Robotics Toolbox
MAE 547
Prof. Hamidreza Marvi

Team Members

Aditya Ramani – 1217146086

Aksheshkumar Ajaykumar Shah – 1217506160

Omkar Satish Kulkarni - 1217203169

Venkatesh Vaidyanathan –1217397597

Index

1. What is Manipulator Dynamics?

Dynamics is the study of forces and the Dynamics of Manipulators is the study of forces associated with manipulators. To perform a task by a manipulator its members and joints have to be moved. To move something, we need force and to move something in a particular way forces and torques have to be applied in a certain way to obtain the desired trajectory the forces applied to the manipulators are examined in dynamics. To perform a particular task the manipulator is accelerated from rest, after which the end-effector may be required to be moved with a constant velocity and then decelerated to bring it to rest at the desired point. Such motion requires variation of torques at the joints by actuators in accordance to the desired trajectory.

Our task in Dynamics of Manipulators is to find the torque to be generated by the torque actuators at the manipulator joints. The functions of the torque variation depend upon the trajectory to be followed by the manipulator, masses of links, friction in link joints and force applied by or payload at the end-effector.Dynamic analysis of manipulator has two types of problems to be solved.

1. The trajectory with variation of position, velocity and acceleration is given and torques required at manipulator joints to move along the desired trajectory are to be found.
2. Torques variations are given and the motion of manipulator has to be found. It may involve finding position, velocity and also acceleration.

The position, velocity and acceleration here also denote the respective angular quantities.

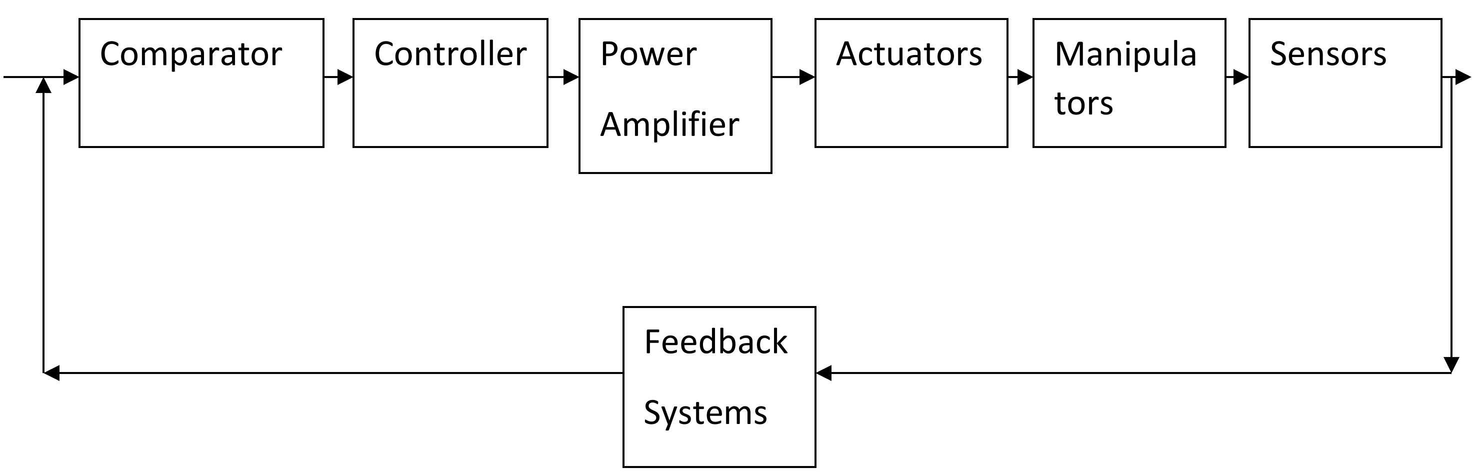
2. What is manipulator Control?

For any robot to perform any task, its end effectors should move accurately and repeatedly. Manipulator control basically ensures the end effectors motion as desired to perform the task. This control system accepts the joint location time history as the input and moves the manipulator to track the desired trajectory. In this system, we provide the desired task as input to trajectory planner. Trajectory planner generates the control set- points such as position, velocity and acceleration and set them as input to manipulator control system. Then manipulator control system creates actuator command and as per these commands end effecter move to desired location. If feedback system present in manipulator control, then we call it as closed loop manipulator control and if feedback system is absent then it is called close loop manipulator system.

If feedback system is present, then actual manipulator location and velocity is provided as feedback to Manipulator control system. By feedback system errors in end effecter position get rectified.

If there is multiple joints or multiple arms present to the robot then we need master joint control system. The master joint control system provides necessary set points to every joint controller.

Main components of any manipulator systems are: Comparator, Controller, Power amplifier, Actuators, Manipulators, Sensors and Feedback systems.



3. How to start the Robotics Toolbox?

This toolbox is made on MATLAB version 2019b and uses peter corke toolbox version 9.10 (The standard version). In order to run the toolbox, you need to have all the files from the folder including rvc tools file. Change the path of MATLAB to the path where you have saved the toolbox files as shown in figure 1.

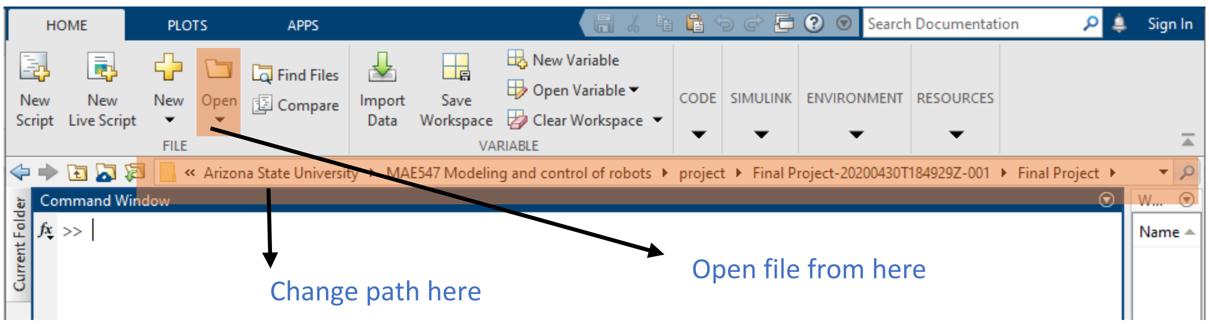


Figure 1

Open the **MainScreen.mlapp** file using the open command in MATLAB as shown in figure 1.

4. How to operate through the Main Menu?

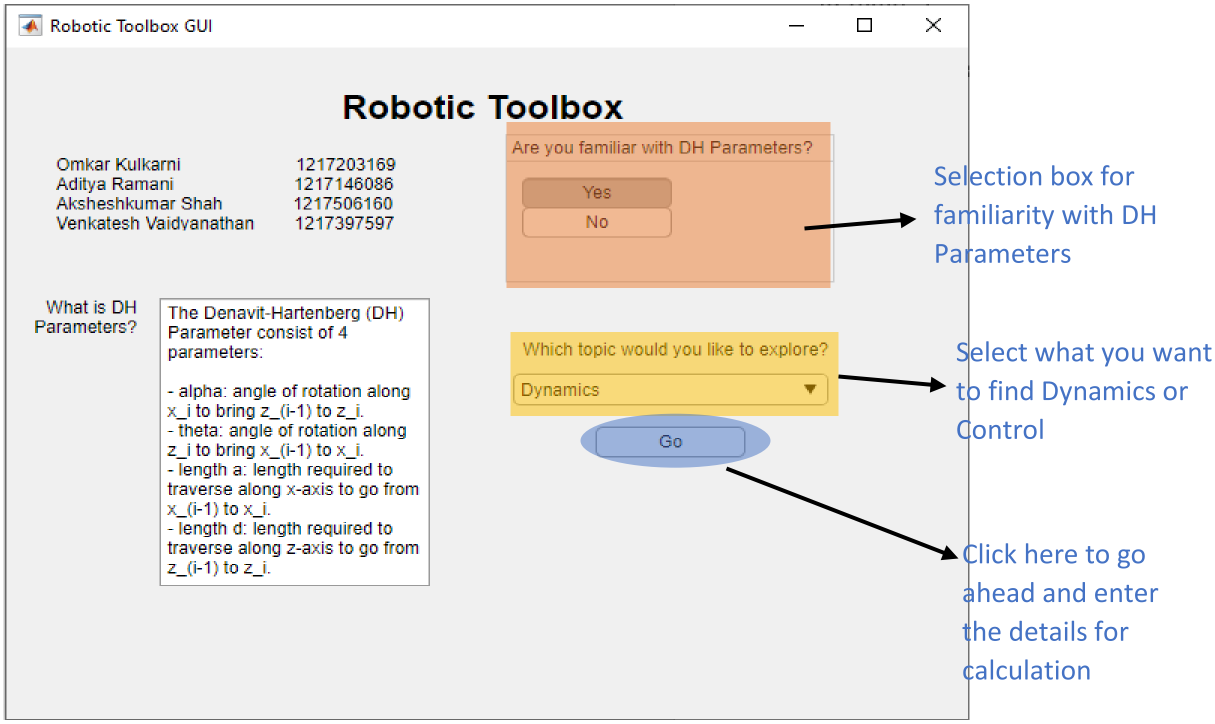


Figure 2.

Step 1. After opening the MainScreen.mlapp file use the run command to start the toolbox.

Step 2. Once the toolbox is open as shown in the figure 2. Select yes if you are familiar with the DH parameters and No if you are not Familiar with DH parameters in the box that is highlighted with red color in the Figure 2.

Step 3. After selecting for DH parameters select what you want to solve Manipulator Dynamics/ Manipulator control in the space highlighted by yellow color in figure 2.

Step 4. Once the selection is done click on the go button highlighted by blue color in the figure 2.

5. How to calculate Manipulator Dynamics when DH Parameters are known?

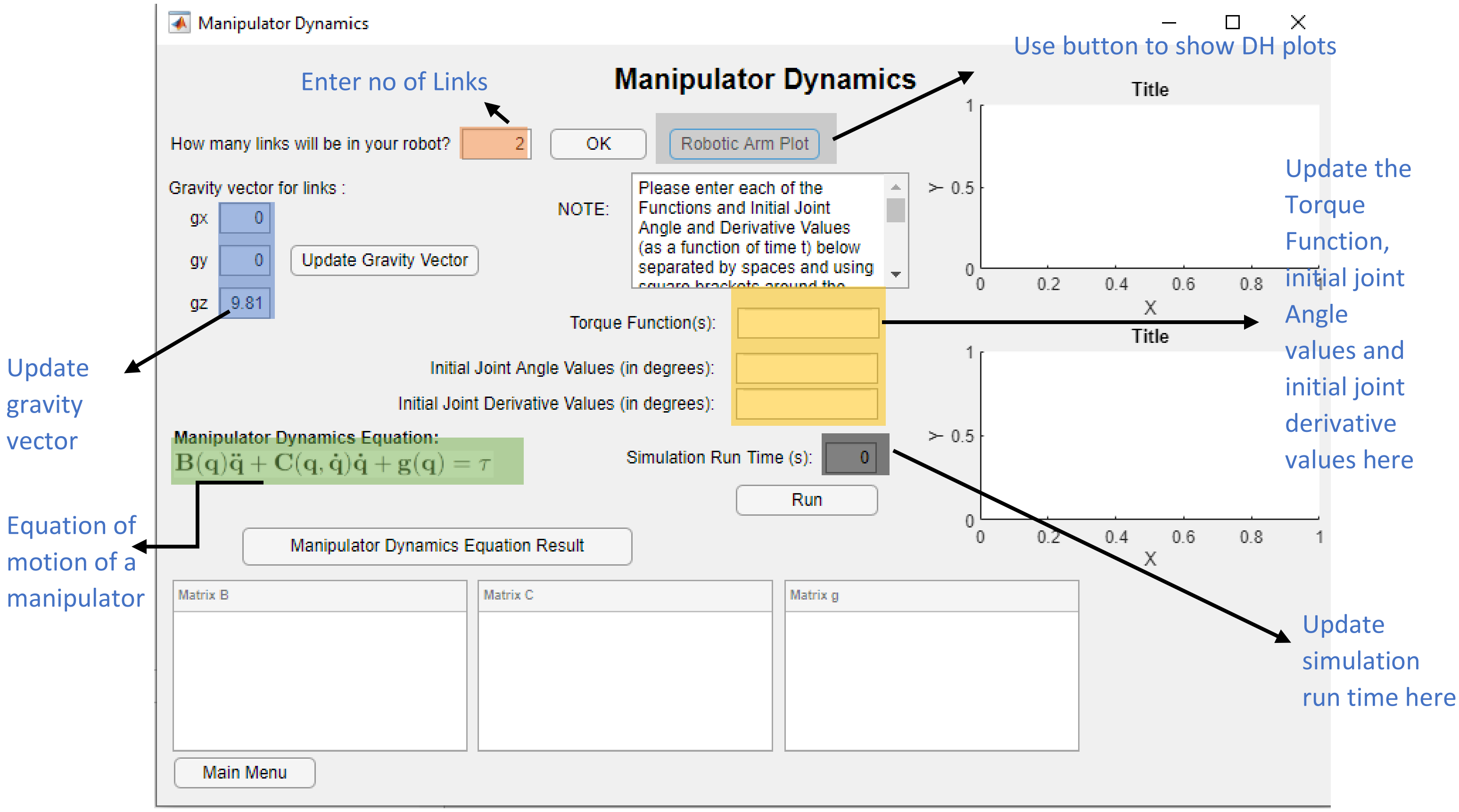


Figure 3.

When you have selected a YES in familiarity of DH Parameters and selected to solve for Manipulator dynamics you will be directed to this window shown in Figure 3.

Step 1. Enter the number of links in the space highlighted by orange in Figure 3. After entering the number of links, you will get a window such as shown in figure 4.

In this window you will have to select if your joint is revolute or prismatic. After that you will have to enter the DH parameters for link 1 like a, d, alpha, theta. Once after you click OK after entering the details for the respective link it will ask you to enter for other links as well. You must perform the above procedure for all the links individually.

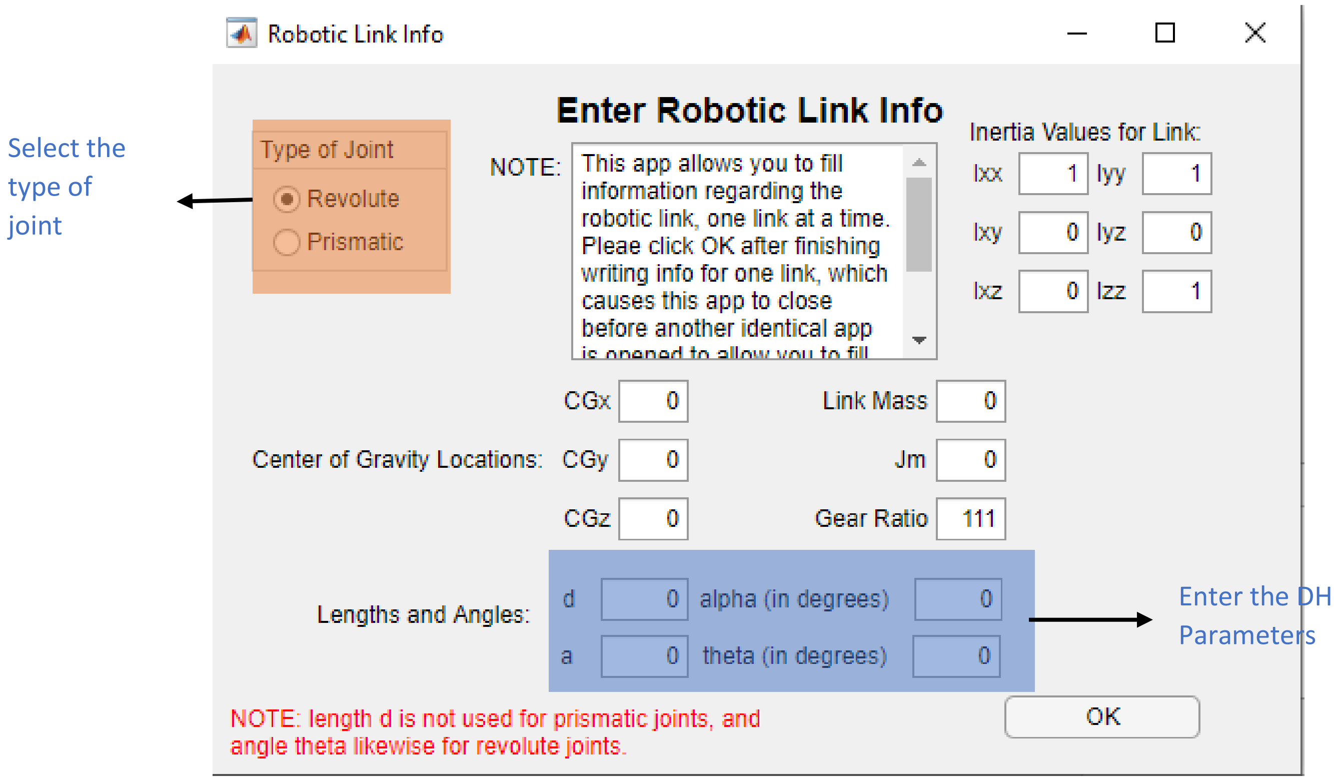


Figure 4.

Step 2. After entering the DH parameters in Figure 4 click on the Robotic Arm Plot button in Figure 3 to get the plot as shown in figure 5.

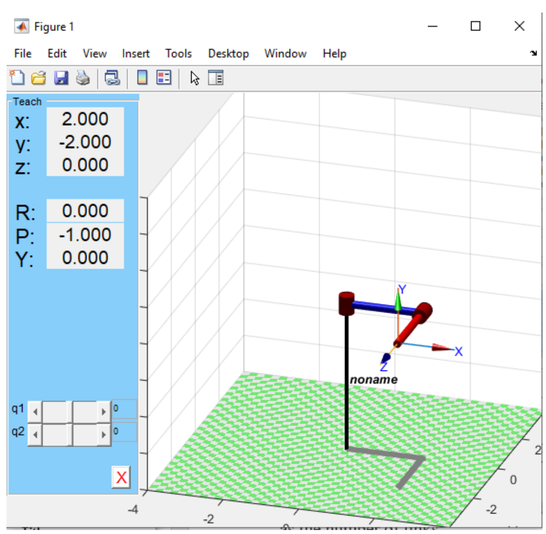


Figure 5.

Step 3. Enter the torque function in this format [t sin(t)] and enter as many functions as the number of links.
Step 4. Enter the joint angle values (in degrees) in the format [0 0] and enter as many values as the number of joints.

Step 5. Enter the joint derivative values (in degrees/s) in the format [0 0] and enter as many values as the number of joints.
Step 6. Enter the run time for which we have to run the simulation in the space highlighted in black in figure 3.
Step 7. After entering all the value click on the run button and it will give you the plots of Q w.r.t Time and Joint derivatives w.r.t Time in the space on the right.
Step 8. Click on the manipulator dynamics equation results button to get the resulting equation after solving which give B, C, g in symbolic format.
Step 9. Click on the main menu button at the bottom left to go back to the main mean screen.

6. How to calculate manipulator dynamics when DH Parameters are not Known?

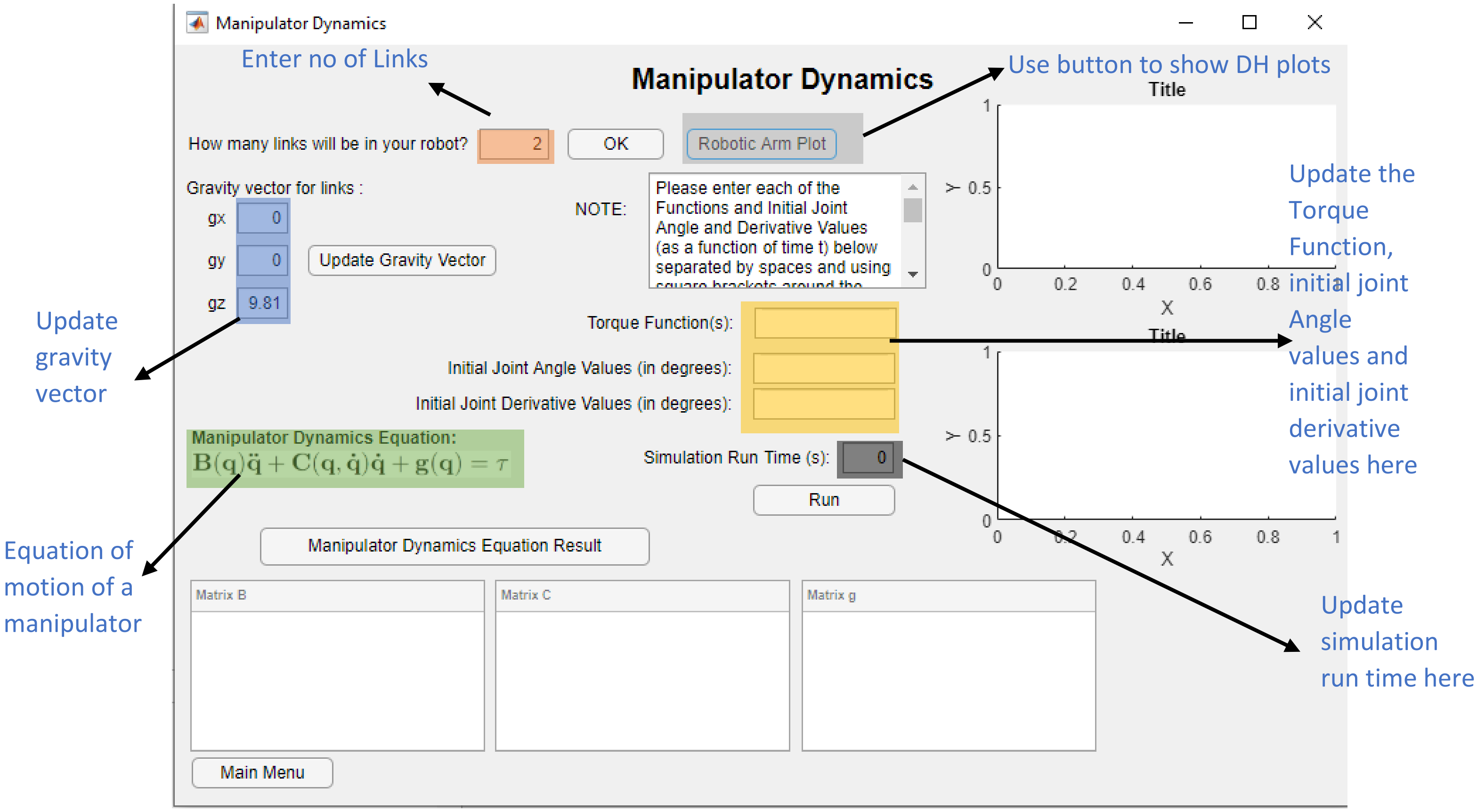


Figure 6.

When you have selected a NO in familiarity of DH Parameters and selected to solve for Manipulator dynamics you will be directed to this window shown in Figure 6.

Step 1. Enter the no of link in the space highlighted by orange in figure 6. Once you click OK you will be shown a window as shown in Figure 7.

In this window you will have to select if your joint is revolute or prismatic. After that select the axis x or z or neither. After that enter the information such as twisting angle and length for the selected axis using the select button in the highlighted area of figure 8. Click OK button after entering the details for the respective link it will ask you to enter for other links as well. You must perform the above procedure for all the links individually.
Note: Clicking 'Neither' automatically sets the relevant information regarding lengths and twist angles to 0

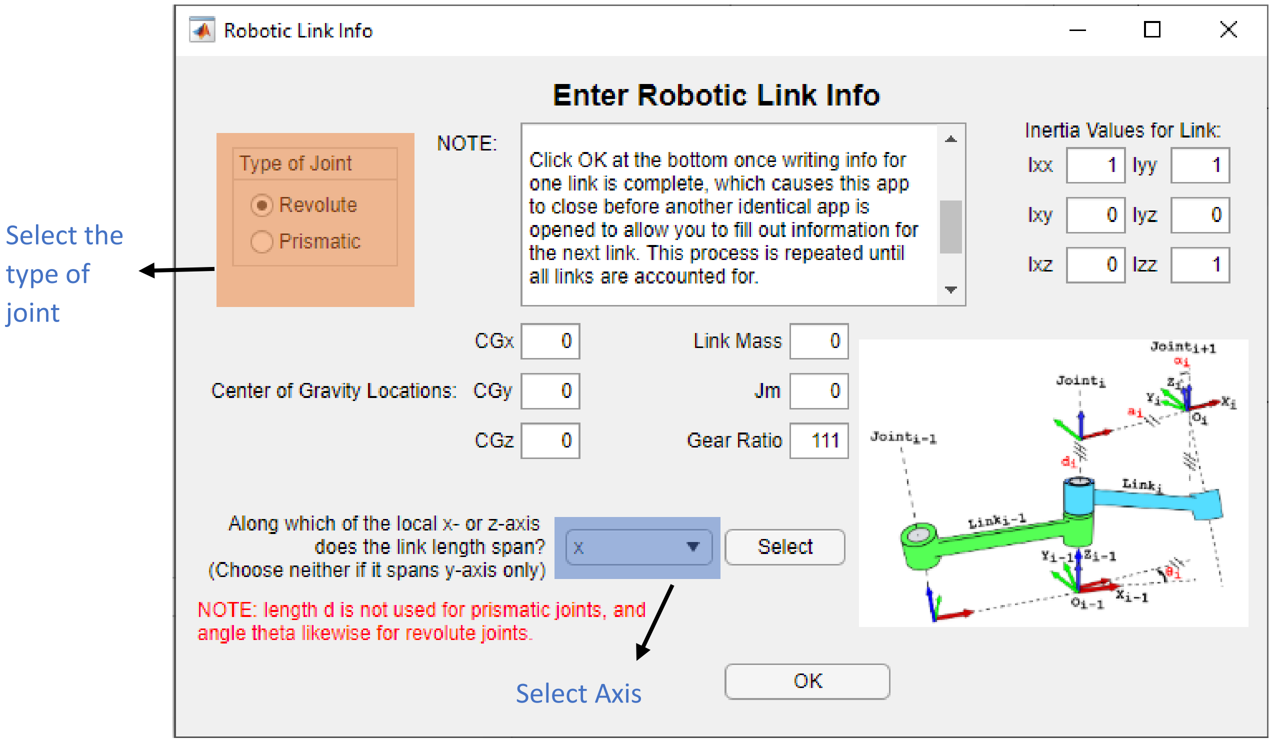


Figure 7.

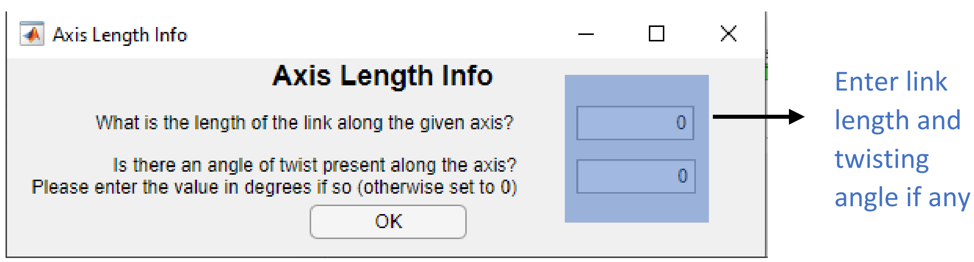


Figure 8.

Step 2. After entering the details in Figure 7 and 8 click on Robotic arm plot button in Figure 6 to get the plot of the robotic arm to assure the DH parameters in Figure 9.

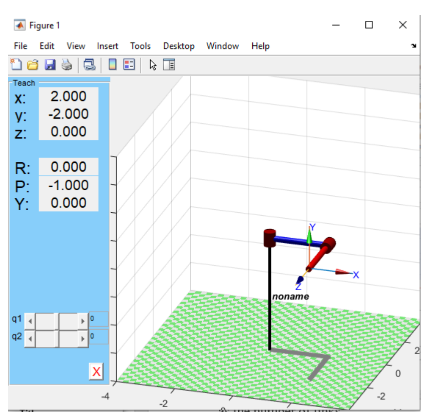


Figure 9.

Step 3. Enter the torque function in this format [t sin(t)] and enter as many functions as the number of links.
Step 4. Enter the joint angle values (in degrees) in the format [0 0] and enter as many values as the number of joints.
Step 5. Enter the joint derivative values (in degrees/s) in the format [0 0] and enter as many values as the number of joints.
Step 6. Enter the run time for which we have to run the simulation in the space highlighted in black in figure 6.
Step 7. After entering all the value click on the run button and it will give you the plots of Q w.r.t Time and Joint derivatives w.r.t Time in the space on the right.
Step 8. Click on the manipulator dynamics equation results button to get the resulting equation after solving which give B, C, g in symbolic format.
Step 9. Click on the main menu button at the bottom left to go back to the main mean screen.

7. How to solve for Motion Control when DH Parameters are known?

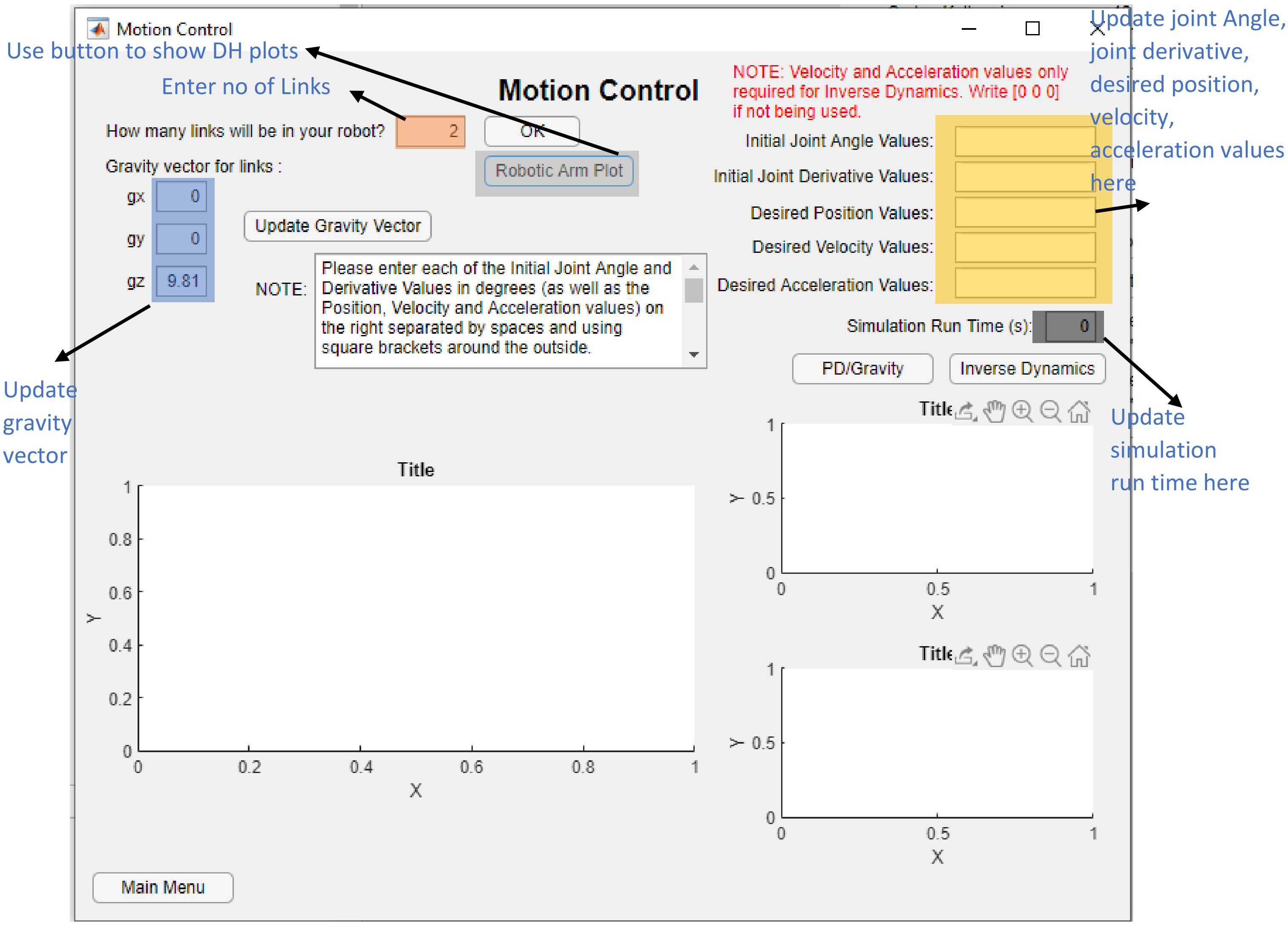


Figure 10.

When you have selected a YES in familiarity of DH Parameters and selected to solve for Manipulator control you will be directed to this window shown in Figure 10. **Step 1.** Enter the number of links in the space highlighted by orange in Figure 10. After entering the number of links, you will get a window such as shown in figure 11.

In this window you will have to select if your joint is revolute or prismatic. After that you will have to enter the DH parameters for link 1 like a, d, alpha, theta. Once after you click OK after entering the details for the respective link it will ask you to enter for other links as well. You must perform the above procedure for all the links individually.

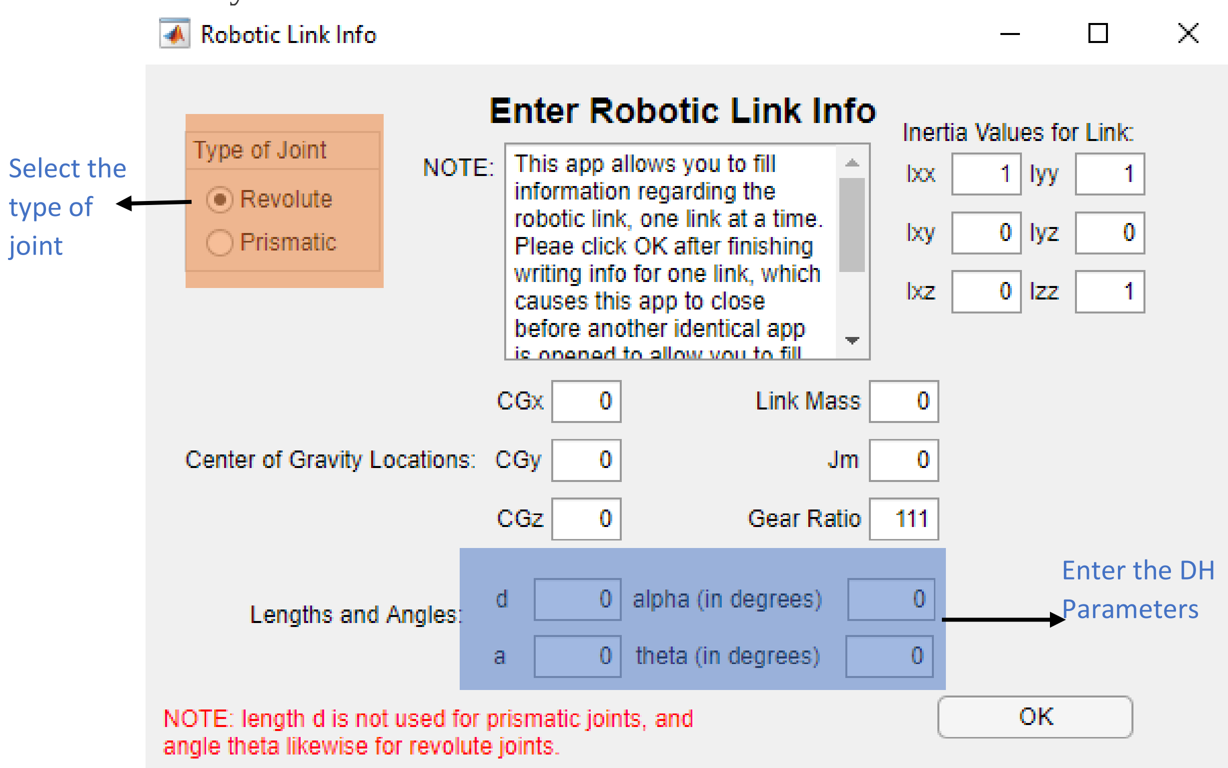


Figure 11.

Step 2. After entering the DH parameters in Figure 11 click on the Robotic Arm Plot button in Figure 10 to get the plot as shown in figure 12.

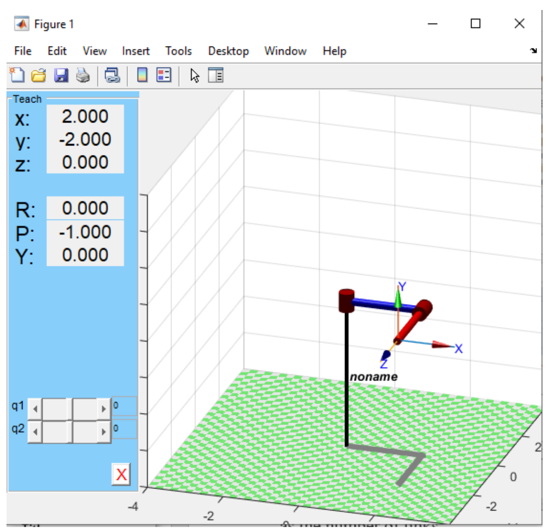


Figure 12.

Step 3. Enter the joint angle values (in degrees) in the format [0 0] and enter as many values as the number of joints.

Step 4. Enter the joint derivative values (in degrees/s) in the format [0 0] and enter as many values as the number of joints.
Step 5. Entire the desired position values in format [1 2 3] and it should be 3 terms no matter how many joints as it is in x, y, z direction.
Step 6. Entire the desired velocity values in format [1 2 3] and it should be 3 terms no matter how many joints as it is in x, y, z direction.
Step 7. Entire the desired acceleration values in format [1 2 3] and it should be 3 terms no matter how many joints as it is in x, y, z direction.
Step 8. Enter the run time for which we have to run the simulation in the space highlighted in black in figure 10.
Step 9. Click on the PD/Gravity to find the x, y, z position w.r.t Time, Q w.r.t Time, $\dot{Q}$ w.r.t Time plots.
Step 10. Click on the inverse dynamics button to get the x, y, z position w.r.t Time, Q w.r.t Time, $\dot{Q}$ w.r.t Time plots.
Step 11. Click on the main menu button to go back to the main menu.

8. How to solve for motion control when DH Parameters are not known?

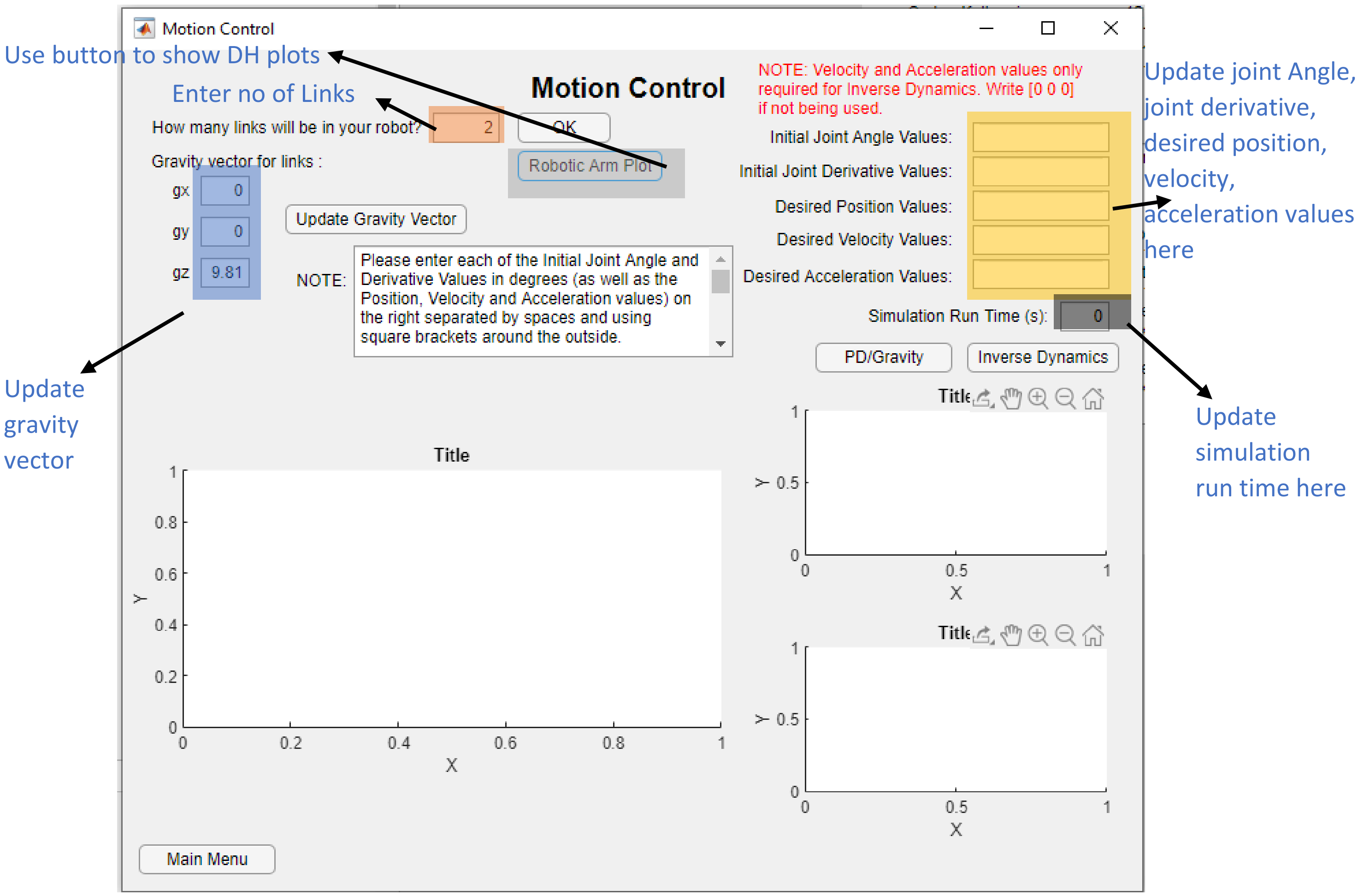


Figure 13.

When you have selected a NO in familiarity of DH Parameters and selected to solve for Manipulator control you will be directed to this window shown in Figure 13. **Step 1.** Enter the no of link in the space highlighted by orange in figure 13. Once you click OK you will be shown a window as shown in Figure 14.

In this window you will have to select if your joint is revolute or prismatic. After that select the axis x or z or neither. After that enter the information such as twisting angle and length for the selected axis using the select button in the highlighted area of figure 15. Click OK button after entering the details for the respective link it will ask you to enter for other links as well. You must perform the above procedure for all the links individually.

Note: Clicking 'Neither' automatically sets the relevant information regarding lengths and twist angles to 0

Select the type of joint

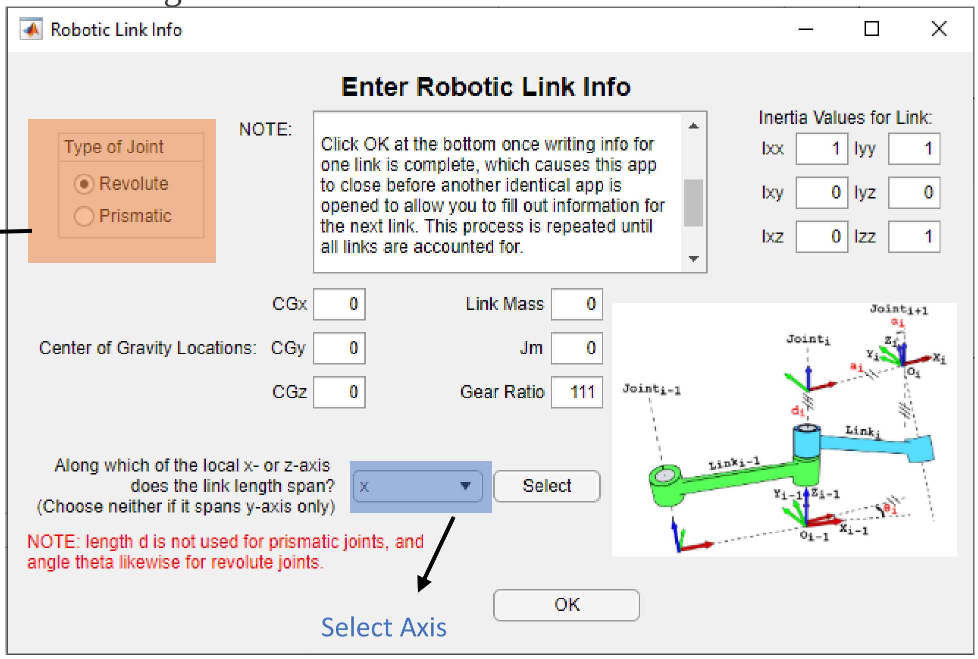
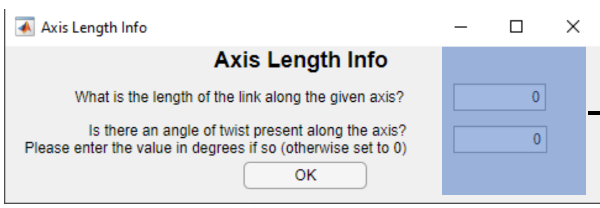


Figure 14.



Enter link length and twisting angle if any

Figure 15.

Step 2. After entering the details in Figure 14 and 15 click on Robotic arm plot button in Figure 13 to get the plot of the robotic arm to assure the DH parameters in Figure 16.

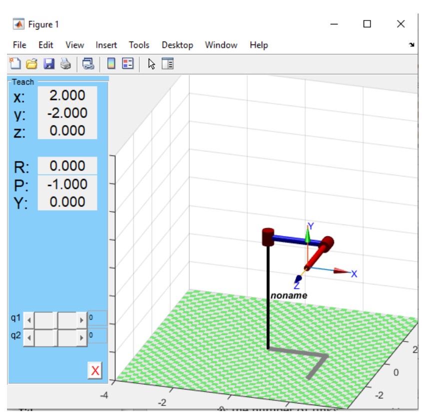


Figure 16.

Step 3. Enter the joint angle values (in degrees) in the format [0 0] and enter as many values as the number of joints.
Step 4. Enter the joint derivative values (in degrees/s) in the format [0 0] and enter as many values as the number of joints.
Step 5. Entire the desired position values in format [1 2 3] and it should be 3 terms no matter how many joints as it is in x, y, z direction.
Step 6. Entire the desired velocity values in format [1 2 3] and it should be 3 terms no matter how many joints as it is in x, y, z direction.
Step 7. Entire the desired acceleration values in format [1 2 3] and it should be 3 terms no matter how many joints as it is in x, y, z direction.
Step 8. Enter the run time for which we have to run the simulation in the space highlighted in black in figure 13.
Step 9. Click on the PD/Gravity to find the x, y, z position w.r.t Time, Q w.r.t Time, $\dot{Q}$ w.r.t Time plots.
Step 10. Click on the inverse dynamics button to get the x, y, z position w.r.t Time, Q w.r.t Time, $\dot{Q}$ w.r.t Time plots.
Step 11. Click on the main menu button to go back to the main menu.

9.Contribution of Team Members

1. Manipulator Dynamics – Aditya,Aksheshkumar, Omkar, Venkatesh
2. Manipulator control
   a) PD/Gravity - Aditya, Aksheshkumar, Omkar, Venkatesh
   b) Inverse Dynamics - Aditya
3. GUI – Aditya, Aksheshkumar, Omkar, Venkatesh
4. Report - Aditya, Aksheshkumar, Omkar, Venkatesh

10. References

1. Peter corke robotics toolbox 9.10
2. Robotics Modelling, Planning and Control by Bruno Sicilliano, Lorenzo Sciavicco, Luigi villani, Giuseppe Oriolo.