Assignment 6

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Contents

Adaptive control design for one-link planar arm.

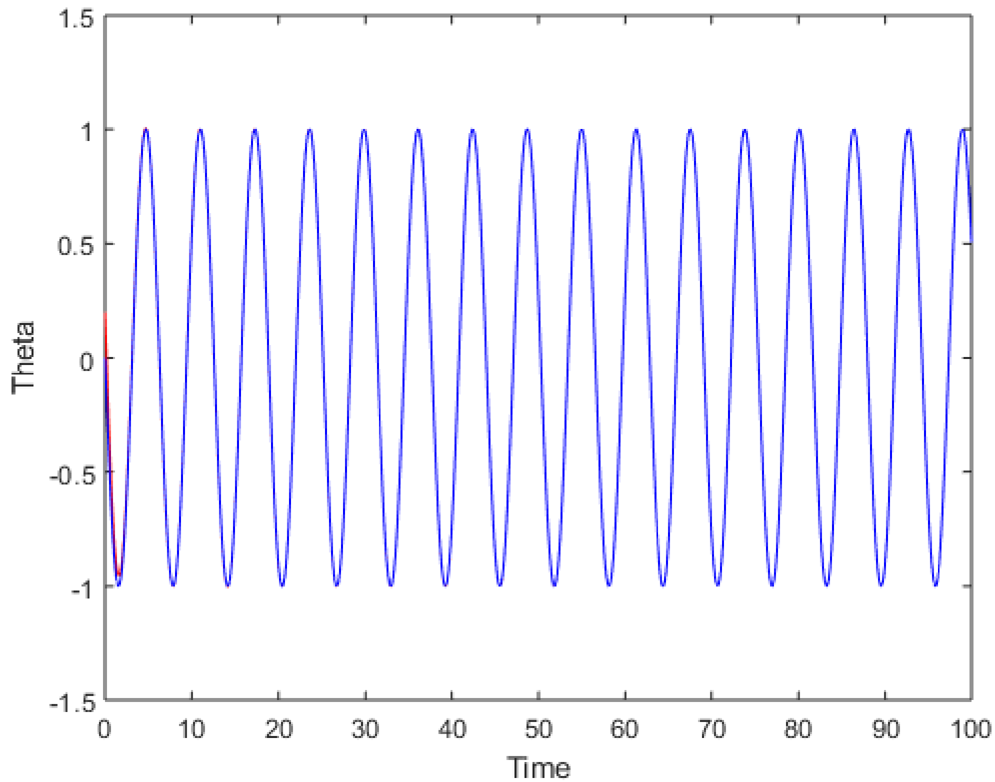
```
clc
clear all;
close all;

% Initial condition
global I mgd fv
% the nominal model parameter:
I = 7.5; mgd = 6.0; fv = 1.5; % parameters in the paper.
Ii = 8.0; mgdi = 5.0; fvi = 2.5; % parameters in the paper.
x0=[0.2,0.2,8.0,5.0,2.5]; %[q,dq,Ii,mgdi,fvi]
tf = 100.0;

global torque
torque=[];
options = odeset('RelTol',1e-4,'AbsTol',[1e-4, 1e-4, 1e-4, 1e-4, 1e-4]);
```

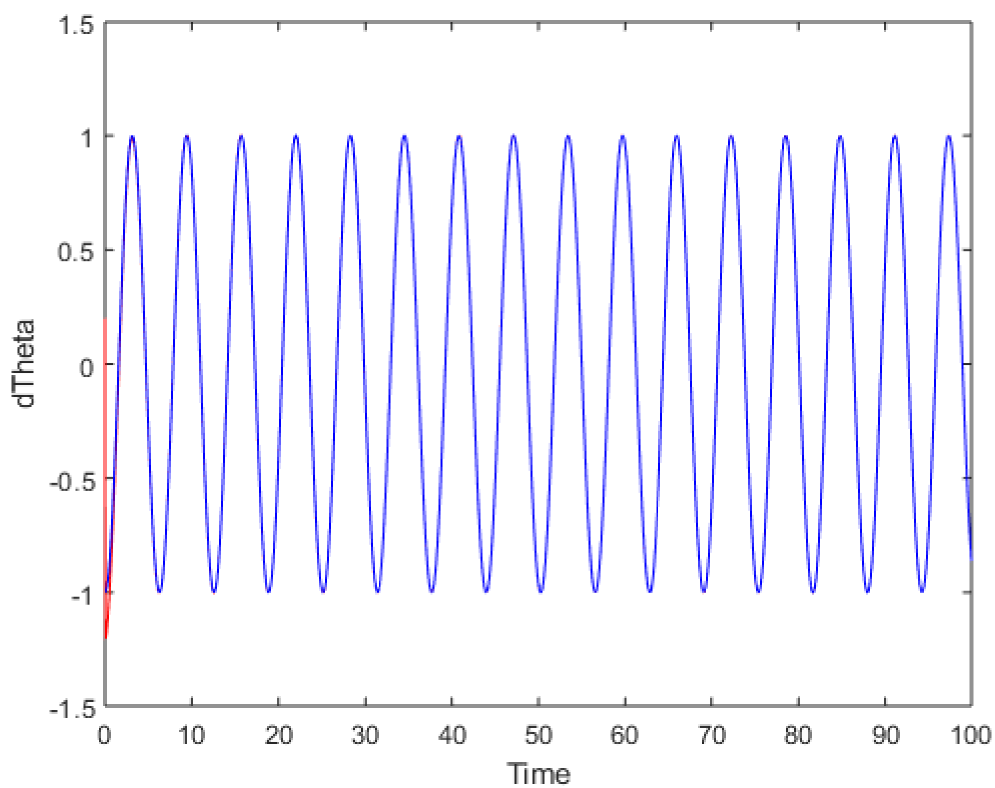
IMPLEMENTING THE CONTROLLER AND PLOTTING THE RESULTS

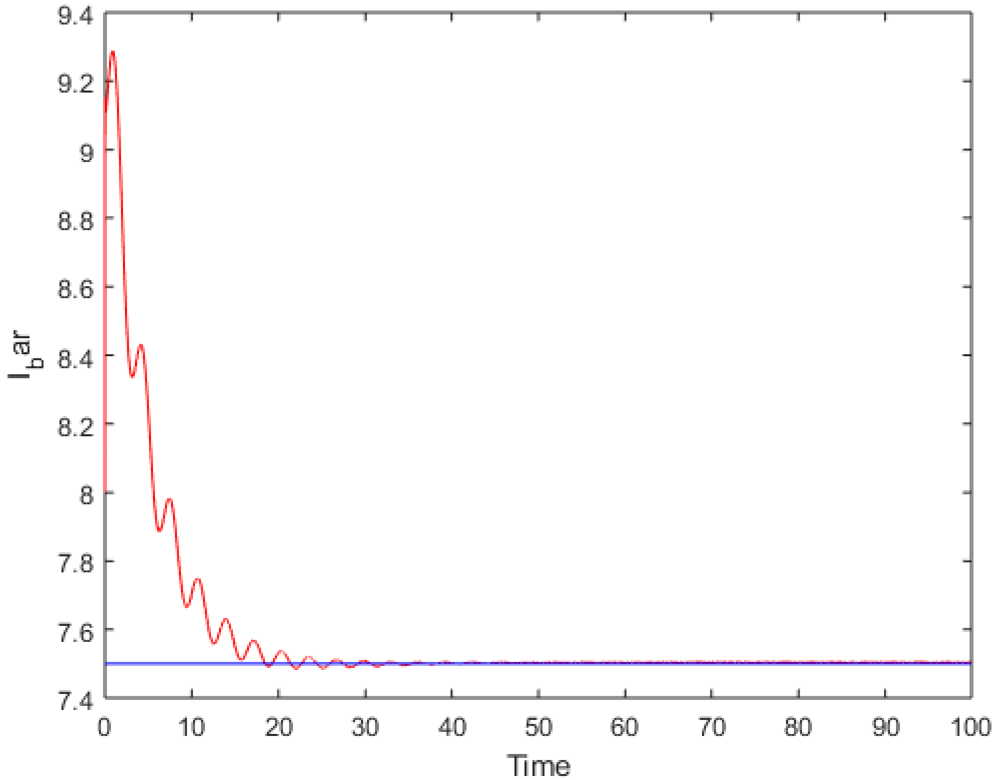
```
[T,X] = ode45(@(t,x)planarArmODEAdaptive(t,x),[0 tf],x0,options);

figure('Name','Theta under Adaptive Control');
plot(T, X(:,1),'r-');
hold on
plot(T, -sin(T),'b-');
ylabel('Theta')
xlabel('Time')

figure('Name','dTheta under Adaptive Control');
plot(T, X(:,2),'r-');
hold on
plot(T, -cos(T),'b-');
ylabel('dTheta')
xlabel('Time')

figure('Name','I_bar under Adaptive Control');
plot(T, X(:,3),'r-');
hold on
plot(T, I*ones(size(T,1),1),'b-');
ylabel('I_bar')
xlabel('Time')

figure('Name','mgd_bar under Adaptive Control');
plot(T, X(:,4),'r-');
hold on
plot(T, mgd*ones(size(T,1),1),'b-');
ylabel('mgd_bar')
xlabel('Time')
```

```
figure('Name','fv_bar under Adaptive Control');
plot(T, X(:,5),'r-');
hold on
plot(T, fv*ones(size(T,1),1),'b-');
ylabel('fv_bar')
xlabel('Time')

figure('Name','Adaptive Control');
plot(T, torque(1,1:size(T,1)),'-');
ylabel('Torque')
xlabel('Time')
hold off
torque=[];

% IMPLEMENTING THE CONTROLLER
function [dx ] = planarArmODEAdaptive(t,x)

    theta_d=[-sin(t)]; % [x1d] Desired trajectory
    dtheta_d=[-cos(t)]; % [x1d_dot]
    ddtheta_d=[sin(t)]; % [x1d_ddot]
    theta=x(1,1); % [x1]=[x(1)]
    dtheta=x(2,1); % [x1_dot]=[x(2)]

    global I mgd fv Mbar Cbar Nbar
    M = I;
    C = fv;
    N = mgd*sin(x(1));
    invM = inv(M);
    invMC= inv(M)*C;
    invMN= inv(M)*N;

    Mbar = x(3);
    Cbar = x(5);
    Nbar = x(4)*sin(x(1));

    tau = Controler(theta_d,dtheta_d,ddtheta_d,theta,dtheta);

    global torque
    torque = [torque, tau];

    global a v r
    H = 0.01*eye(3);

    dx=zeros(5,1);
    dx(1) = x(2);
    dx(2) = -invMC* x(2) -invMN +invM*tau; % because ddot theta = -M^{-1}(C \dot Theta) + M^{-1} tau
    Y = [a, sin(x(1)), v];
    dx(3:5) = -inv(H)*transpose(Y)*r;
end

% Adaptive Control Law
function tau = Controler(theta_d,dtheta_d,ddtheta_d,theta,dtheta)
   P_e = theta - theta_d;
   V_e = dtheta - dtheta_d;

   global r a v
   Kv= 450*eye(1);
   L = 1*eye(1);
   a = ddtheta_d - L*V_e;
   v = dtheta_d - L*P_e;
   r = V_e + L*P_e;
```

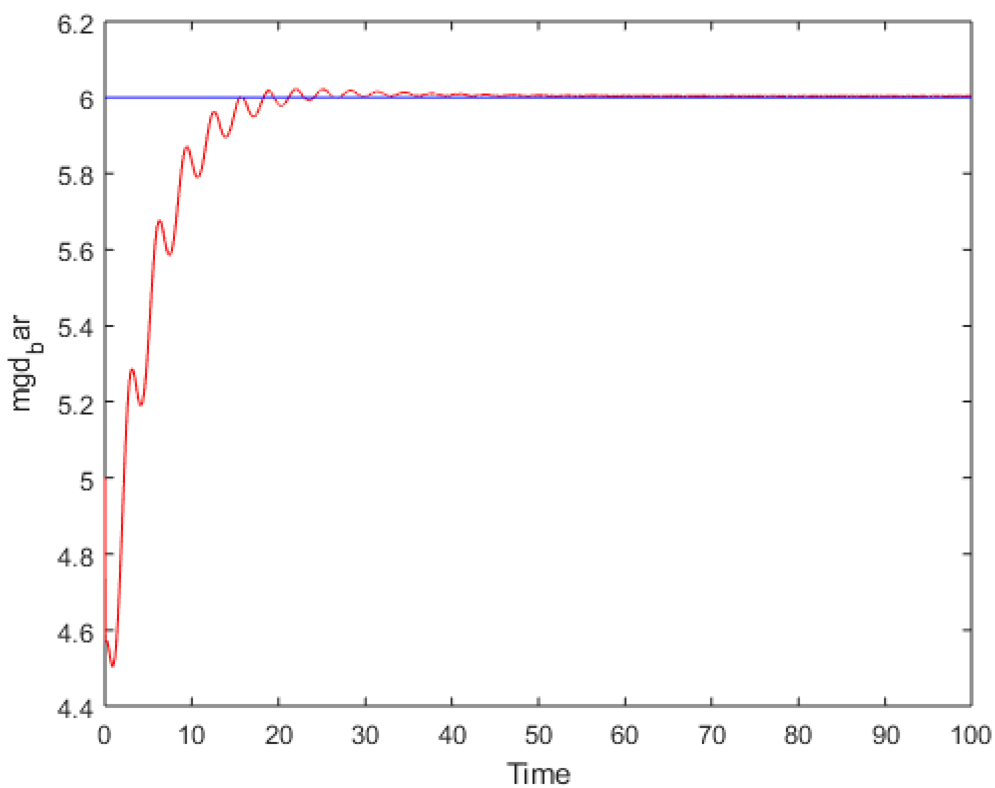
```
    global Mbar Cbar Nbar
    tau = Mbar*a + Cbar*v + Nbar - Kv*r;
end
```



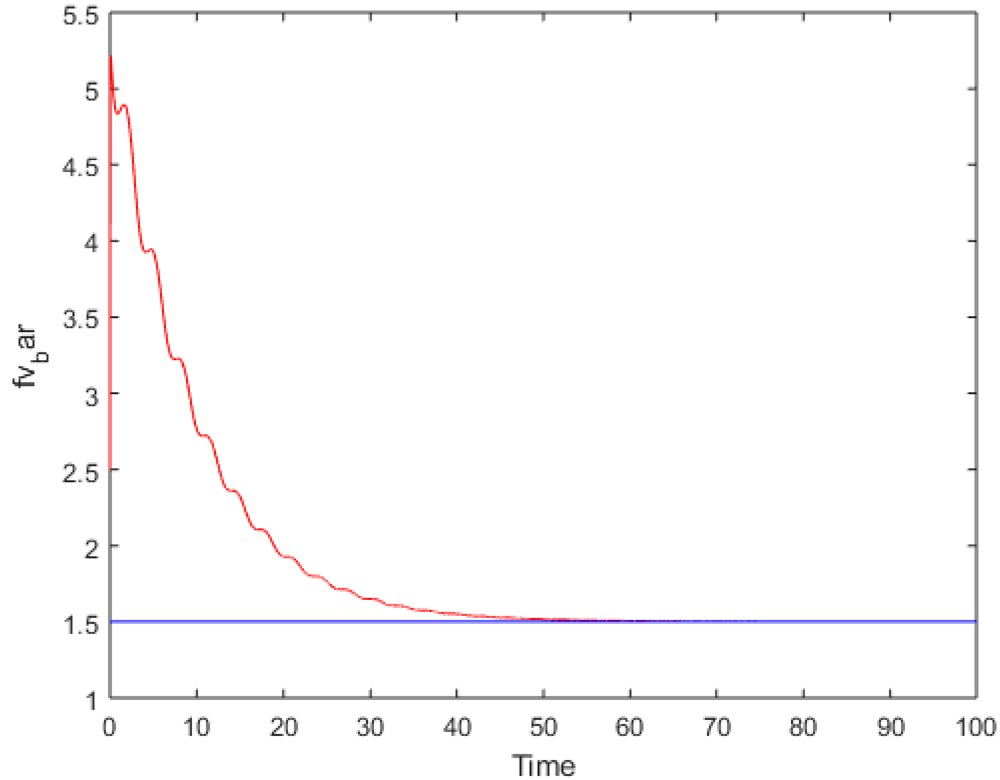


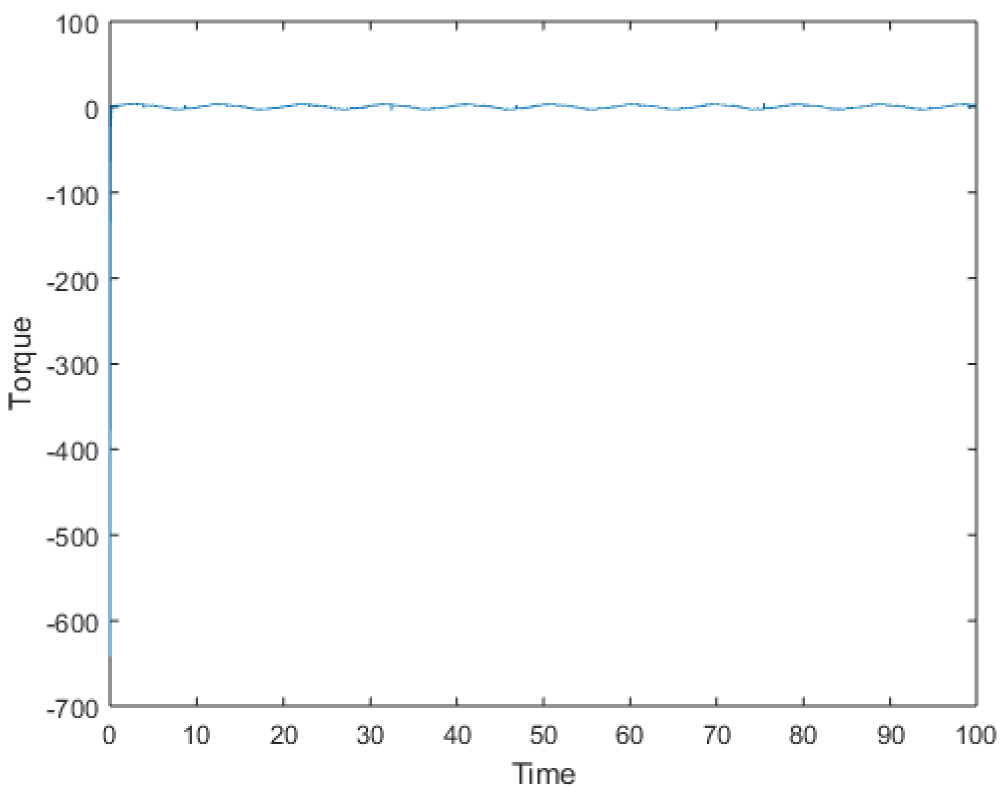


$I_b$ar
Time
9.4
9.2
9
8.8
8.6
8.4
8.2
8
7.8
7.6
7.4
0 10 20 30 40 50 60 70 80 90 100



mgd_bar
Time
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
0 10 20 30 40 50 60 70 80 90 100


5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
fv_bar
0
10
20
30
40
50
60
70
80
90
100
Time


100
0
-100
-200
-300
-400
-500
-600
-700
Torque
0
10
20
30
40
50
60
70
80
90
100
Time

→ Given dynamic Model:

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + N(q) = \tau$$

Control law:

$$\tau = \bar{M}(q)\underset{\uparrow\ \ddot{q}^d - \Lambda\dot{e}}{a} + \bar{C}(q,\dot{q})\underset{\uparrow\ \dot{q}^d - \Lambda e}{v} + \bar{N}(q) - K_v \underset{\uparrow\ \dot{e} + \Lambda e}{r} \qquad (\Lambda \text{ pos def})$$

- Closing the loop:

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + N(q) = \bar{M}(q)a + \bar{C}(q,\dot{q})v + \bar{N}(q) - K_v r$$

With no error $= M(q)\dot{r} + C(q,\dot{q})r + K_v r$.

$$= (\bar{M}(q) - M)a + (\bar{C}(q) - C)v + \bar{N} - N$$

$$= Y(a,v,q,\dot{q})(\bar{\theta} - \theta)$$

→ We know, $M(q) = I$, $C(q,\dot{q}) = fv$, $N(q) = mgd\sin\theta$

& $\bar{M}(q) = \bar{I}$, $\bar{C}(q,\dot{q}) = \bar{f}v$, $\bar{N}(q) = \bar{mgd}\sin\theta$

$$\therefore Y(a,v,q,\dot{q})(\bar{\theta} - \theta) = (\bar{I} - I)a + (\bar{fv} - fv)v + (\bar{mgd} - mgd)\sin\theta$$

$$= \begin{bmatrix} a & \sin\theta & v \end{bmatrix} \begin{bmatrix} \bar{I} - I \\ \bar{mgd} - mgd \\ \bar{fv} - fv \end{bmatrix}$$

$$\therefore Y = \begin{bmatrix} a & \sin\theta & v \end{bmatrix}$$