EML 6531-Adaptive Control Project 3

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1)Simulation Section for Standard Adaptive Controller

1) Control Gains used:

- K_1 multiplying r in the design of τ
- Learning Rate Matrix Γ in the adaptive update law
- α multiplying e in the definition of the error signal r

The values of which were picked as follows: $K_1 = 9$, $\Gamma = \begin{bmatrix} 300 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 \\ 0 & 0 & 20 & 0 & 0 \\ 0 & 0 & 0 & 20 & 0 \\ 0 & 0 & 0 & 0 & 20 \end{bmatrix}$ and $\alpha = 1$

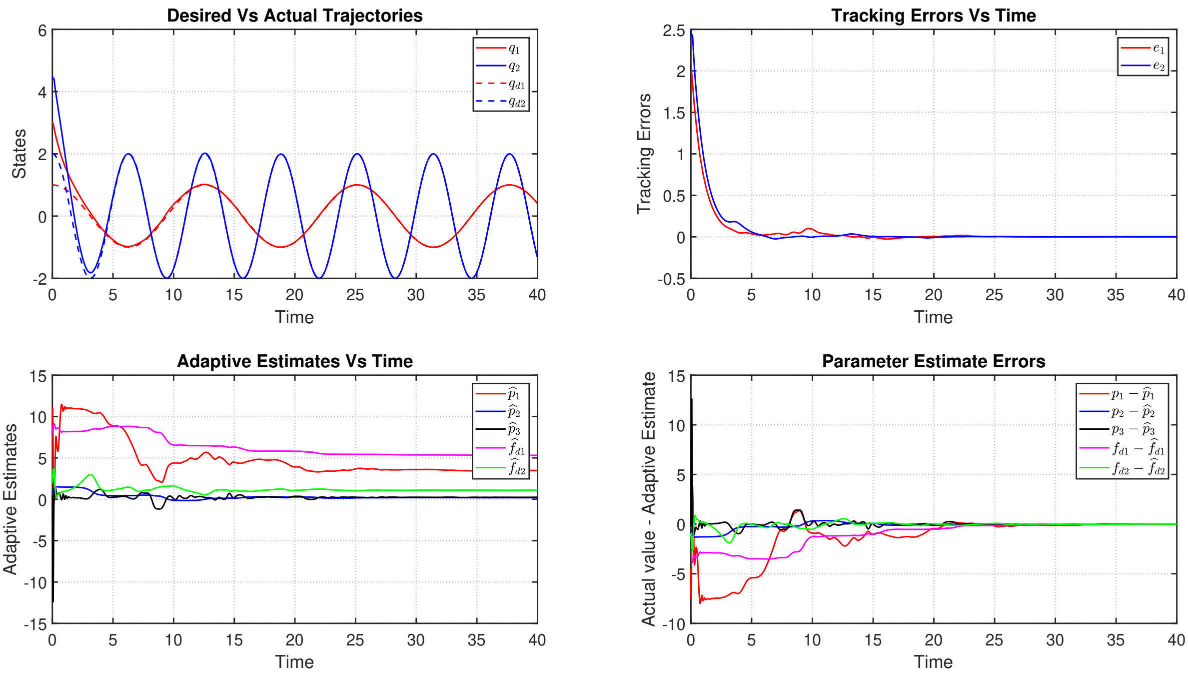

Figure 1: Standard Adaptive Control

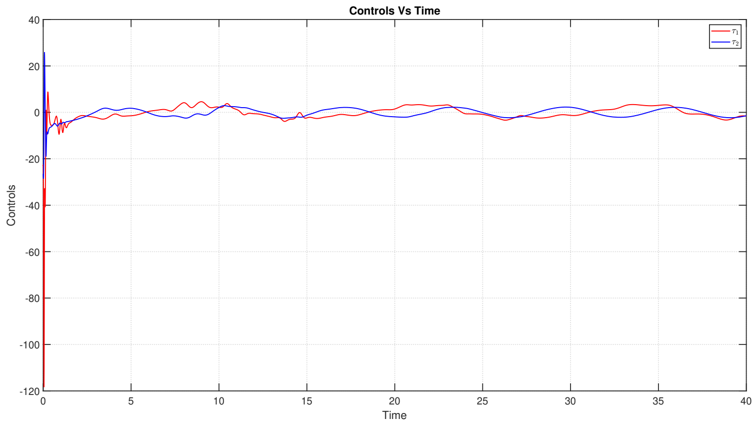

Figure 2: Control Inputs - Standard Adaptive Control

Maximum values of the torques are 118.2700 Nm and 28.4475 Nm respectively.

2)Simulation Section for Adaptive Controller with Concurrent Learning

1) Control Gains used:

- K_1 multiplying r in the design of τ
- K_2 multiplying the concurrent learning portion in the adaptive update law
- Learning Rate Matrix Γ in the adaptive update law
- α multiplying e in the definition of the error signal r

The values of which were picked as follows: $K_1 = 9$,$K_2 = 0.01$, $\Gamma = \begin{bmatrix} 300 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 \\ 0 & 0 & 20 & 0 & 0 \\ 0 & 0 & 0 & 20 & 0 \\ 0 & 0 & 0 & 0 & 20 \end{bmatrix}$

and $\alpha = 1$

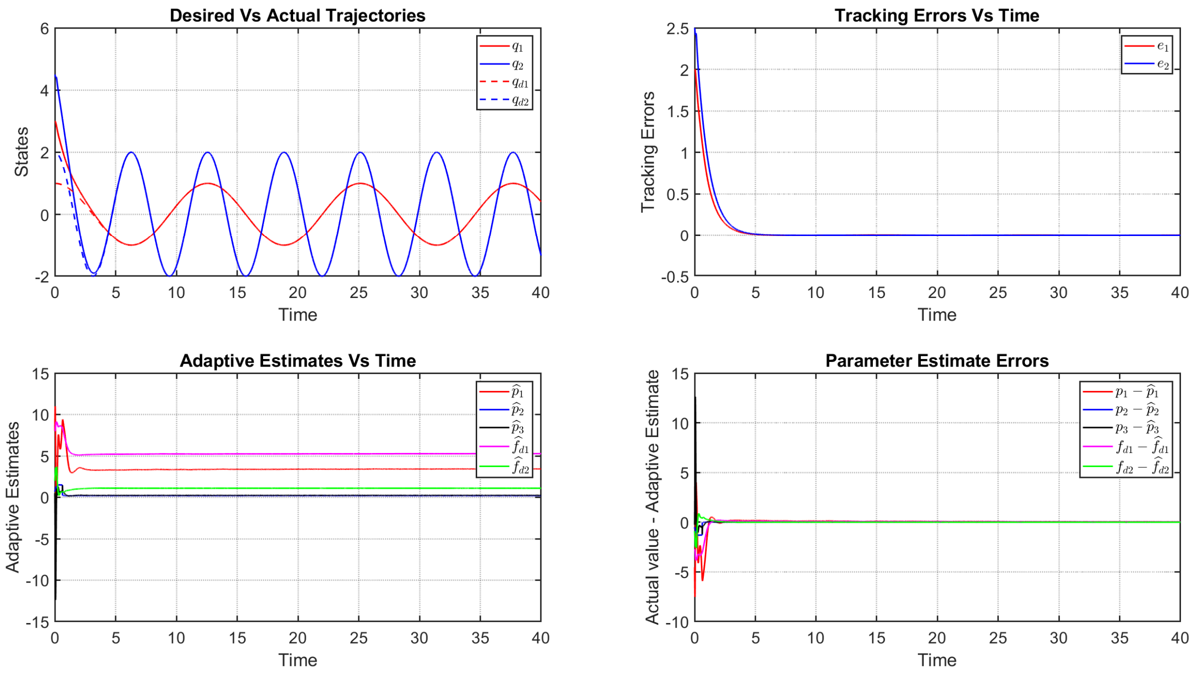

Figure 3: Adaptive Control with Concurrent Learning

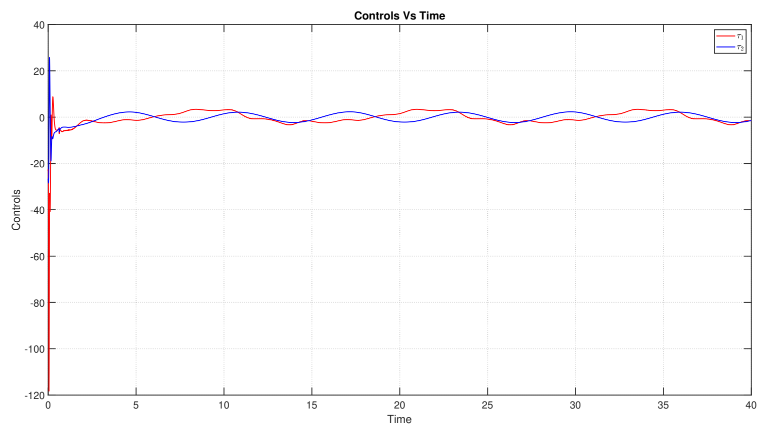

Figure 4: Control Inputs - Adaptive Control with Concurrent Learning

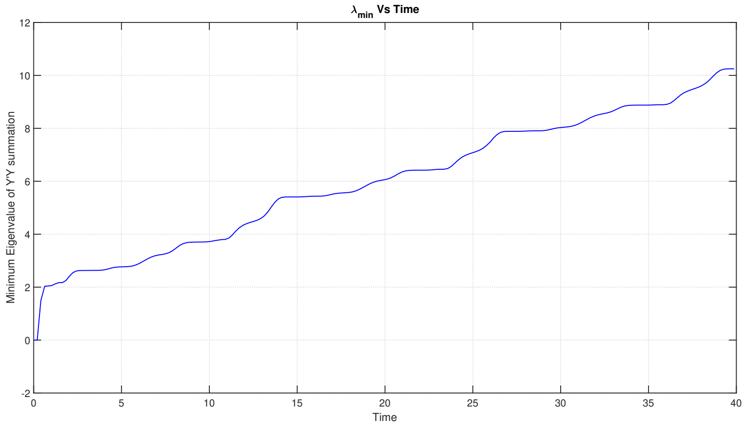

Figure 5: Minimum Eigenvalue of Y'Y summation

Maximum values of the torques are 118.2700 Nm and 28.4475 Nm respectively.

3)Simulation Section for Adaptive Controller with Integral Concurrent Learning

1) Control Gains used:

- K_1 multiplying r in the design of τ
- K_2 multiplying the concurrent learning portion in the adaptive update law
- Learning Rate Matrix Γ in the adaptive update law
- α multiplying e in the definition of the error signal r

The values of which were picked as follows: $K_1 = 9$,$K_2 = 0.01$, $\Gamma = \begin{bmatrix} 300 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 \\ 0 & 0 & 20 & 0 & 0 \\ 0 & 0 & 0 & 20 & 0 \\ 0 & 0 & 0 & 0 & 20 \end{bmatrix}$

and $\alpha = 1$

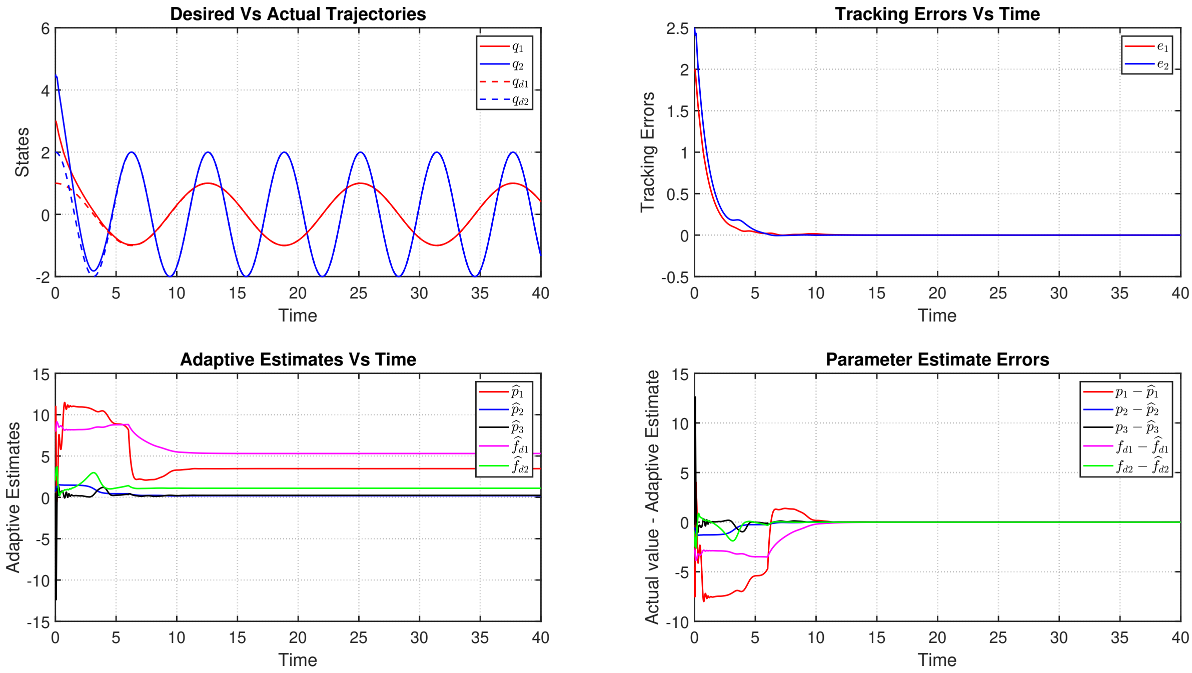

Figure 6: Adaptive Control with Integral Concurrent Learning

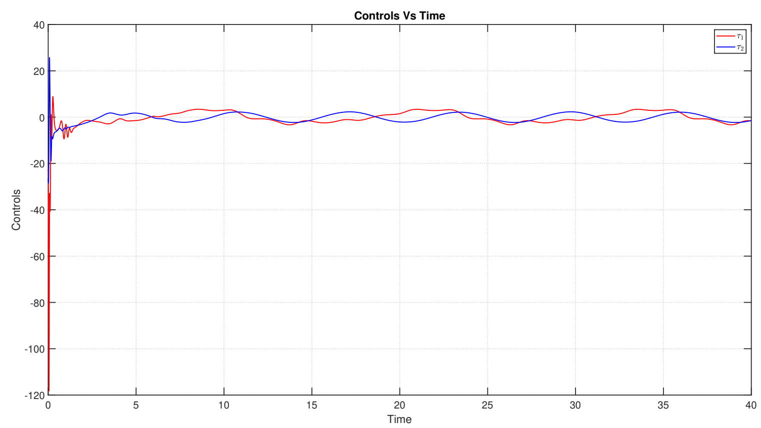

Figure 7: Control Inputs - Adaptive Control with Integral Concurrent Learning

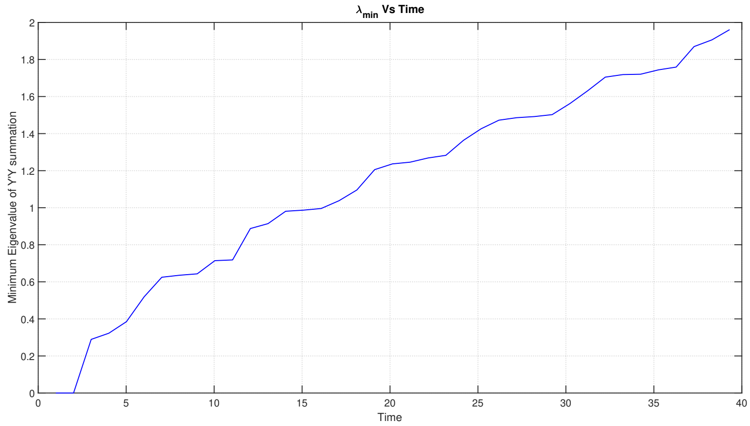

Figure 8: Minimum Eigenvalue of Y$'_s Y_s summation$

Maximum values of the torques are 118.1787 Nm and 28.4532 Nm respectively.

4)Discussion Section

- In all the three controllers increasing the gain K_1 brings the tracking error to zero faster. However, this comes at the cost of a higher control torque requirement.
- In the concurrent learning and the integral concurrent learning techniques K_2 is the gain multiplying the concurrent learning portion. Higher the value of K_2 larger the influence of the concurrent learning portion on the adaptive update law. However since the $Y^T Y$ summation gets pretty big really quick, so $K2$ needs to be chosen very small to avoid the estimates becoming unstable. Even a small value of K_2 has a considerable influence on the update law.
- Our choice of the Learning Gain Matrix determines the speed of convergence of the adaptive estimates to the actual parameter values. The above gains along the diagonal of the matrix have been chosen by trail and error in view of getting a good speed of convergence.
- Tracking error converges to zero faster in the concurrent and integral concurrent learning controllers as compared to the standard adaptive controller (as can be seen from the plots).
- Adaptive estimates also converge faster in the concurrent and integral concurrent learning controllers as compared to the standard adaptive controller. In fact, the

disparity is much more pronounced for convergence of adaptive estimates as compared to the convergence of tracking errors. This is due to the fact that convergence of the adaptive estimates can be shown for these two controllers in the Lyapunov Analysis (while it cannot be shown for the standard adaptive controller).