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Robot Control Assignment 4 Report

A1 =

$$\begin{bmatrix} 1 & t_0 & {t_0}^2 & {t_0}^3 \\ 0 & 1 & 2\,t_0 & 3\,{t_0}^2 \\ 1 & t_1 & {t_1}^2 & {t_1}^3 \\ 0 & 1 & 2\,t_1 & 3\,{t_1}^2 \end{bmatrix}$$

```
B1 = 4×1
       3.1416
            0
            0
            0

B2 = 4×1
       1.5708
            0
            0
            0
```

J1 =

$$\begin{bmatrix} \dfrac{\pi\ \left(-{t_1}^3 + 3\,t_0\,{t_1}^2\right)}{-{t_1}^3 + 3\,t_0\,{t_1}^2 - 3\,{t_0}^2\,t_1 + {t_0}^3} \\ -\dfrac{6\,\pi\,t_0\,t_1}{-{t_1}^3 + 3\,t_0\,{t_1}^2 - 3\,{t_0}^2\,t_1 + {t_0}^3} \\ \dfrac{3\,\pi\ (t_1 + t_0)}{-{t_1}^3 + 3\,t_0\,{t_1}^2 - 3\,{t_0}^2\,t_1 + {t_0}^3} \\ -\dfrac{2\,\pi}{-{t_1}^3 + 3\,t_0\,{t_1}^2 - 3\,{t_0}^2\,t_1 + {t_0}^3} \end{bmatrix}$$

J2 =

$$\left[\begin{array}{c} \frac{\pi\ \left(-{t_1}^3+3\,t_0\,{t_1}^2\right)}{2\ \left(-{t_1}^3+3\,t_0\,{t_1}^2-3\,{t_0}^2\,t_1+{t_0}^3\right)}\\ -\frac{3\,\pi\,t_0\,t_1}{-{t_1}^3+3\,t_0\,{t_1}^2-3\,{t_0}^2\,t_1+{t_0}^3}\\ \frac{3\,\pi\ \left(t_1+t_0\right)}{2\ \left(-{t_1}^3+3\,t_0\,{t_1}^2-3\,{t_0}^2\,t_1+{t_0}^3\right)}\\ -\frac{\pi}{-{t_1}^3+3\,t_0\,{t_1}^2-3\,{t_0}^2\,t_1+{t_0}^3} \end{array}\right]$$

X =

$$\left[\begin{array}{c} \theta_1\\ \theta_2\\ \theta_{\dot{1}}\\ \theta_{\dot{2}} \end{array}\right]$$

dX =

$$\left[\begin{array}{c} \theta_{\dot{1}}\\ \theta_{\dot{2}}\\ \theta_{\ddot{1}}\\ \theta_{\ddot{2}} \end{array}\right]$$

A = 4×4

0	0	1	0
0	0	0	1
0	0	0	0
0	0	0	0

```
B = 4×2
     0     0
     0     0
     1     0
     0     1
```

Rank of matrix is 4 hence it is controllable

```
lamdas = 1×4
    -1    -1    -2    -2
```

The values of Kp and Kd are

```
K = 2×4
    2.0000         0    3.0000         0
         0    2.0000         0    3.0000
```

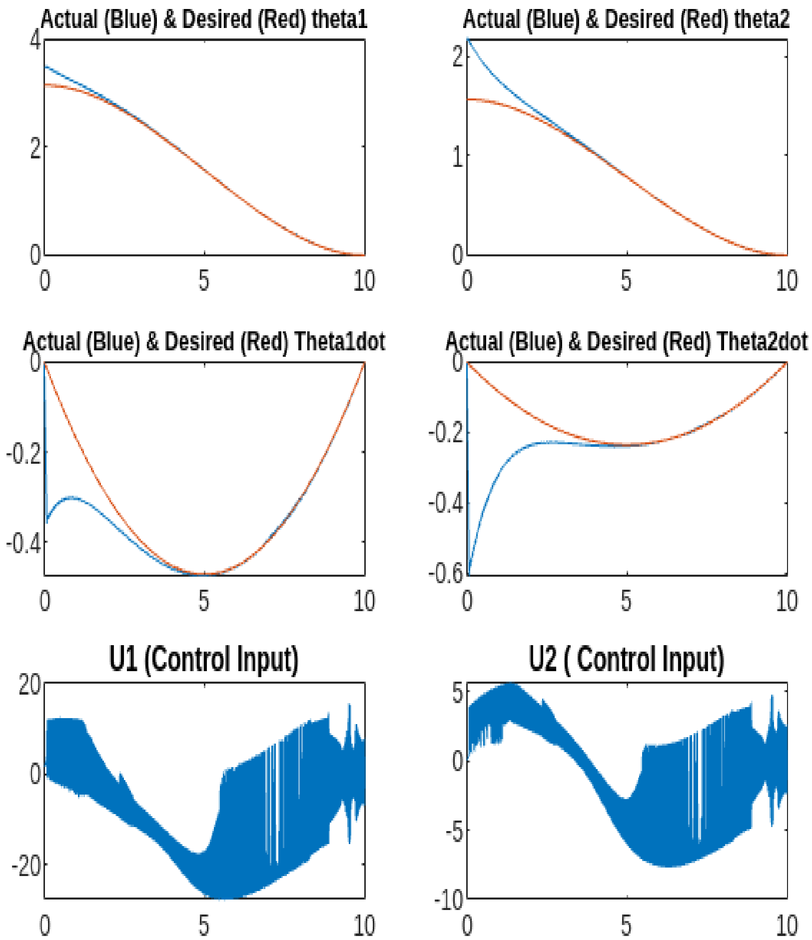
```
Q = 4×4
    10     0     0     0
     0    10     0     0
     0     0    10     0
     0     0     0    10
```

```
Acl = 4×4
         0         0    1.0000         0
         0         0         0    1.0000
   -2.0000         0   -3.0000         0
         0   -2.0000         0   -3.0000
```

```
P = 4×4
   12.5000         0    2.5000         0
         0   12.5000         0    2.5000
    2.5000         0    2.5000         0
         0    2.5000         0    2.5000
```

MATLAB Trajectories without any boundary layer

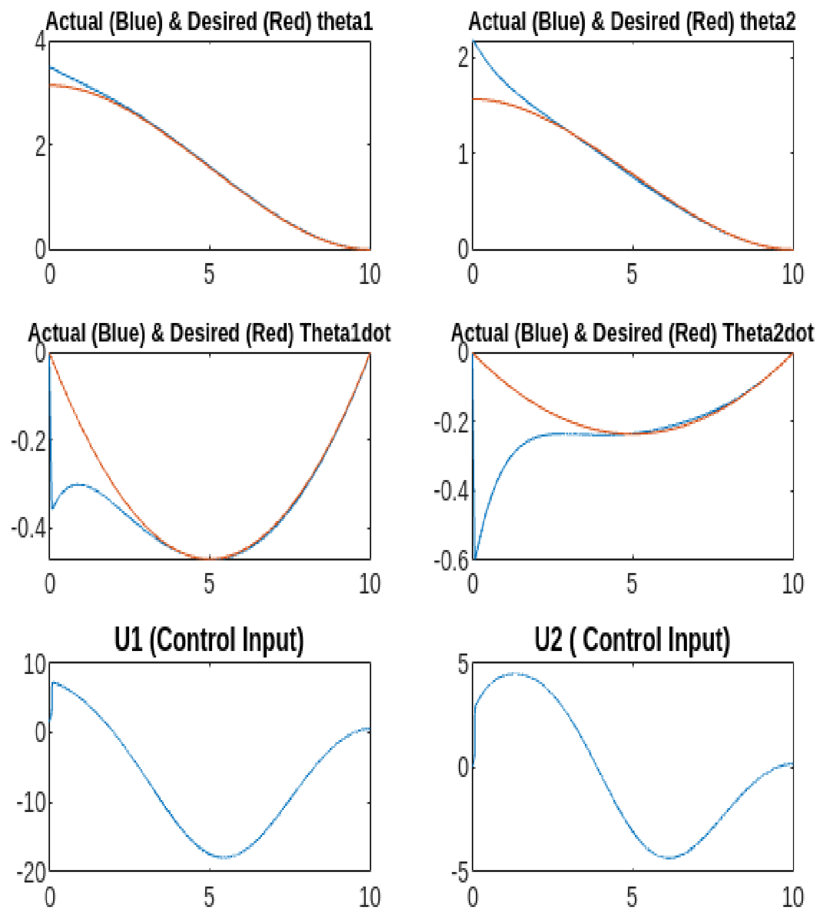
rho = 8; phi = 0



As there was no boundary layer, chattering issue can be seen in the control input. After checking for different values of rho, trajectories were converging the best with the rho value as 8. This chattering issue is due to the flipping of values (signs in the control law)

MATLAB Trajectories with boundary layer

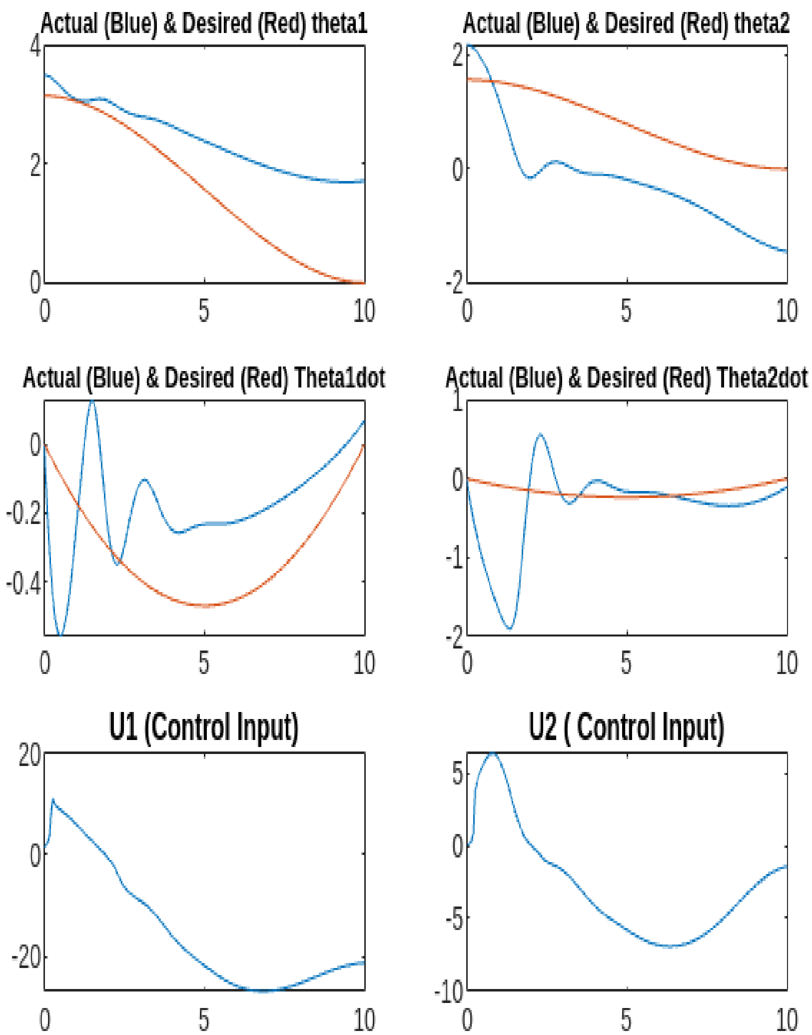
rho = 8; phi = 0.1



In order to get rid of the chattering issues, a boundary layer was added (value greater than 0). I have chosen the value of my phi as 0.1 and we can see that the trajectory stabilizes within the bound of 0.1 and chattering was removed.

MATLAB Trajectories without the Vr term

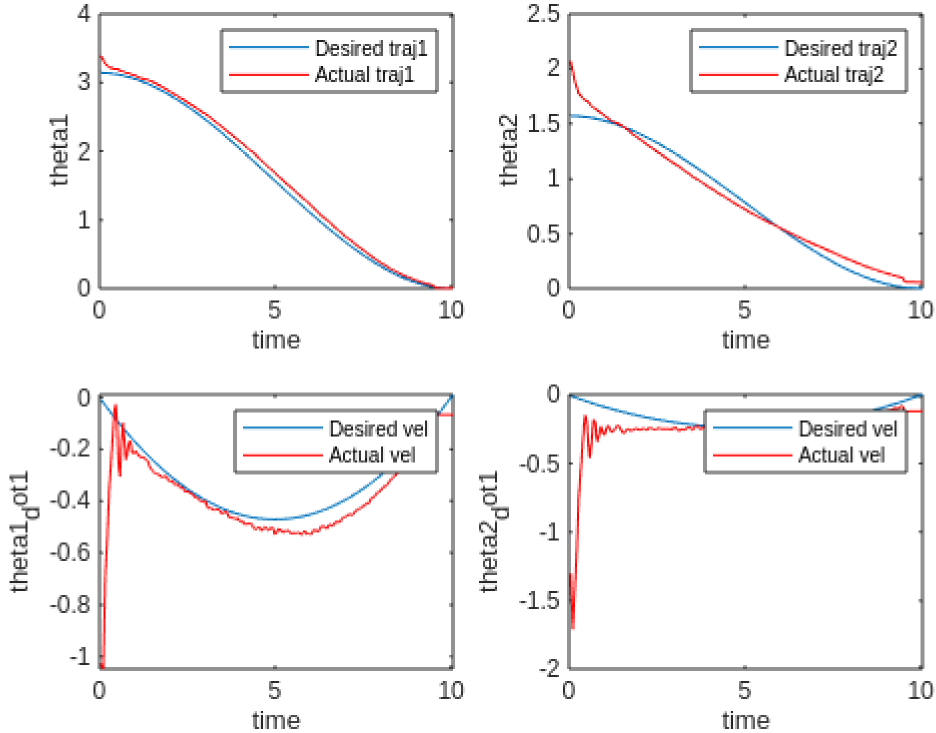
rho = 8; phi = 0.1

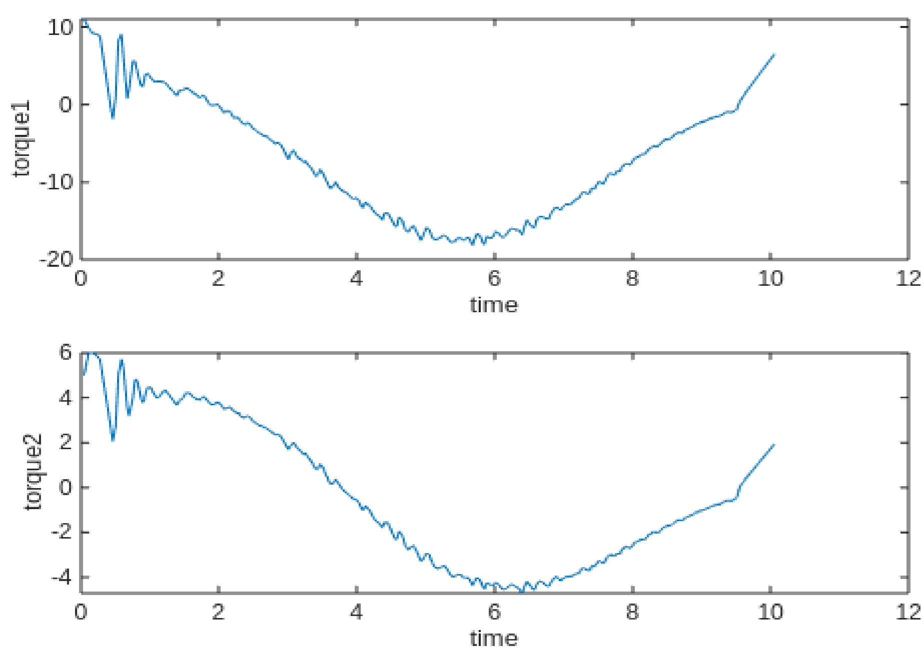


Discussion:
There is obvious disturbance in the plots in the absence of the Vr term as compared to when it is present. Vr was introduced in the system to compensate for external disturbances and non linearity in the system.

Gazebo plots

Rho = 8 phi = 0.6





Due to gazebo having physics applied to the robot, parameters such as friction and other disturbances affect the graph of the systems. These parameters are however absent in MATLAB which leads to a smoother plot. Hence, we can see that there are a lot of oscillations and irregularities in Gazebo and not in MATLAB. The values in gazebo have been slightly changed for better plot.

Discussion regarding the tuning parameters used in the code :
There are different design parameters which were used in the code:

1) Q = [10 0 0 0; 0 10 0 0 ; 0 0 10 0; 0 0 0 10]
   I have used this value of Q in my code. As all the diagonal elements in my Q are same, so there is not effect of Q on the overall system.

2) rho = 8
   rho is the design parameter which I have considered to be constant, and I have designed it to be as worst case parameter i.e the maximum uncertainty which can occur in the system.

3) phi = 0.1
   I have also tried to use different values of rho like 8,7,6,5,4. But with all those parameters I was not getting the control input within the bounds mentioned.