*** Q-1, DIRECT MRAC ***

PROBLEM

Consider the plant

$$Y(s) = \frac{b_1 s + b_0}{s^3 + a_2 s^2 + a_1 s + a_0} U(s)$$

Where, $a_0, a_1, a_2, b_0, b_1, b_2$ are unknown constants. $b_0 > 1$, $b_1 > 1$

(a) Derive adaptive control law for the plant to track a reference model given by

$$Y_m(s) = \frac{1}{s^2 + 3.6s + 4} R(s)$$

(After converting into state-space form you can assume that all the states are available for measurement)

(b) Simulate the system with the derived control law by taking any initial condition and $r(t) = 4\sin(t) + \cos(0.5t)$. For simulation use $a_2 = 2, a_1 = 2, a_0 = 3, b_1 = 2, b_0 = 3$.

INITIAL CONDITIONS ASSUMED

```
X = [1    2   -2]'          % Plant
Xm = [2    0.1   -2]'       % Reference model
Kx = [-1    0.2   2]        % Parameter Estimated
Kr = [2]                    % Parameter Estimated
```

MATLAB code

>> main_Q1_AS_03.m

```
%% Question 1 (ASSIGNMENT-03)

close all
clear all
clc

% Initial conditions to start the Simulation
% y0(1:3) = x(3x1)
% y0(4:6) = xm(3x1)
% y0(7:9) = Kx(1x3)
% y0(10) = Kr(1x1)
% y0 = [x xm Kx Kr]
y0 = [1    2   -2   ...
      2    0.1   -2   ...
      -1    0.2     2 ...
      2];

[t,y] = ode45(@dy_dt_Q1, [0 50], y0);

plotting_Q3;
```

>> dy_dt_Q1.m

```
%% dydt function
function dy = dy_dt_Q1(t, y)

A = [0 1 0; 0 0 1; -3 -2 -2];
B = [0; 0; 1];
Am = [0 1 0; 0 0 1; 0 -4 -3.6];
Bm = [0; 0; 1];

x = reshape(y(1:3), [3 1]);
xm = reshape(y(4:6), [3 1]);
Kx = reshape(y(7:9), [1 3]);
Kr = y(10);

r = 4*sin(t) + cos(0.5*t);

% Controller
u = Kx*x + Kr*r;

% Plant & Reference model
x_dot = A*x + B*u;
xm_dot = Am*xm + Bm*r;

% Adaptive Laws
```

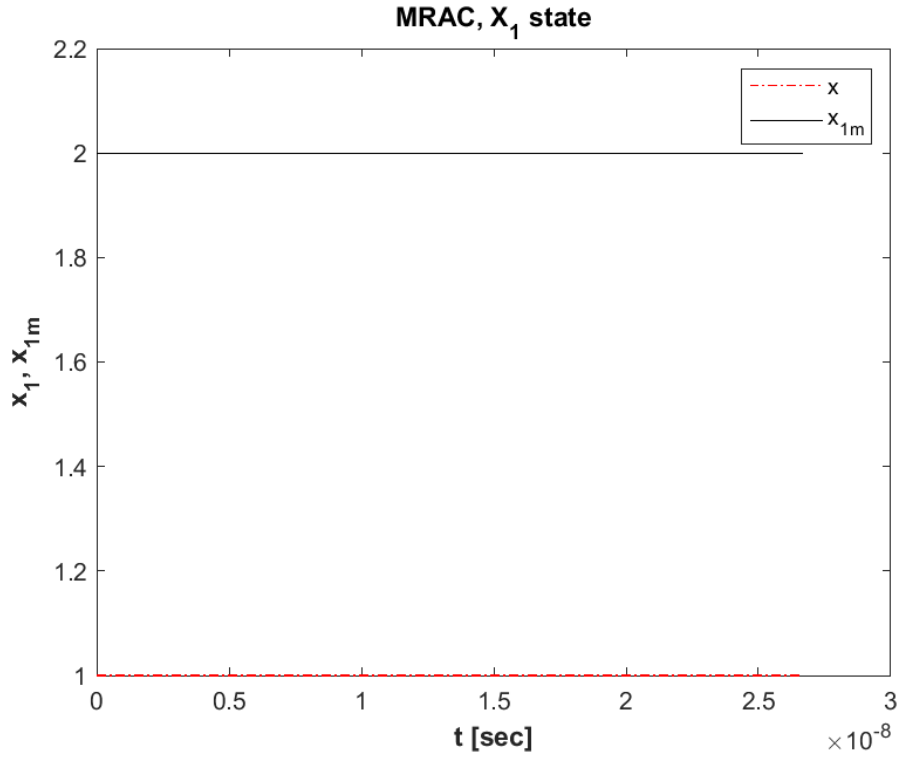
```
gammax = eye(1);
gammar = eye(1);
P = lyap(Am', eye(3));          % Solution of Lyapunov function AX+XA'+Q=0 (Q=eye(3))
e = xm - x;

dKx = gammax * B' * P * e * x' ;
dKr = gammar * B' * P * e * r ;

dKx = reshape(dKx, [3 1]);      % Conversion to get compatible with vector
% dKr = reshape(dKr, [4 1]);

dy = [x_dot; xm_dot; dKx; dKr];

end
```

>> plotting.m

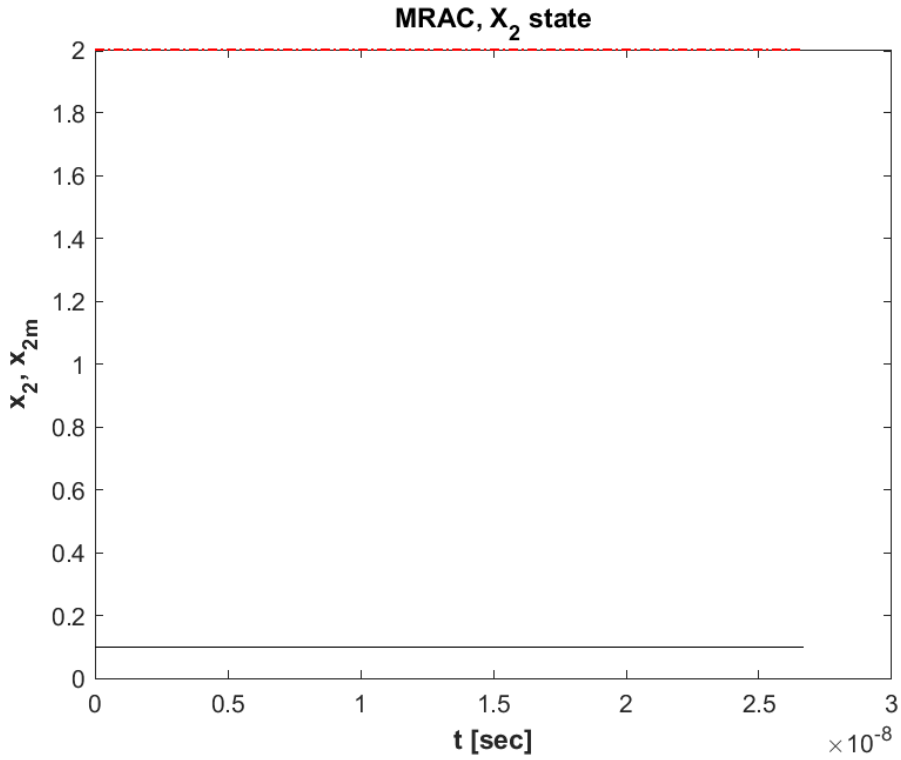
```
%% Plotting Q1
figure(1);

plot(t,y(:,1), t,y(:,4));
xlabel('t [sec]', 'FontWeight','bold');
ylabel('x1, x1_m', 'FontWeight','bold');
legend('x','x_m');
title('MRAC, X_1 state', 'FontWeight','bold')

figure(2);
plot(t,y(:,2), t,y(:,5));
xlabel('t [sec]', 'FontWeight','bold');
ylabel('x2, x2_m', 'FontWeight','bold');
title('MRAC, X_3 state', 'FontWeight','bold')

figure(3);
plot(t,y(:,3), t,y(:,6));
xlabel('t [sec]', 'FontWeight','bold');
ylabel('x3, x3_m', 'FontWeight','bold');
title('MRAC, X_3 state', 'FontWeight','bold')
```

OUTPUT PLOT

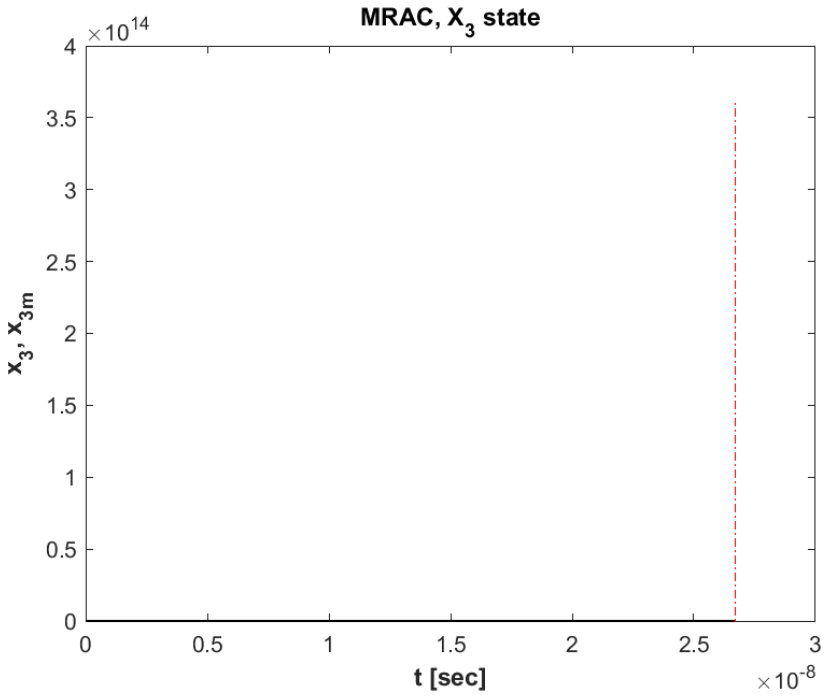
>> Plot 1



>> Plot 2



>> Plot 3


MRAC, X3 state
×10^14
4
3.5
3
2.5
2
1.5
1
0.5
0
X3, X3m
0
0.5
1
1.5
2
2.5
3
t [sec]
×10^-8