PROJECT REPORT

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DATE: 11/13/2022

Problem-1:

- In the first question, we must implement the second order algorithm for the kinematic inversion with Jacobian inverse along the given trajectory using Matlab and Simulink.
- The desired output for the manipulator is already given in the kinematic trajectory file along with the question.
- The current or the actual output of the manipulator is found using the formula which is shown below.

$$\ddot{\boldsymbol{q}} = \boldsymbol{J}_A^{-1}(\boldsymbol{q})\Big(\ddot{\boldsymbol{x}}_d + \boldsymbol{K}_D\dot{\boldsymbol{e}} + \boldsymbol{K}_P\boldsymbol{e} - \dot{\boldsymbol{J}}_A(\boldsymbol{q},\dot{\boldsymbol{q}})\dot{\boldsymbol{q}}\Big)$$

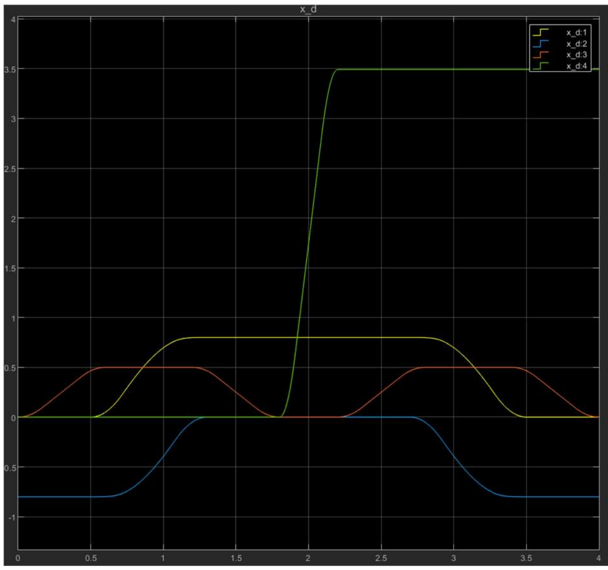
- The above formula is a second order algorithm using Jacobian inverse.

  Where,

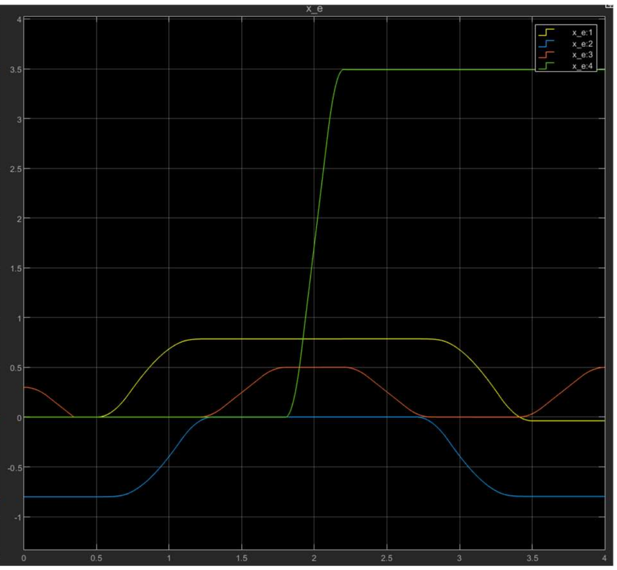
  - q_dot_dot - is the acceleration of joint.
  - q_dot – is the velocity of the joint.
  - q - is the joint variable.
  - Kd - is the gain value for the error in the velocities of the joints.
  - e_dot – is the error in the joint velocities of the desired output to the actual output.
  - Kp - is the gain value for the error in the positions of the joints.
  - e – is the error in the joint positions of the desired output to the actual output.
  - Xd_dot_dot – is the desired acceleration from the kinematic trajectory file.

- The q_dot_dot is found using the above equation and the q_dot and q values are found by integrating the q_dot_dot value using Matlab and Simulink and then they are compared with the values from the kinematic trajectory file and finally they are plotted.

Desired Trajectory Vs Actual Trajectory:

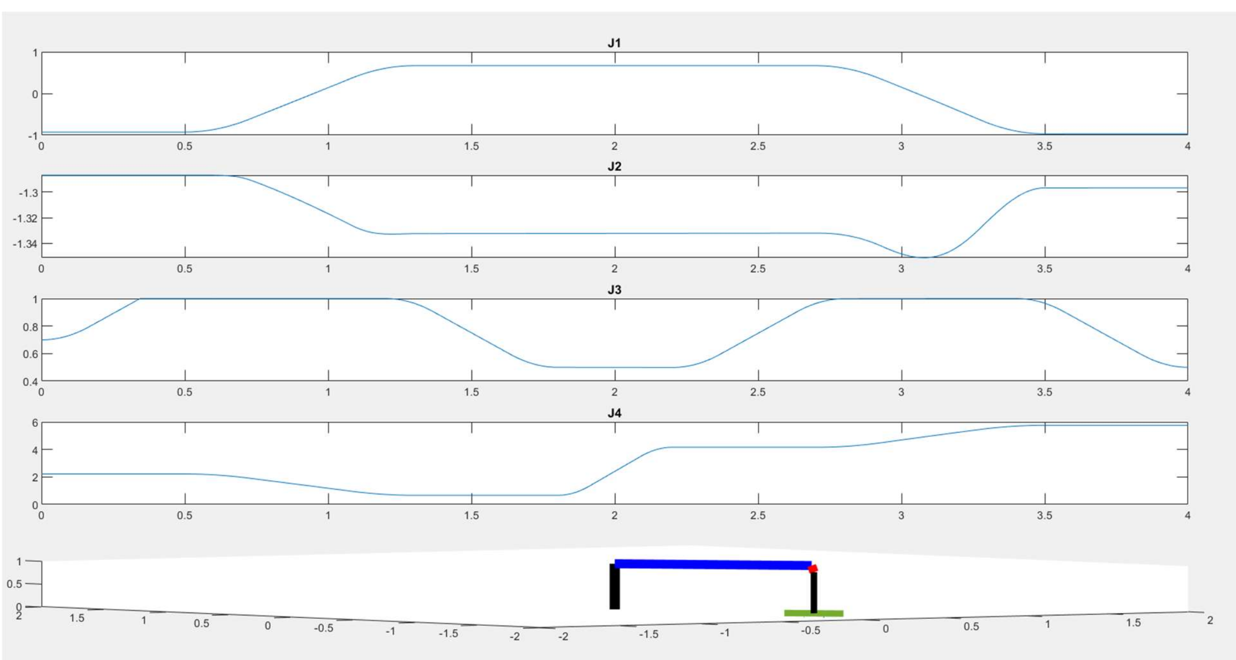


Desired Trajectory



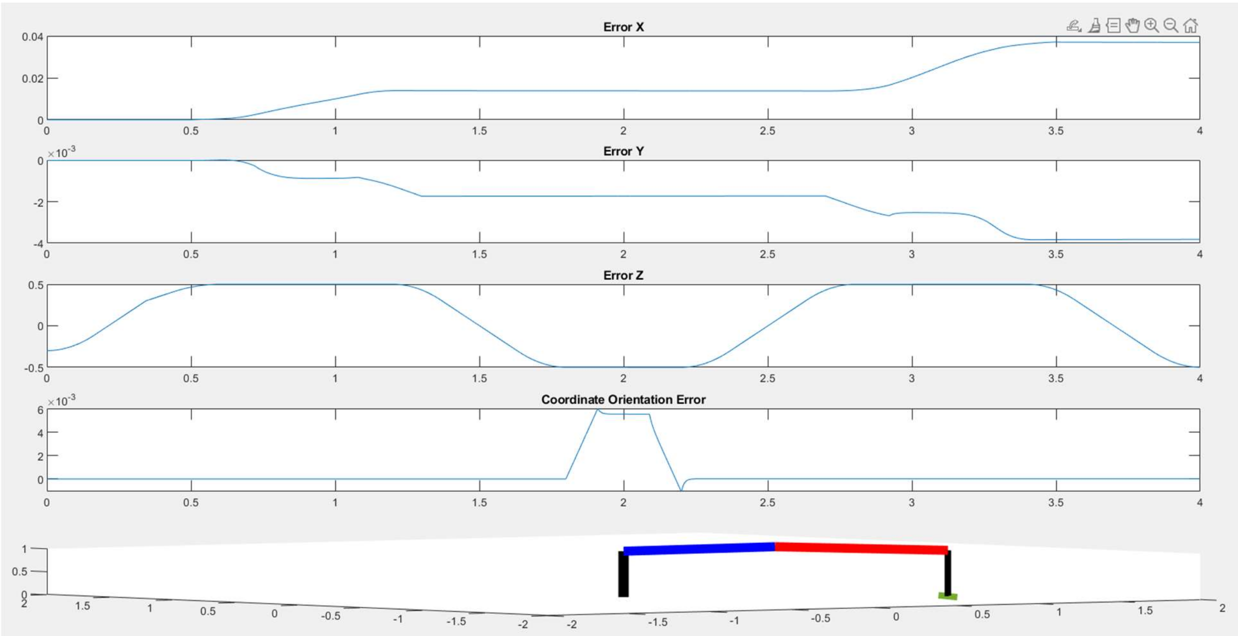
Actual Trajectory

Joint Values Plots:



The above graph depicts the orientation and the position of the end effector of the manipulator.

<u>Error Values Plot:</u>



The above graph depicts the error value, that is the difference between the actual output and the desired output.

<u>Conclusion:</u>

- The accuracy of the actual output that is expected from the manipulator is increased as we are using second order algorithms for calculating the values of q.

Problem-2:

- In the second question, we must relax one component in the operational space, and they have also mentioned to relax the z component in the operational space.
- We must implement the second order algorithm for kinematic inversion with Jacobian pseudo-inverse along the given trajectory using Matlab and Simulink.
- We should also maximize the end effector distance from the obstacle (the center of the obstacle is given) along the end effector path.
- The current or the actual output of the manipulator is found using the formula which is shown below in this case.

$$\ddot{\boldsymbol{q}} = \boldsymbol{J}_A^{\dagger}\left(\ddot{\boldsymbol{x}}_d + \boldsymbol{K}_D\dot{\boldsymbol{e}} + \boldsymbol{K}_P\boldsymbol{e} - \dot{\boldsymbol{J}}_A(\boldsymbol{q},\dot{\boldsymbol{q}})\dot{\boldsymbol{q}}\right) + \left(\boldsymbol{I}_n - \boldsymbol{J}_A^{\dagger}\boldsymbol{J}_A\right)\ddot{\boldsymbol{q}}_0$$

Where,

- In – is an identity matrix
- The Jacobian pseudo inverse is found using the formula

$$\boldsymbol{J}^{\dagger} = \boldsymbol{J}^T\left(\boldsymbol{J}\boldsymbol{J}^T\right)^{-1}$$

  The Jacobian pseudo inverse can also be found using the Matlab function pinv in Matlab.
- The q0_dot_dot is found using the following formulae,

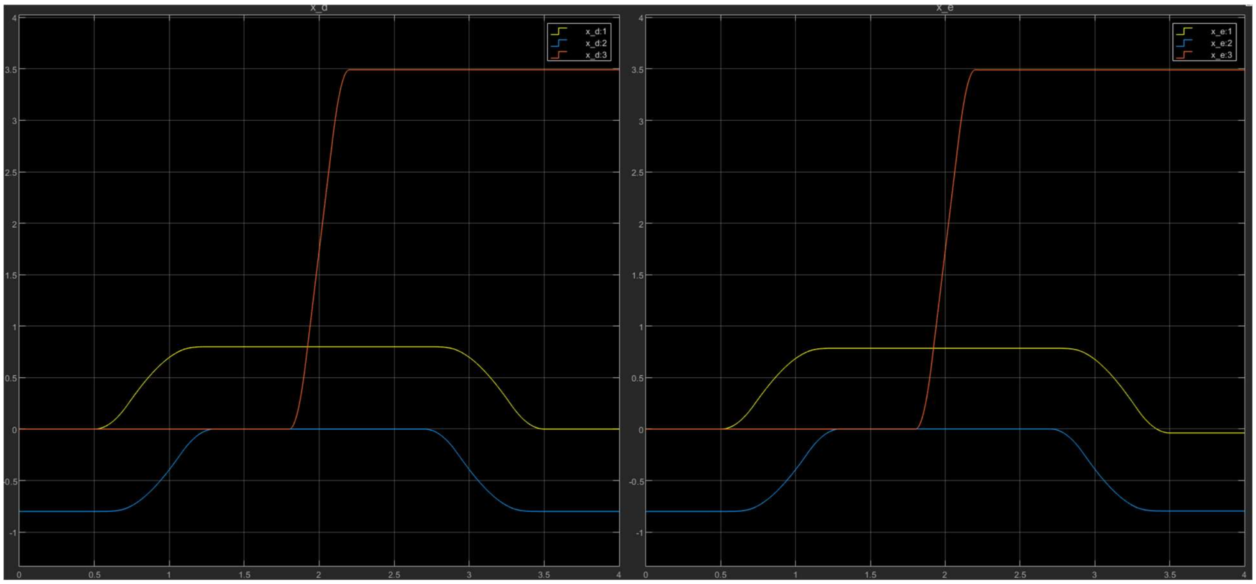
$$w(\boldsymbol{q}) = \min_{\boldsymbol{p},\boldsymbol{o}} \|\boldsymbol{p}(\boldsymbol{q}) - \boldsymbol{o}\|$$

$$\dot{\boldsymbol{q}}_a = k_a\left(\frac{\partial w(\boldsymbol{q})}{\partial \boldsymbol{q}}\right)^T$$

- Ka – is a gain factor.

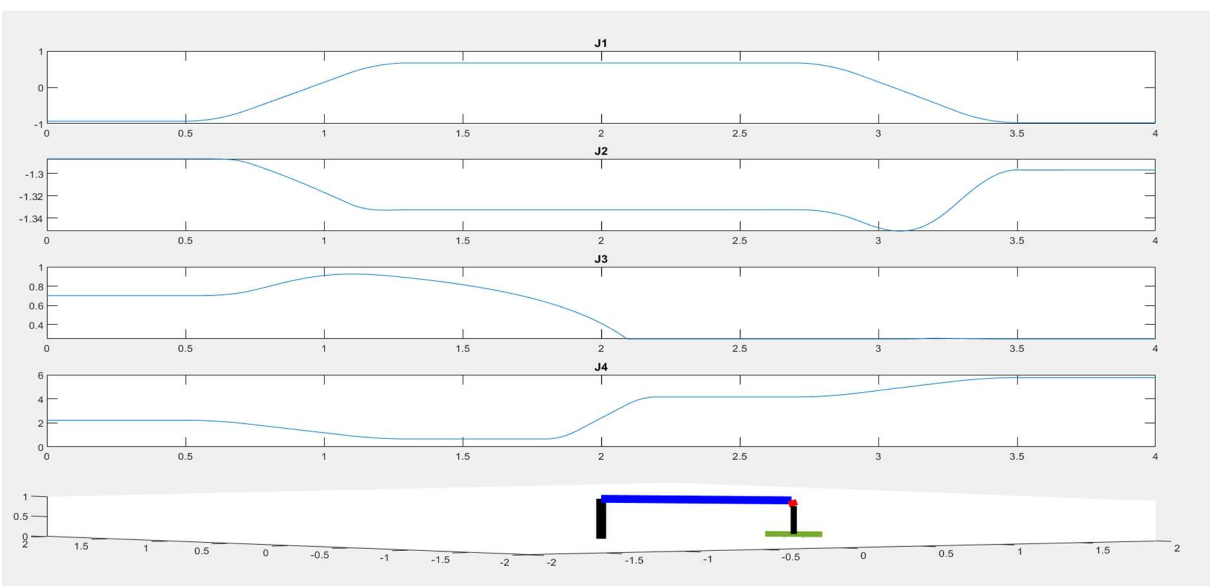
- The q value is found from the q_dot_dot and then the q value is compared with the values from the kinematic trajectory file and finally they are plotted.

Desired Trajectory Vs Actual Trajectory:



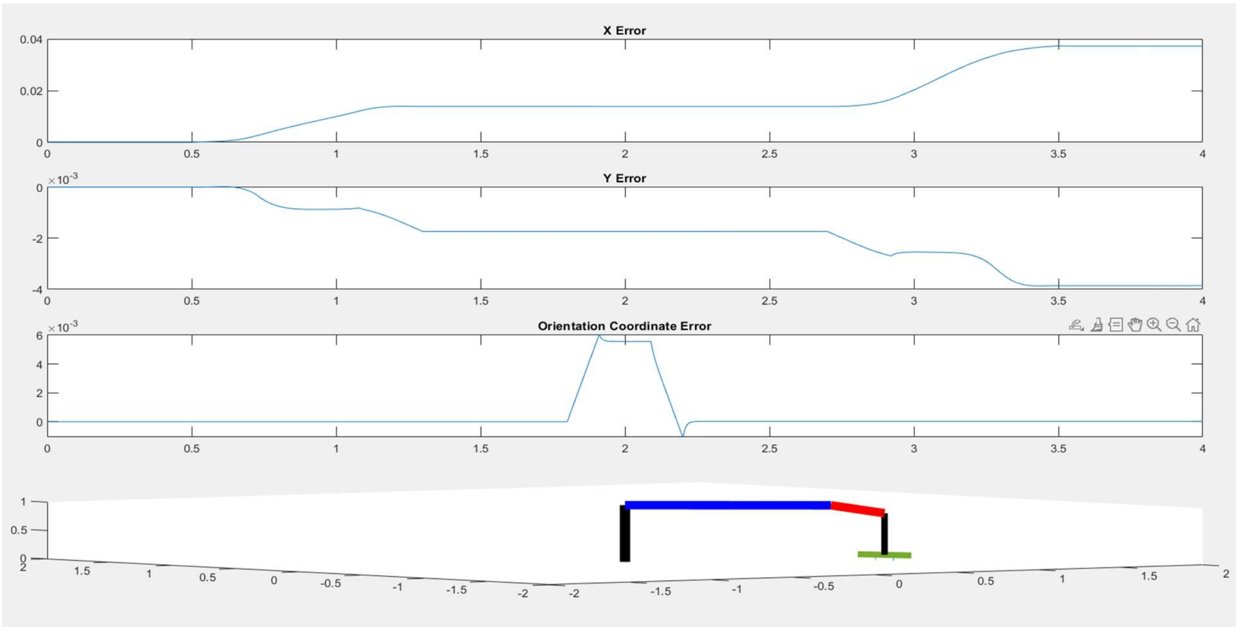
Desired Trajectory   Actual Trajectory

Joint Values Plots:



The above graph depicts the orientation and the position of the end effector of the manipulator.

Error Values Plot:



The above graph depicts the error value, that is the difference between the actual output and the desired output.

Conclusion:

- The obstacle is avoided by the end effector of the manipulator by relaxing the z component of the manipulator in the operational space.

Reference:

- Chapter 3- B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, “Robotics: Modelling, Planning and Control”, Springer