A3.A4.A5

$$Rth=\begin{pmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -1 & 0 & 0 & -319 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

From the above matrix Rth, we can imply:

P_x=0;

P_y=0;

P_z= -319

4.3 Code for moving the arm:

The code for running and controlling the angles of the servo motors is written in such a way that it is controlled in the serial monitor. As an instruction is given, which in this case is a letter for each position, the arm will move in the required directions to come to that particular position.

The pseudo code is as shown below:

Pseudo Code:

1. Import Servo.h library
2. Initialize 11 Servo Variables

Function Setup

{

1. Delay by 1000 milliseconds
2. Set baud rate for serial monitor
3. Attach values to the servo variables
4. Delay by 1000 milliseconds
5. Write Initial positions of a ROBO ARM

}

Function loop

{

1. Iterate while loop till Serial.available
2. Read the data using Serial.read() and write it later using Serial.write
3. Switch case(data)

```
{
case 'w': Serial.println(" Saying hi ");  hi(); delay(10); break;
case 's': Serial.println(" Home position "); back(); delay(10); break;
case 'r': Serial.println(" Looking right ");  right(); delay(10); break;
case 'l': Serial.println(" Looking left "); left(); delay(10); break;
case 'h': Serial.println(" Shaking Hand "); shakehand(); delay(10); break;
}
}
```

Function hi()

{

//To move arm so that it can make a Hi movement.

//The rest of the body is at home position

1. Give servo motors different positions
2. Delay by 1000 milliseconds

}

Function back()

{

// Function for going to home position

1. Give servo motors different positions
2. Delay by 1000 milliseconds

}

Function right()

{

// to make the neck turn right

//The rest of the body is at home position

1. Give servo motor 11 a position
2. Delay by 1000 milliseconds

}

Function left()

{

// to make the neck turn left;

//The rest of the body is at home position

1. Give servo motor 11 a position
2. Delay by 1000 milliseconds

}

Function shakehand()

{

//possible movements for the ROBO Arm to perform shakehand

The rest of the body is at home position

1. Give servo motors different positions
2. Delay by 1000 milliseconds

}

4.4 MATLAB SIMULATION:

First a file is created on MATLAB, the code for the forward kinematics of 5 DOF robot is written in MATLAB to plot the 5R robot. The below figures show the code used in MATLAB

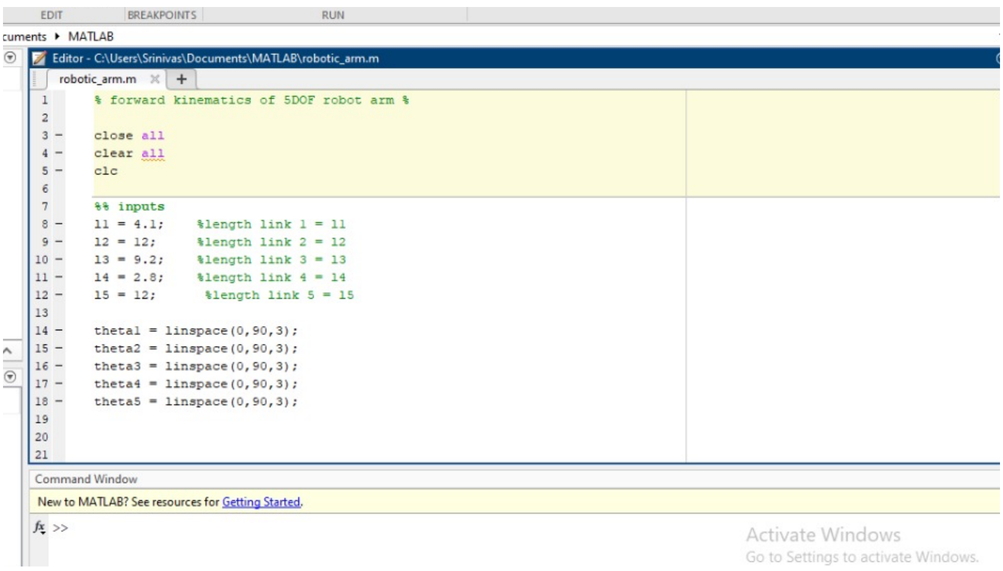


Figure 12: MATLAB code (1)

In figure 12, the code starts with giving the inputs as link lengths (l1, l2, l3, l4, l5) and theta values (theta1, theta2, theta3, theta4, theta5). Each link length is taken from the Solidworks file. The theta values are given by the command *linspace(a,b,n)*. The command '*linspace*' is used to generate linearly spaced vectors. For example, A= linspace(x,y,z) generates a row vector A of z points linearly spaced between and including x and y.

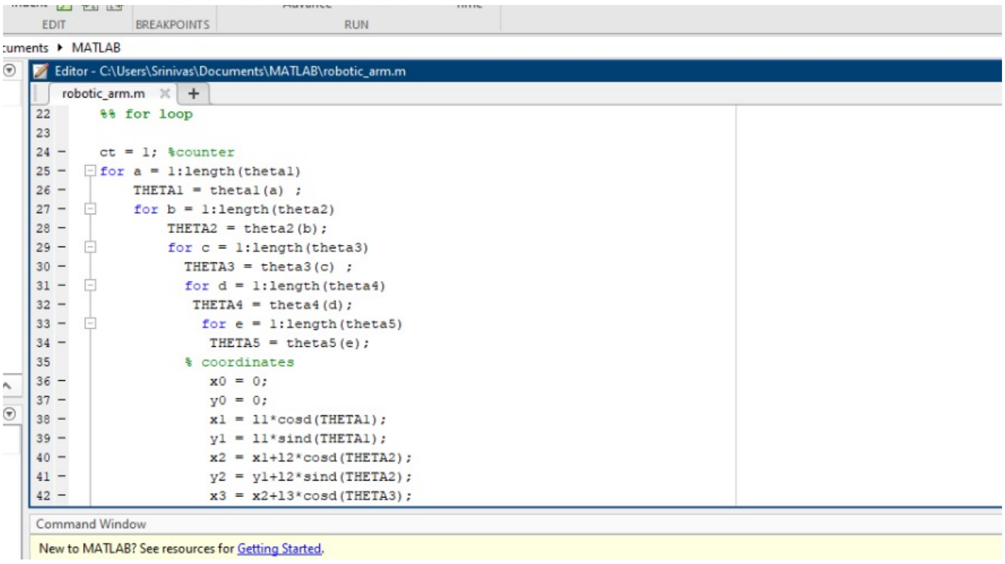


Figure 13: MATLAB code (2)

In figure 13, the code is a continued with a for loop in which a counter, ct1 is given with an initial value of 1. There are 5 for conditions in which each theta value is given by 1: length(theta value). This means for each variable a theta value is given such that the row vector starts from 1 to the length of each theta row vector shown in figure 1.

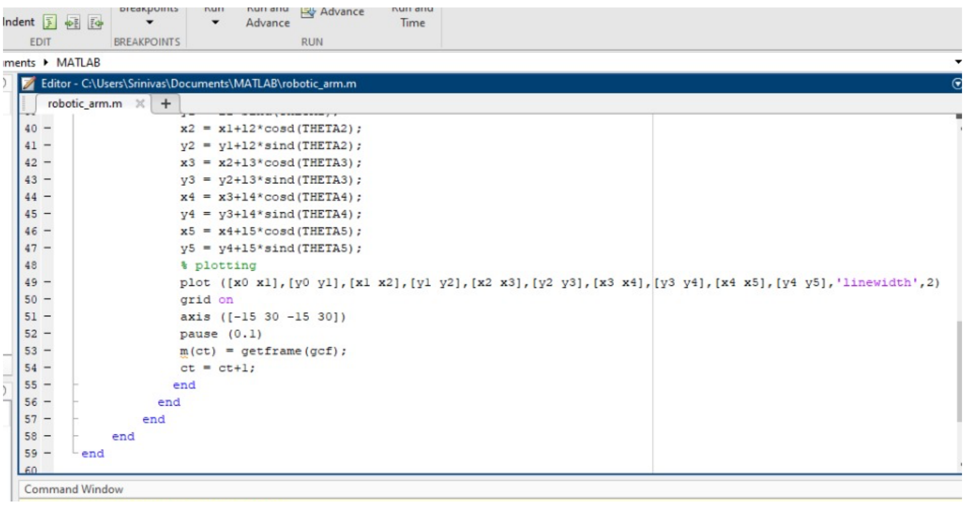


Figure 14: MATLAB code (3)

In figure 13 and 14, it is shown that the coordinates of each of the 5 links are assigned. The starting coordinates x0 and y0 are given as (0,0). From the coordinates x1 to x5 and y1 to y5, the formula $x_i=x_{i-1} + l_i * \cos(\theta_i)$ and $y_i=y_{i-1} + l_i * \sin(\theta i)$ is applied.

In figure 3 the code for plotting the robot is written as well. The function plot is used which holds the coordinates of each joint and the line width of 2 points. A function for turning on the grid mode in the graph is used and a function for the axis range is used. The counter, ct is incremented by 1. The for loops are ended as shown in the figure.

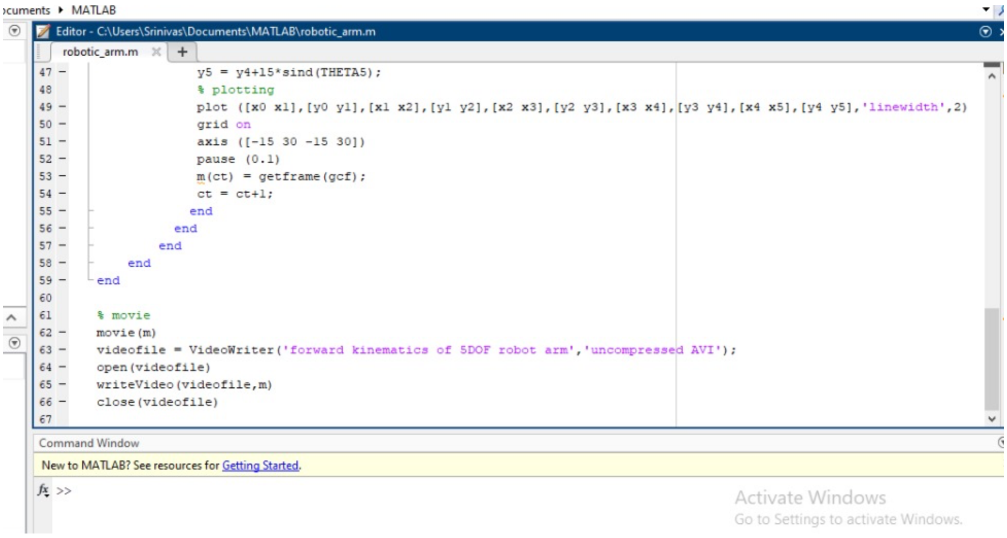


Figure 15: MATLAB code (4)

For creating an animation of the plot of the robot, the function movie is used as shown in the figure 15. This saves the resultant output as an animation file; hence the movie of the output is created.

The command is given by videofile = VideoWriter('filename').

The output is the result of the plotted graph of the robot arm that appears as soon as the code is run on MATLAB. The robot arm is continuously moving achieving all the angles of the theta values. The below figure 5 shows the output as a screenshot from the running graph.

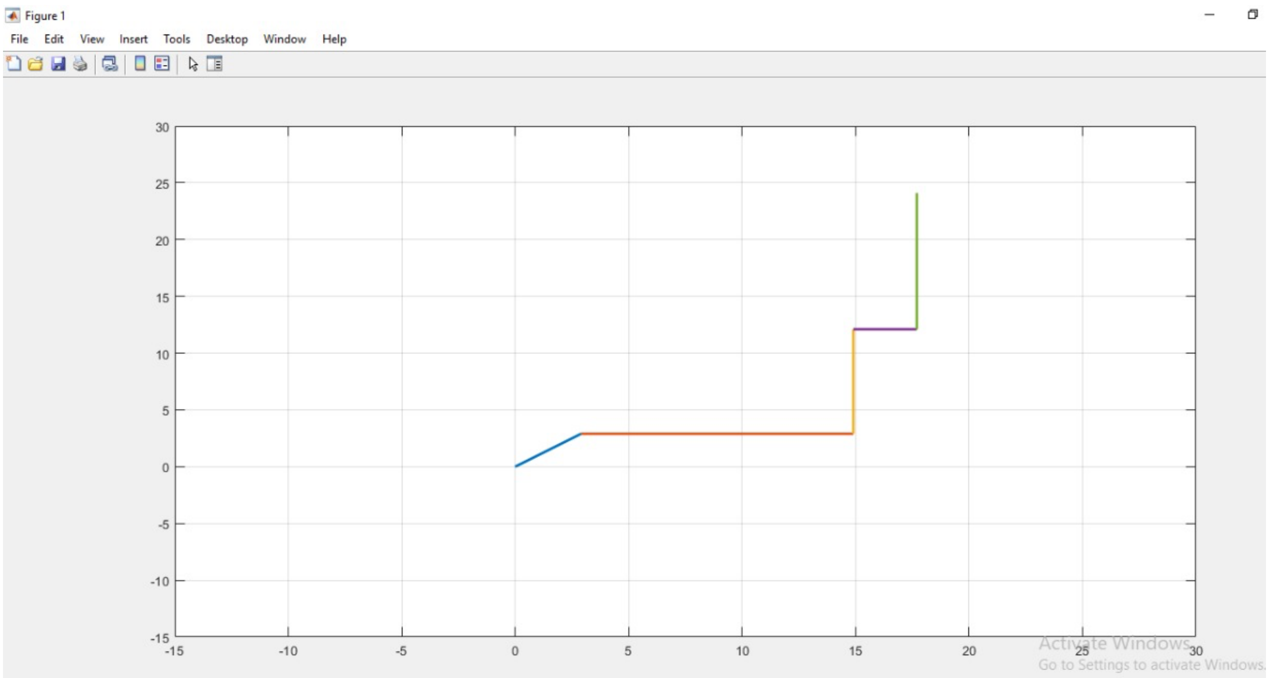


Figure 16: Output (1)

Chapter 5: Result and Analysis:

5.1 Result of kinematic analysis:

The kinematic analysis of the arm is done and from the DH table, the transformation matrices of each link are obtained. The total transformation matrix is the multiplication of all the individual transformation matrices. The resultant position is given by **P_x=0; P_y=0; P_z= -319**. This is obtained from the total transformation matrix.

5.2 Result of movement of arm:

The parts of the arm assembled in such a way to look like a human arm. The arm is then coded on Arduino IDE. The 5 joints of the arm move to form different positions when an instruction is given on the serial monitor. When the letter 's' is given on the serial monitor, the arm moves to Hi position and likewise with different letters it will move to different positions. The arms and head are mounted to a metal body, which as a whole forms the humanoid robot. The humanoid robot has a mobile base with moving arms and a neck. Below picture shows the humanoid robot made.

Figure 17: Humanoid robot

5.3 Result of MATLAB simulation:

The MATLAB simulation gives the output of the robot arm that is plotted. The below figures 12 and 13 show the output. The output is also shown in the figure 5. The figures are screenshot of the originally continuously running plot.

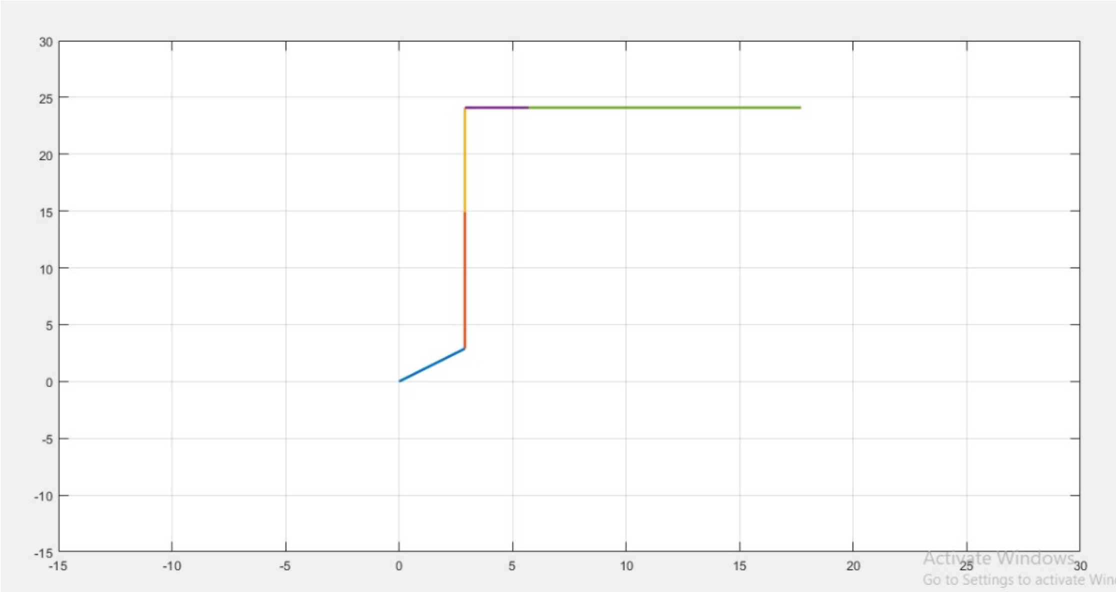


Figure 18: Output (2)

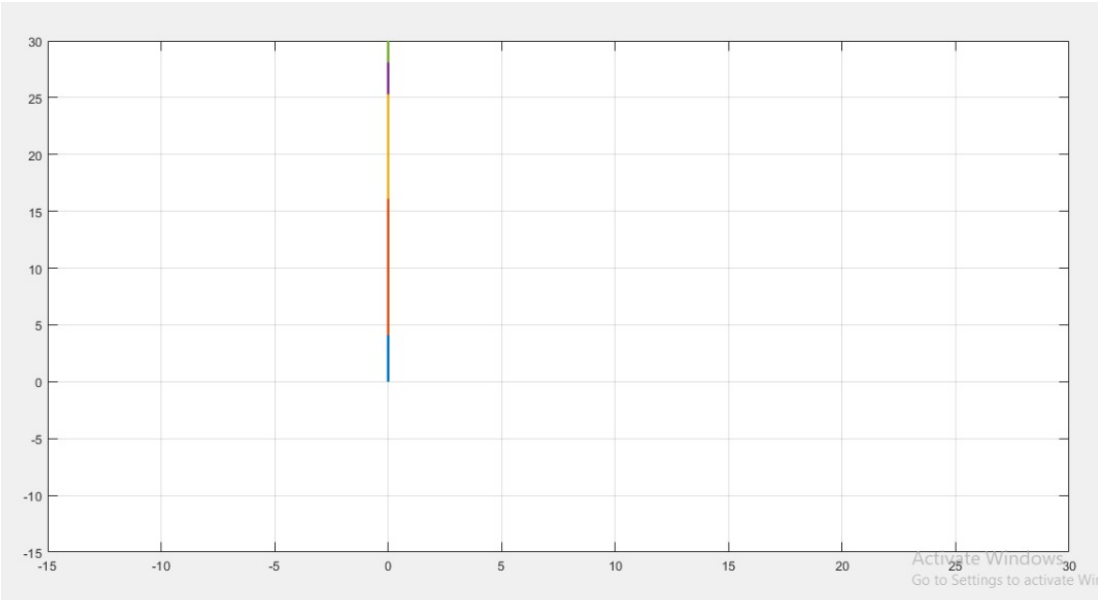


Figure 19: Output (3)

Chapter 6: Conclusion and future scope:

6.1 Conclusion:

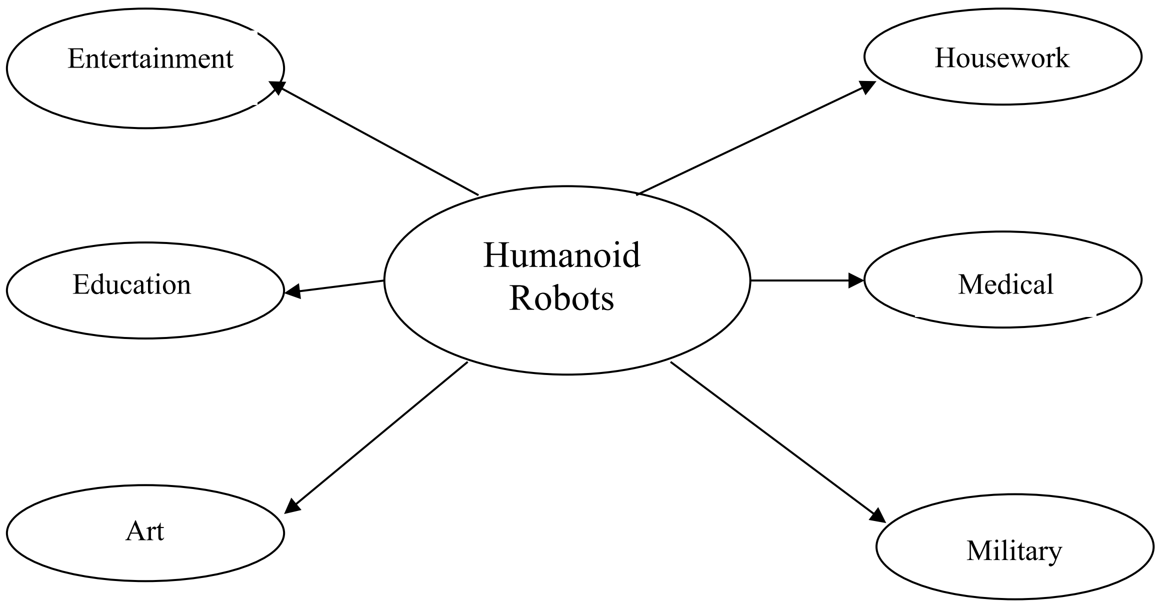
The robotic arm can be designed to perform various activities. A humanoid robotic arm can perform human-like tasks like assisting humans in human environments, while other robotic arms are used in industries for different purposes. The end effector also plays an important role as a specific task can be performed by the arm such as welding, gripping, snipping etc.

The kinematic analysis of the robot arm provides the relation between the base of the robot and the end effector of the robot. It gives the position and orientation of the robot. The movement of the joints is due to the rotation of the servo motors at particular angles. The coding for the arms is done accordingly to provide an instruction in the serial monitor and the arm moves to a particular position.

There is a wide range of tasks that humanoid robots can perform from automation to disaster response and from house hold chores to surgeries and medical assistance. They bring down the need for human labor and can perform dangerous tasks that humans may not be able to perform. Robots are essential for the future as the need for robots in different industries has been increasing drastically.

6.2 Future scope:

Currently most robotic arms are being used for industrial and automation purposes but the future of robotics holds the vast applications of the humanoid robots. Humanoid robots will be used to assist humans in military, space exploration, hospitals, on-field duties, labor, firefighting and many such human like activities. Apart from these activities, humanoid robots can also assist in house hold chores. Humanoid robots can perform tasks that are dangerous and risky for humans to perform. Humanoid robots are also used in research purposes. Humanoid robots can also understand and process human-like information.



Humanoids robots are the future of robotics. Humanoids are expected to serve as companions and assistants for humans in daily life activities. Humanoids are expected to help in case of natural disasters as well as in military and army. Many humanoid robots have already been made for such purposes, but in the future many more such humanoids will be available to the people as technology is the main driving factor of development.

The future also holds the development of existing technologies like AI, neural networks, IoT etc. The advanced AI and neural networks can help build advanced humanoid robots like Sofia the robot and many other robots that are capable of resembling humans in every way possible. Humanoid robots add to the technological developments and can change a country’s status and economy in different ways. Humanoid robots or already on the go with developing technologies and in the future there will be a rise in the development and advancement of Humanoid robots.

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