Drives, Controls and Modelling Laboratory (MTE 3161)

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MODELLING, SIMULATION AND CONTROL OF SCARA(RRP) MANIPULATOR ARM

SUBMITTED BY

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MINI PROJECT

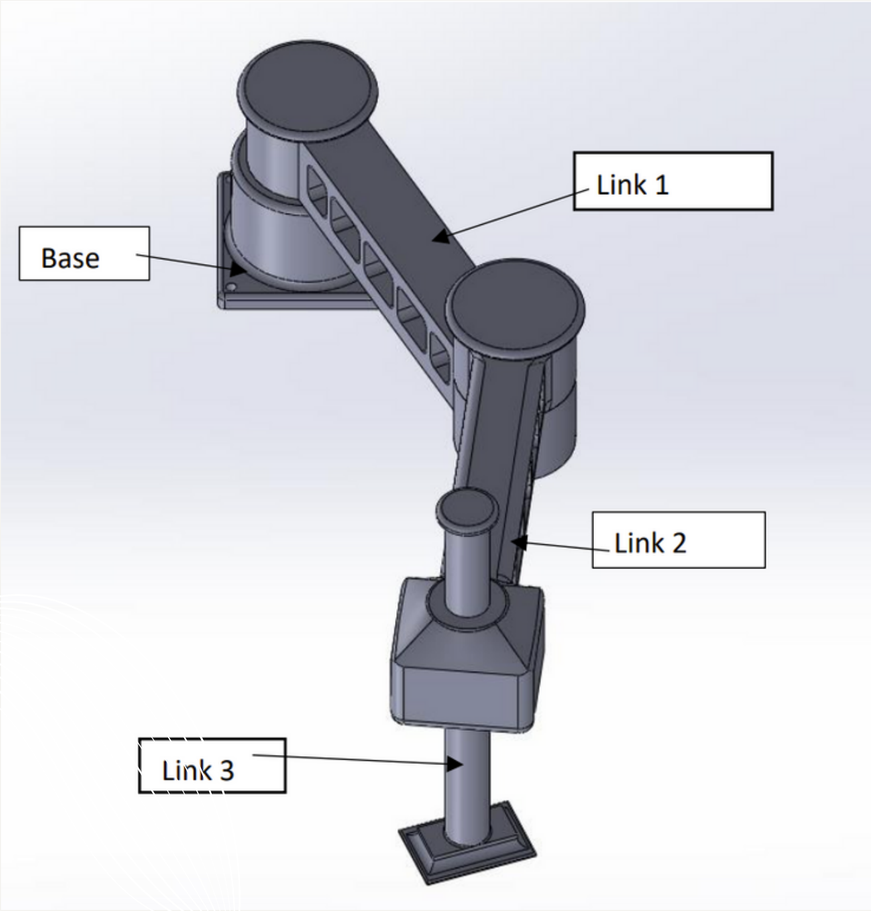
OBJECTIVES

The increasing prevalence of robots in modern industrial production emphasises how important it is to research robotic arms as essential instruments in this field. Our goal is to study the modelling and simulation of SCARA robotic arms in various contexts. In theory and in simulated conditions, this investigation could make robots achieve greater flexbility and be able to do more in the industrial settings.

The manipulator follows predefined trajectories that are tailored to certain purposes. Many methods, such as forward and inverse kinematics, have been used to guarantee accurate arm motion. Furthermore, PID tuning has been applied to optimise the arm's performance. In addition, motors are used for control, which makes it possible to carry out a variety of activities precisely and effectively.

ABOUT SCARA

- THE SCARA ACRONYM STANDS FOR SELECTIVE COMPLIANCE ASSEMBLY ROBOT ARM OR SELECTIVE COMPLIANCE ARTICULATED ROBOT ARM.
- SCARA IS A TYPE OF INDUSTRIAL ROBOT.
- THE SCARA ROBOT IS MOST COMMONLY USED FOR PICK-AND-PLACE OR ASSEMBLY OPERATIONS WHERE HIGH SPEED AND HIGH ACCURACY IS REQUIRED.
- GENERALLY A SCARA ROBOT CAN OPERATE AT HIGHER SPEED AND WITH OPTIONAL CLEANROOM SPECIFICATION



Overview of the Project

1

STEP

Making CAD Model of a SCARA

2

STEP

Transfering the CAD model into Simscape Module

3

STEP

Applying Inverse and Forward Kinematics

4

STEP

Adding and Tuning PID Controller

5

STEP

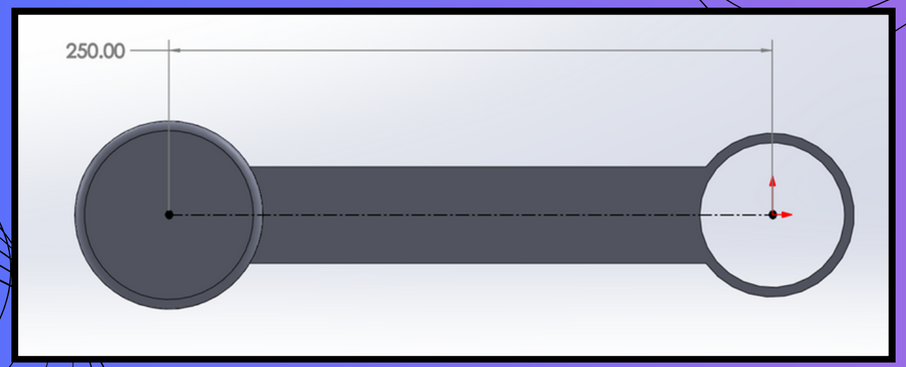
Adding the Parameters,Trajectories and Testing them

6

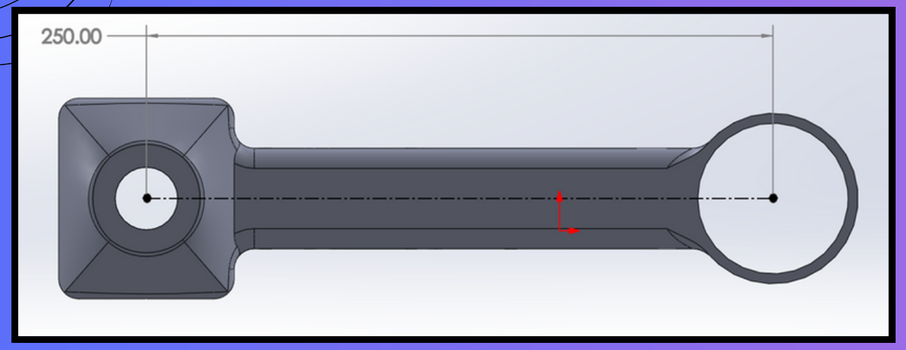
STEP

Tuning the controllers with dc motors

MAKING CAD MODEL OF A SCARA

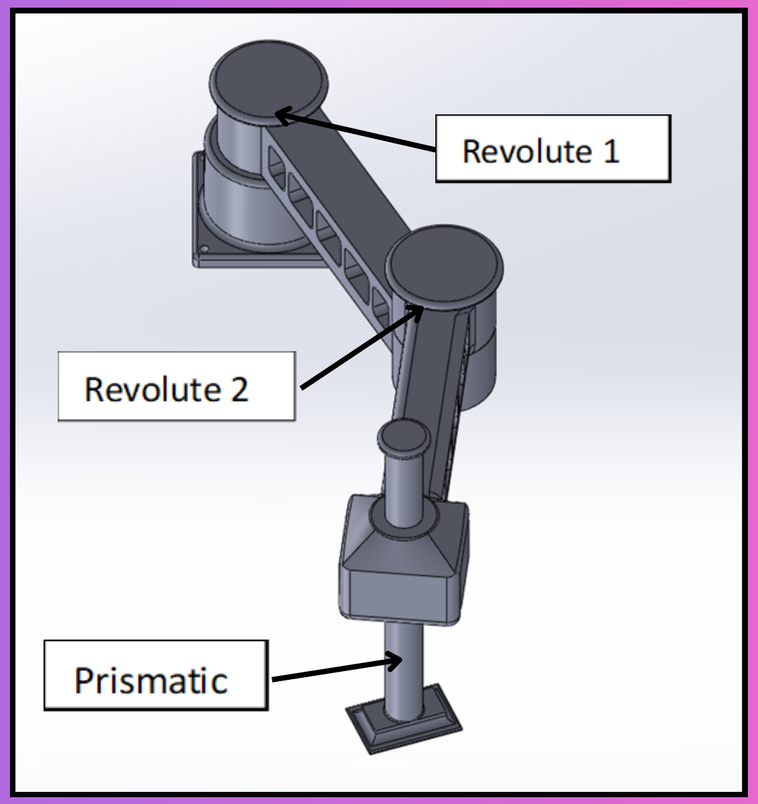


Link 1



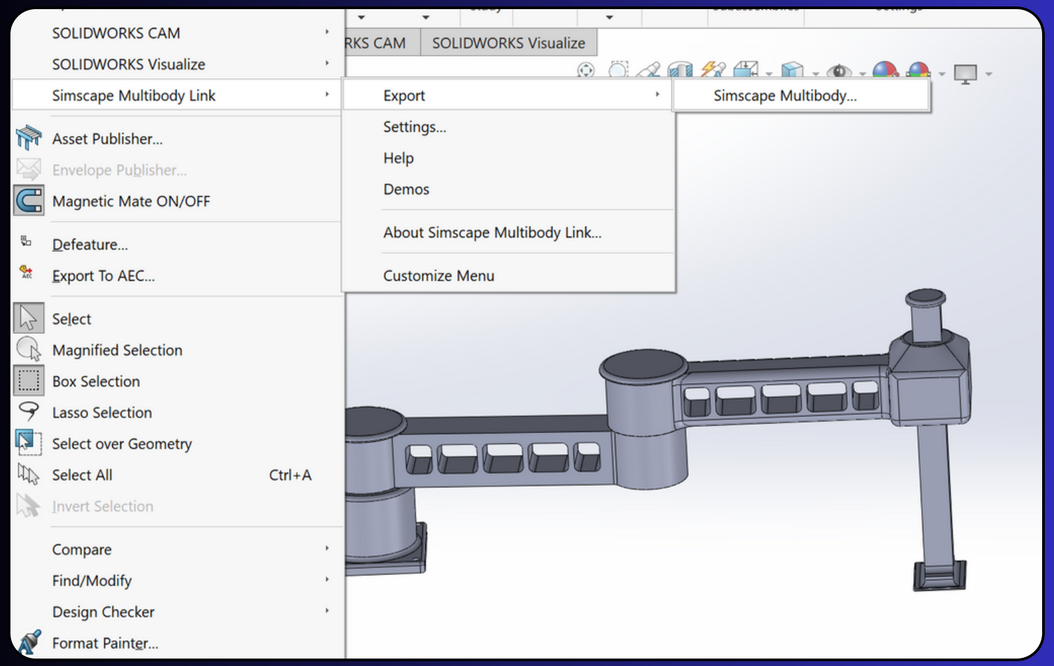
Link 2

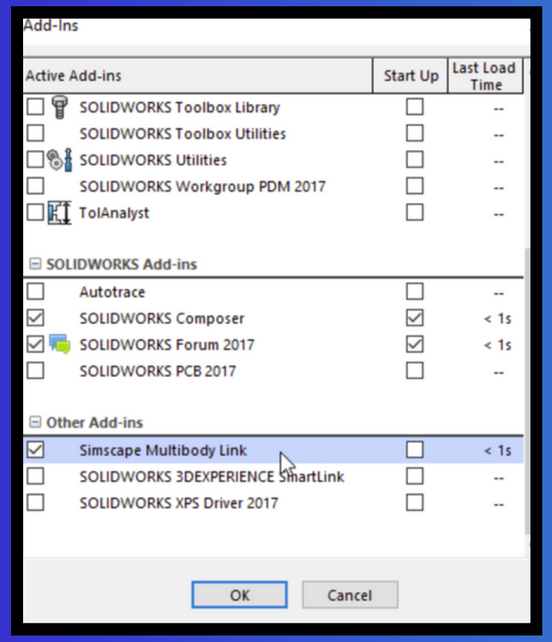
Link dimensions



Joints

TRANSFERING THE CAD MODEL INTO SIMSCAPE MODULE





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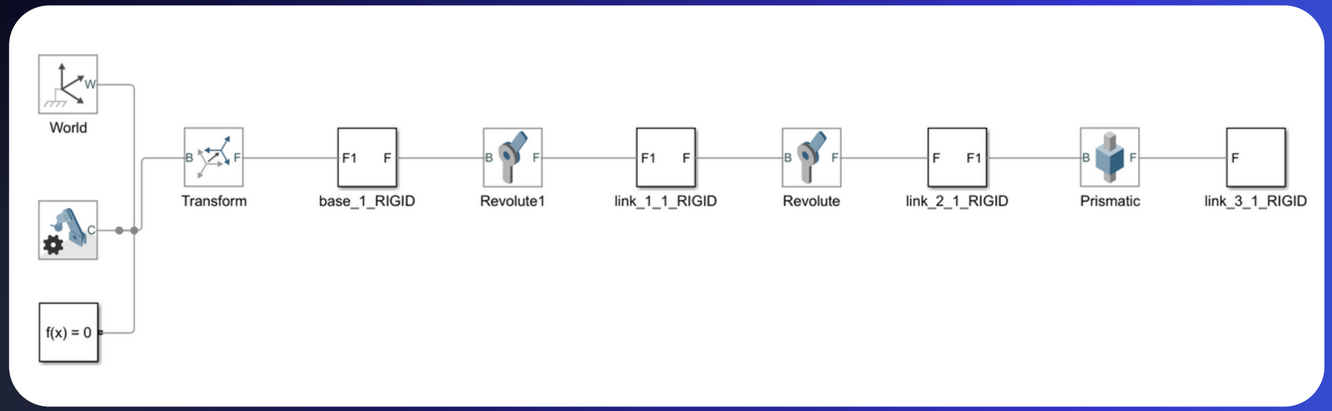



```
>> smimport('scara.xml')
```

Imported model in Matlab

SIMULATION AND MODELLING

Added Kinematics and Inverse Kinematics function blocks

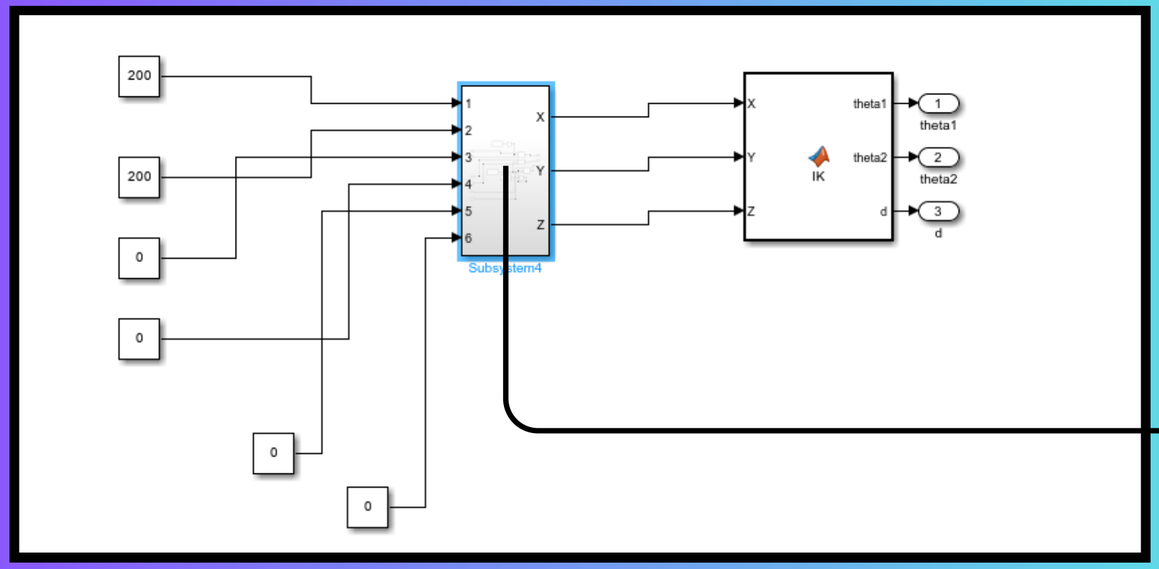
Forward Kinematics

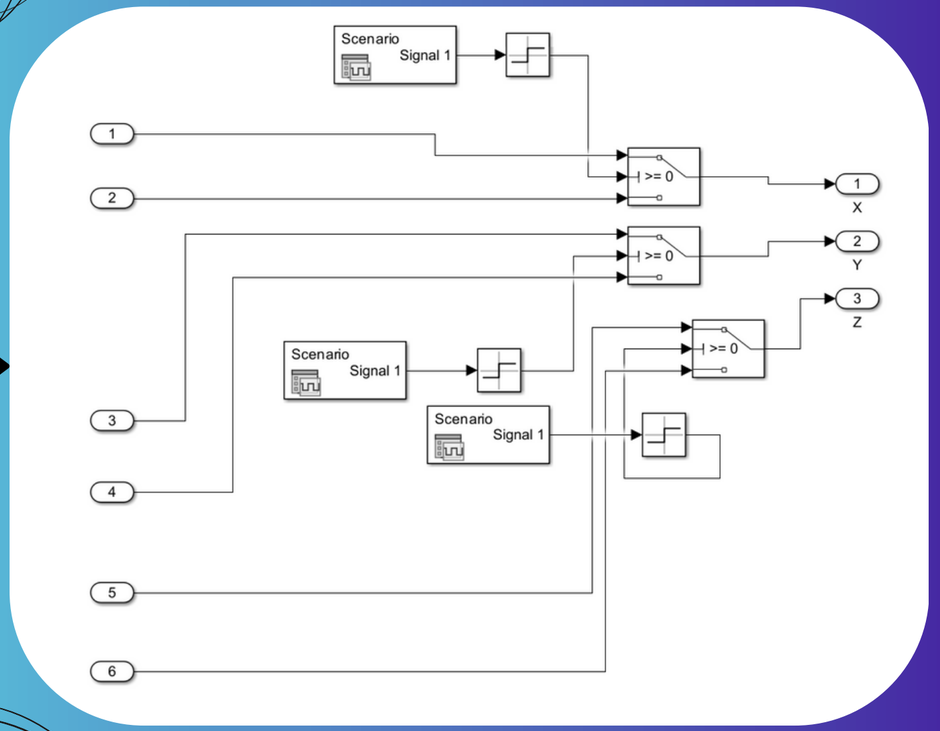
```
function [Xa,Ya,z] = FK(theta1,theta2,d)

l1 = 250;
l2 = 250;

Xa = l1*cos(theta1) + l2*cos(theta2 + theta1);
Ya = l1*sin(theta1) + l2*sin(theta2 + theta1);
z = d;
```

```
function [theta1,theta2,d] = IK(X,Y,Z)

l1 = 250; % length of first arm
l2 = 250; % length of second arm
if(Z<-140)
    Z = -100;
end
c2 = (X.^2 + Y.^2 - l1^2 - l2^2)/(2*l1*l2);
s2 = sqrt(1 - c2.^2);
theta2 = atan2(s2,c2);
theta1 = atan2(Y,X)-atan2(l2*sin(theta2),l1+l2*cos(theta2));
d = Z ;
```

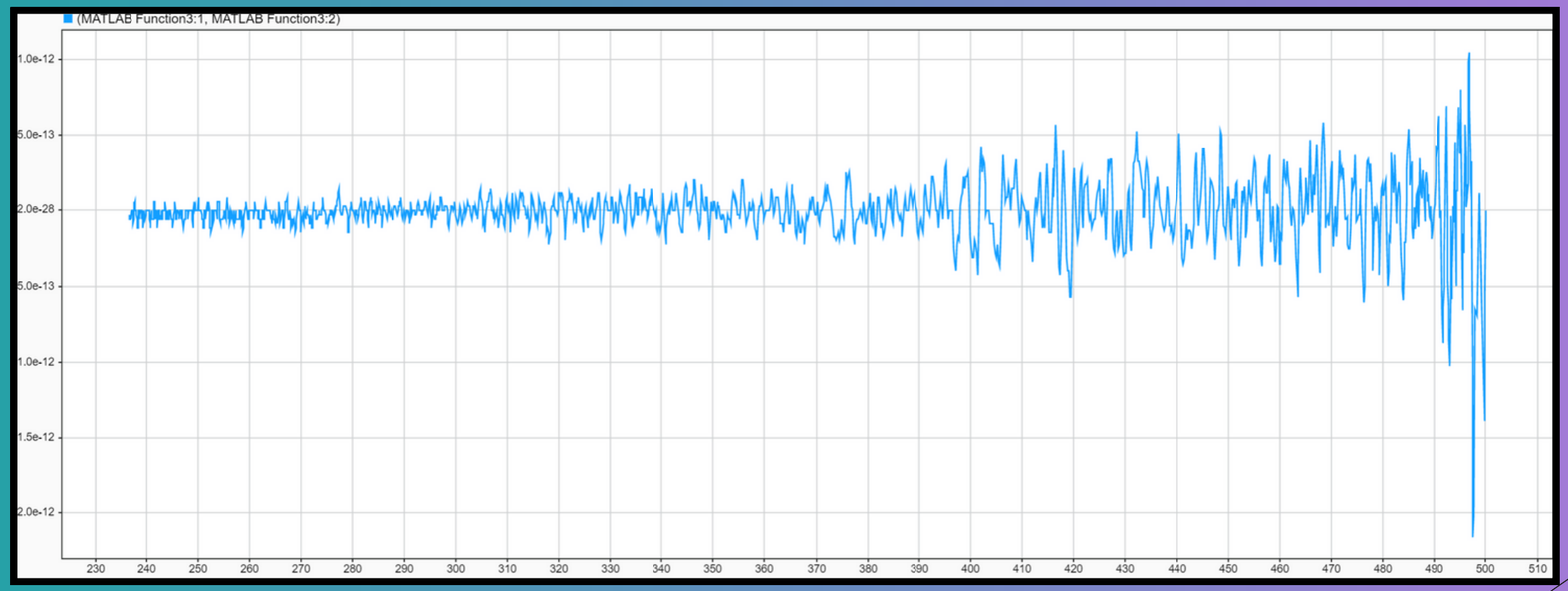
Inverse Kinematics

- Provided input coordinates to inverse kinematics block
- Using Signal Editors and switches the desired coordinates were given in order to visualise the motion of the robot
- this method of using the signal editors and switches would make debugging easier





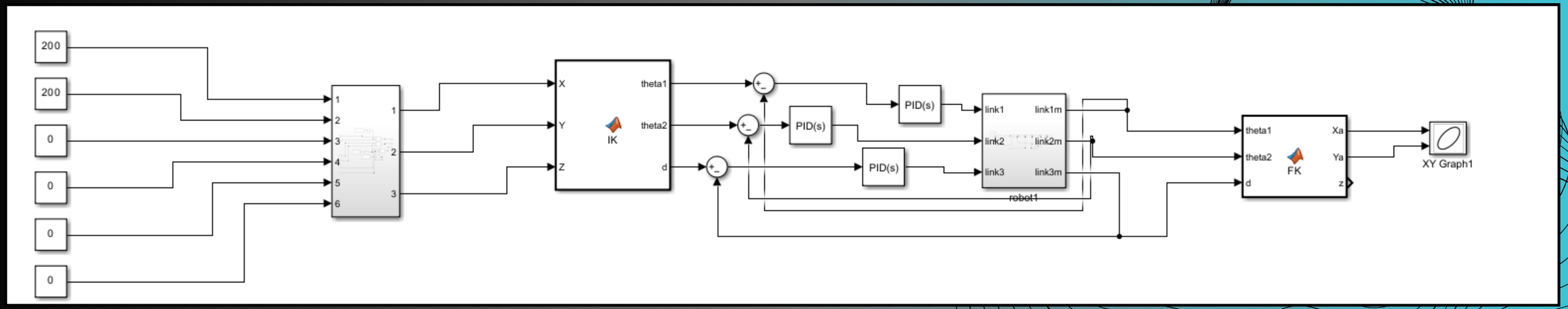
Tuning the System (before adding motors)



Result of XY graph of tuned Scara Manipulator

- **We tuned the Model before adding the motors to visualise the ideal condition and compared it further after adding the motors**
- **First, we changed and tuned the P value till the steady-state error was achieved and to reduce the error we tuned the I value**
- **We tuned the D value to reduce the oscillation.**

Tuning



Proportional (P):	5
Integral (I):	80
Derivative (D):	0.001
Filter coefficient (N):	100

PID model 1

Proportional (P):	5
Integral (I):	80
Derivative (D):	0.001
Filter coefficient (N):	100

PID model 2

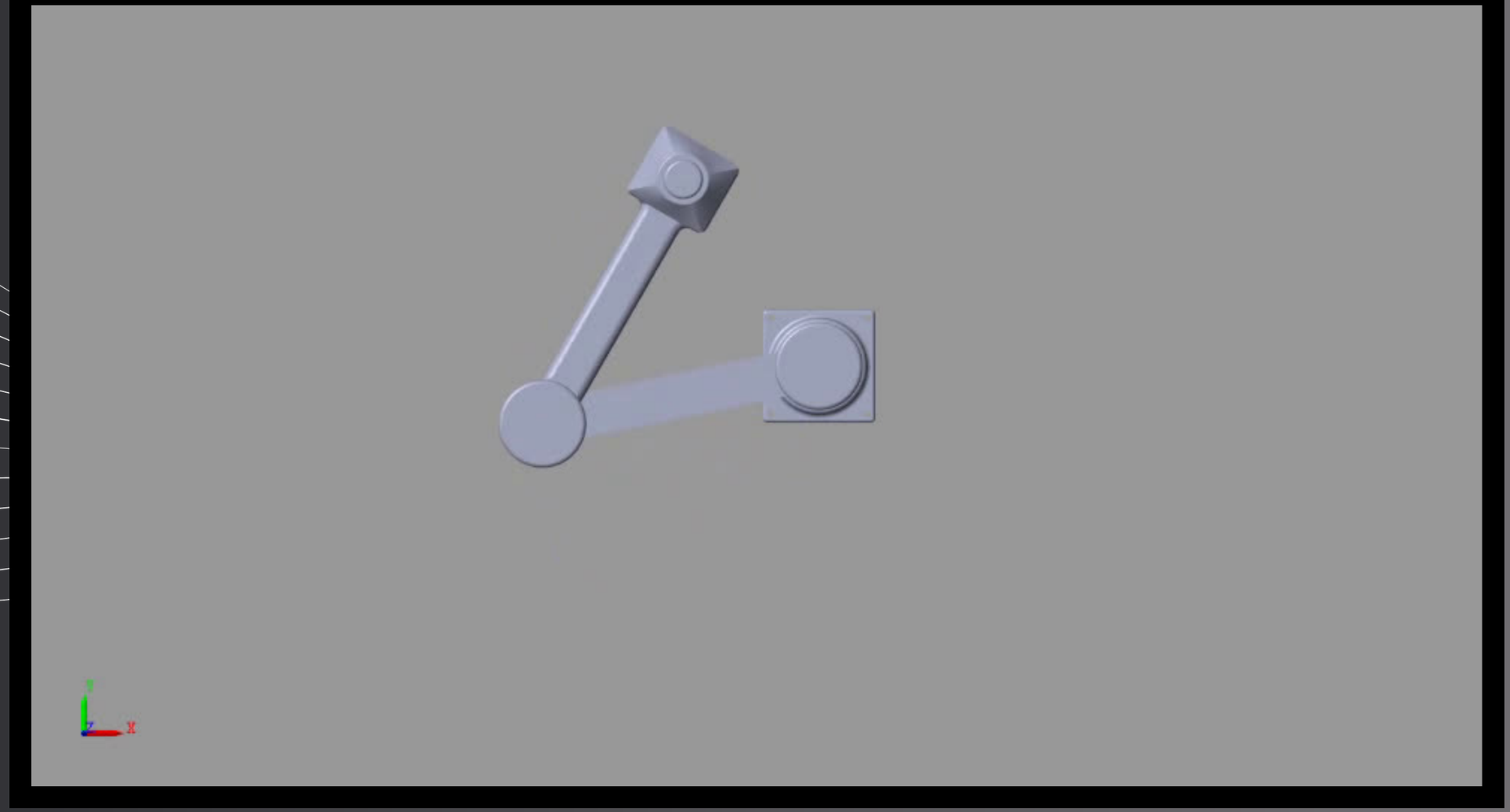
Proportional (P):	0.2
Integral (I):	1
Derivative (D):	0
Filter coefficient (N):	100

PID model 3

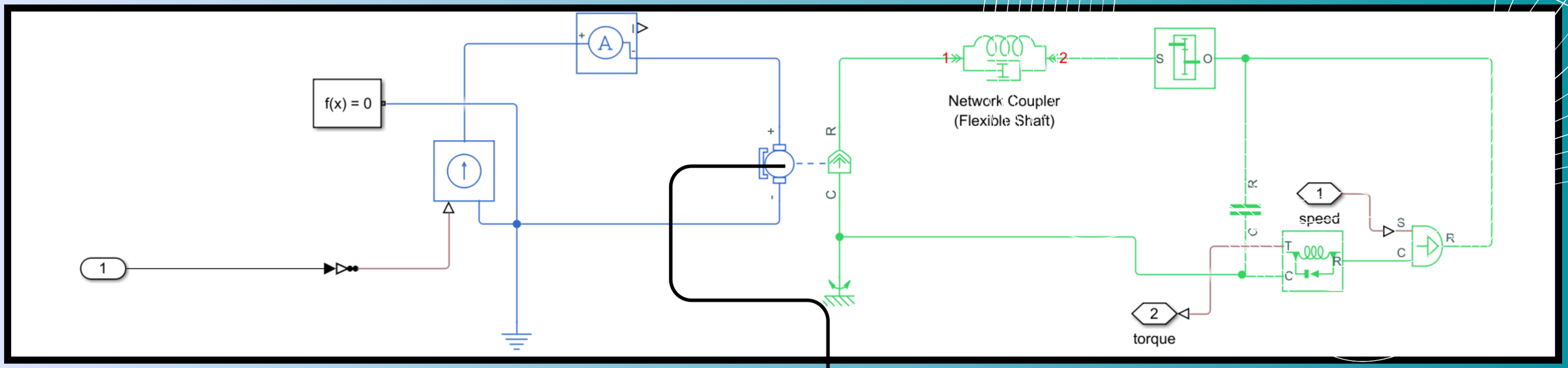
SIMULATION

Moving the Bot from (500,0) Coordinate to (200,0)-> (0,200)

The end effector covers an angle of 90 degree.



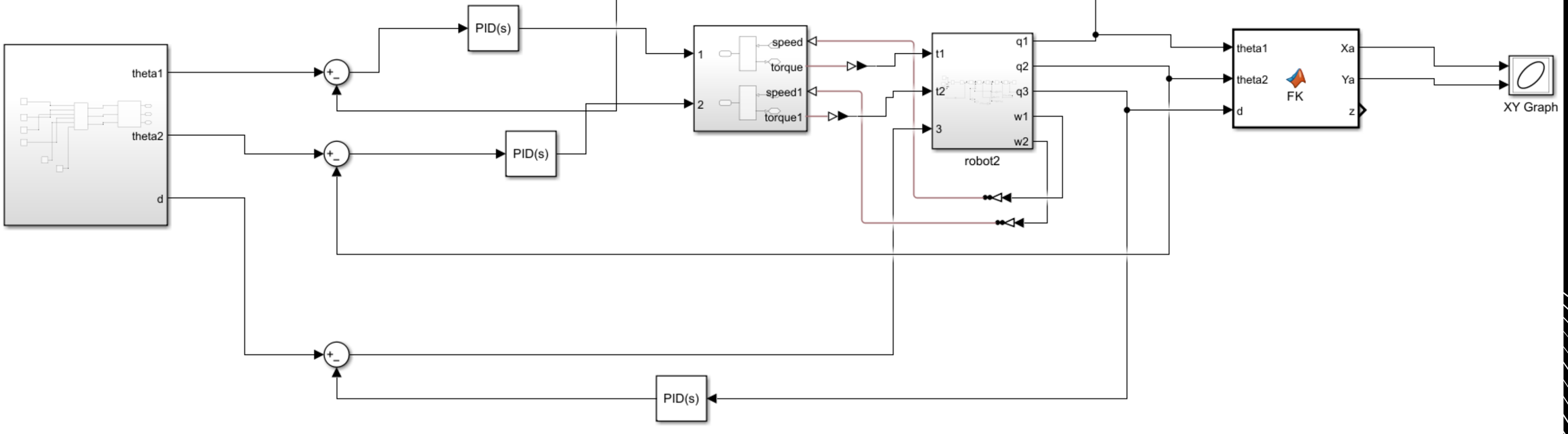
Adding Motors



- IG-45 a industrial grade DC motor is chosen for the application of Manipulator
- it is cost effective and robust and has great accuracy and control while its motor drivers are also easily available and comparatively lighter

Modeling option	No thermal port	
Selected part	<click to select>	
Electrical Torque		
Field type	Permanent magnet	
Model parameterization	By equivalent circuit parameters	
Armature resistance	2	Ohm
Armature inductance	1.1	mH
Define back-emf or torque constant	Specify torque constant	
Torque constant	1.26	N*m/A
Rotor damping parameterization	By damping value	
Mechanical		
Rotor inertia	0.01	g*cm^2
Rotor damping	0	N*m*s/rad
Initial rotor speed	0	rpm

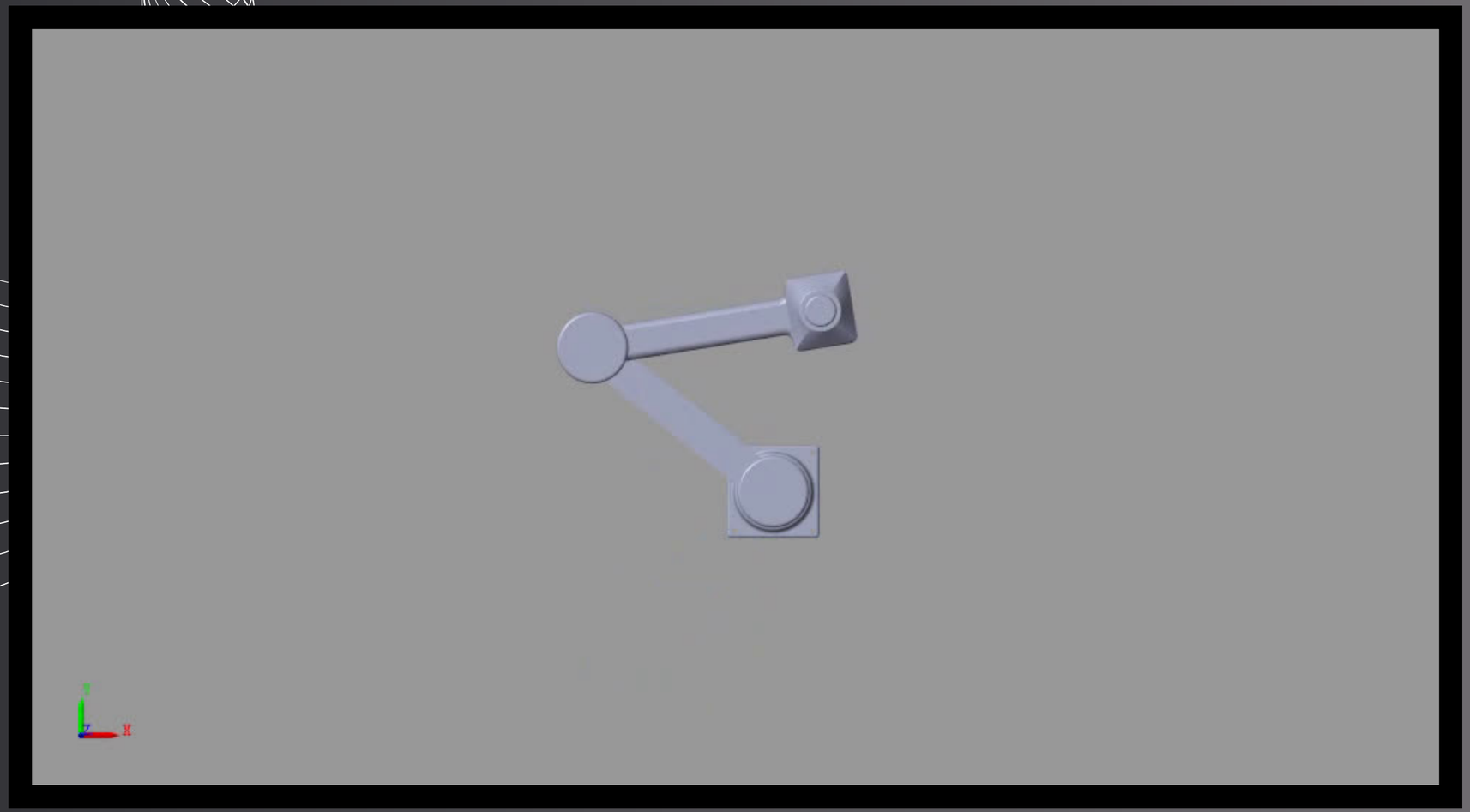
Final Model


theta1
theta2
d
PID(s)
PID(s)
PID(s)
1
2
speed
torque
speed1
torque1
t1
t2
3
q1
q2
q3
w1
w2
robot2
theta1
theta2
d
FK
Xa
Ya
z
XY Graph

SIMULATION (AFTER ADDING MOTOR)

Moving the Bot from (500,0) Coordinate to (200,0)-> (0,200)

The end effector covers an angle of 90 degree.



Tuning it again

Proportional (P):	0.099
Integral (I*Ts):	0.1
Derivative (D):	0
Filter coefficient (N):	300

PID model 1

Proportional (P):	0.19
Integral (I*Ts):	0.4
Derivative (D):	0
Filter coefficient (N):	300

PID model 2

Proportional (P):	0.2
Integral (I):	1
Derivative (D):	0
Filter coefficient (N):	100

PID model 3

Result and conclusion

We saw that the simulation after adding the motors adds a lot of error in the overall calculation of current which ultimately controls the motors. This makes it much harder for the controller to process rapidly changing values as the motor is not capable enough of having that much high resolution.

FUTURE SCOPE

- THESE DC MACHINES CAN BE TUNED BETTER BY USING CONTROLLERS LIKE FUZZY LOGIC CONTROL
- MORE DETAILED ANALYSIS CAN BE PERFORMED AFTER VARYING THE VOLTAGES AND CURRENT PROVIDED TO THE MOTOR WHICH IS THE REAL LIFE SCENRIO
- A BROADER PERSPECITVE ON HOW DIFFERENT MOTOR APART FROM BRUSHED DC MOTOR LIKE SERVO OR STEPPER MOTOR CAN BE USED TO GET FURTHER CONCLUSIONS

CONTRIBUTION

Bhavya Doshi

Setting up the model on Matlab, converting the coordinates to angles using Inverse Kinematics, PId tuning and control of Model, making of PPT and report

Shantanu Baranwal

Making CAD model of scara in SolidWoks, Writing Forward Kinematics code, Adding and configuring motors and its control and PID tuning, Coordinates generator, PPT and Report

Abhishek Biswas

Setting the Cordinate System of the links of CAD model, Using Simcape Multibody Link Plugin to Convert CAD to XML file, Generating Simscape Multibody Model of the CAD,Configuring Joints,PPT

REFERENCES

➡ DAS, TAYLAN & DÜLGER, LALE. (2005). MATHEMATICAL MODELLING, SIMULATION AND EXPERIMENTAL VERIFICATION OF A SCARA ROBOT. SIMULATION MODELLING PRACTICE AND THEORY. 13. 257-271. 10.1016/J.SIMPAT.2004.11.004.

➡HTTPS://WWW.YOUTUBE.COM/WATCH?V=PDIWAA1CNB0&T=2790S&PP=YGUGBW9KZWXSAW5NIG9MIHNJYXJHIGFYBSBPBIBTYXRSYWI%3D

➡J. LIU AND Q. LUO, "MODELING AND SIMULATION OF ROBOTIC ARM IN MATLAB FOR INDUSTRIAL APPLICATIONS," 2019 11TH INTERNATIONAL CONFERENCE ON INTELLIGENT HUMAN-MACHINE SYSTEMS AND CYBERNETICS (IHMSC), HANGZHOU, CHINA, 2019, PP. 346-349, DOI: 10.1109/IHMSC.2019.00086.

➡ HTTPS://NRSYED.COM/2018/01/21/HOW-TO-READ-A-DC-MOTOR-DATASHEET/

➡ HTTPS://WWW.YOUTUBE.COM/WATCH?V=S3O5ZRS6DDC

THANK YOU