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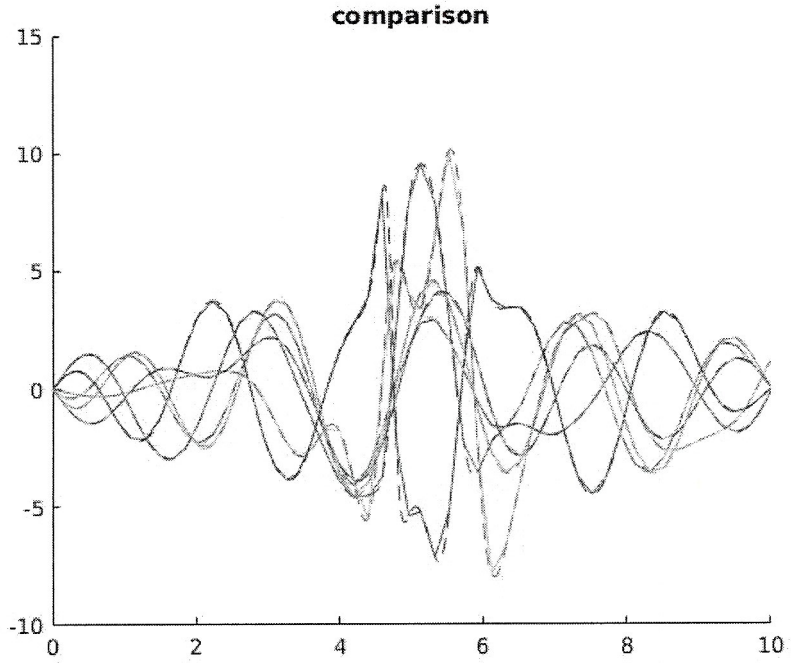
HW#6

Problem 1

```
%%
clear all
clc;

%define the robotics toolbox Puma 560 arm
mdl_puma560;

%set the Coulomb friction terms to zero to help with numerical simulation
p560 = p560.nofriction;

%load the torque profile and open the simulink model
load puma560_torque_profile.mat
open sl_puma_hw6

%%
% part (a)
q = out.get('q_sim');
q_dot = out.get('qd_sim');
q_ddot = out.get('qdd_sim');
global t_sim;
t_sim = out.get('t_sim');

global tau;
global tau_time;
global p560;
tau = torque;
tau_time = time;

x_0 = [0 0 0 0 0 0 0 0 0 0 0 0];
t_range = [time(1) time(end)];
[t, x] = ode45(@eom, time, x_0);

qdd_accel = p560.accel(x(:,7:12),x(:,1:6),interp1(tau_time,tau,t));
figure(2); hold on;
plot(t_sim, q_ddot);
plot(t, qdd_accel,'--');
title('comparison');
% % part (b)
% global tau_sample;
% global p560;
% tau_sample = interp1(time,torque,t_sim);
%
% x_0 = [0 0 0 0 0 0 0 0 0 0 0 0];
% t_range = [t_sim(1) t_sim(end)];
% [t, x] = ode45(@eom, t_range, x_0);
%
% qdd_accel = p560.accel(x(:,7:12),x(:,1:6),interp1(t_sim,tau_sample,t));
%
% figure(2); hold on;
% plot(t_sim, q_ddot);
% plot(t, qdd_accel,'--');
```

```
function xdot = eom(t,x)
% % keyboard
% global tau_sample;
% global t_sim;
% global p560;
%
% tau_now = interp1(t_sim,tau_sample,t);
% xdot(7:12,1) = x(1:6);
% xdot(1:6) = p560.accel(x(7:12)',x(1:6)',tau_now);

% keyboard
global tau;
global tau_time;
global p560;

tau_now = interp1(tau_time,tau,t);
xdot(7:12,1) = x(1:6);
xdot(1:6) = p560.accel(x(7:12)',x(1:6)',tau_now);

end
```



Problem 2

```
clear;
close all;
clc;

length = 0.4;
Izz = 0.01;
%   theta d a alpha
L(1) = Link([ 0     0   length  0], 'standard');
L(2) = Link([ 0     0   length  0], 'standard');
L(3) = Link([ 0     0   length  0], 'standard');
L(1).m = 1;
L(2).m = 1;
L(3).m = 1;
L(1).r = [-length/2; 0; 0];
L(2).r = [-length/2; 0; 0];
L(3).r = [-length/2; 0; 0];
I = Izz*eye(3);
L(1).I = I;
L(2).I = I;
L(3).I = I;
L(1).G = 0;
L(2).G = 0;
L(3).G = 0;
L(1).Jm = 0;
L(2).Jm = 0;
L(3).Jm = 0;

rrr = SerialLink(L(1:3), 'name', 'RRR');
% rrr.base = [1 0 0 0;
%             0 0 -1 0;
%             0 1 0 0;
%             0 0 0 1];

qz = [0 0 0];
rrr.plot(qz);

q = [pi/4, pi/4, pi/4];
qd = [pi/6, -pi/4, pi/3];
qdd = [-pi/6, pi/3, pi/6];
figure(1)
rrr.plot(q)

g = [0; -9.81; 0];
% Part (b)
tau_rtb = rrr.rne(q, qd, qdd, g)

% Part (a)
g = [0; 9.81; 0];
tau_mine = my_rne(q,qd,qdd,g,rrr,length,L)
```

```
% Part (c)
inertia_rtb = rrr.inertia(q)
qd = [0 0 0];
g = [0; 0; 0];
inertia_mine = zeros(3);
inertia_mine(1,:) = my_rne(q,qd,[1;0;0],g,rrr,length,L);
inertia_mine(2,:) = my_rne(q,qd,[0;1;0],g,rrr,length,L);
inertia_mine(3,:) = my_rne(q,qd,[0;0;1],g,rrr,length,L);
inertia_mine
```

```
tau_rtb =

   -5.5155    1.5871    1.4951


tau_mine =

   -5.5155    1.5871    1.4951


inertia_rtb =

    1.0825    0.5428    0.1066
    0.5428    0.3731    0.1066
    0.1066    0.1066    0.0500


inertia_mine =

    1.0825    0.5428    0.1066
    0.5428    0.3731    0.1066
    0.1066    0.1066    0.0500
```

```
function tau = my_rne(q,qd,qdd,g,rrr,length,L)
T1 = rrr.A(1,q);
T2 = rrr.A(2,q);
T3 = rrr.A(3,q);
R1 = T1(1:3,1:3);
R2 = T2(1:3,1:3);
R3 = T3(1:3,1:3);

R0_1 = R1;
R0_2 = R1*R2;
R0_3 = R1*R2*R3;

z = [0; 0; 1]; %For all links

w_0 = [0;0;0];
alpha0 = [0;0;0];
ae_0 = [0;0;0];


w_1 = R1'*w_0 + R0_1'*z*qd(1);
w_2 = R2'*w_1 + R0_2'*z*qd(2);
w_3 = R3'*w_2 + R0_3'*z*qd(3);

alpha1 = R1'*alpha0 + R0_1'*z*qdd(1) + cross(w_1,R0_1'*z*qd(1));
alpha2 = R2'*alpha1 + R0_2'*z*qdd(2) + cross(w_2,R0_2'*z*qd(2));
alpha3 = R3'*alpha2 + R0_3'*z*qdd(3) + cross(w_3,R0_3'*z*qd(3));

r0_1 = [length; 0; 0];
r1_2 = [length; 0; 0];
r2_3 = [length; 0; 0];

ae_1 = R1'*ae_0 + cross(alpha1,r0_1) + cross(w_1,cross(w_1,r0_1));
ae_2 = R2'*ae_1 + cross(alpha2,r1_2) + cross(w_2,cross(w_2,r1_2));
ae_3 = R3'*ae_2 + cross(alpha3,r2_3) + cross(w_3,cross(w_3,r2_3));

r1_c1 = r0_1/2;
r2_c2 = r1_2/2;
r3_c3 = r2_3/2;

ac_0 = [0;0;0];
ac_1 = R1'*ae_0 + cross(alpha1,r1_c1) + cross(w_1,cross(w_1,r1_c1));
ac_2 = R2'*ae_1 + cross(alpha2,r2_c2) + cross(w_2,cross(w_2,r2_c2));
ac_3 = R3'*ae_2 + cross(alpha3,r3_c3) + cross(w_3,cross(w_3,r3_c3));

g_temp = g;
f_4 = [0;0;0];
f_3 = L(3).m*ac_3 - L(3).m*R0_3'*g_temp;
f_2 = R2*f_3 + L(2).m*ac_2 - L(2).m*R0_2'*g_temp;
f_1 = R1*f_2 + L(1).m*ac_1 - L(1).m*R0_1'*g_temp;

tau_4 = [0;0;0];
tau_3 = -cross(f_3,r3_c3) + cross(R3*f_4,-r2_3/2) + L(3).I*alpha3 + cross(w_3, L
(3).I*w_3);
tau_2 = R2*tau_3 - cross(f_2,r2_c2) + cross(R2*f_3,-r1_2/2) + L(2).I*alpha2 + cross
(w_1, L(2).I*w_1);
tau_1 = R1*tau_2 - cross(f_1,r1_c1) + cross(R1*f_2,-r0_1/2) + L(1).I*alpha1 + cross
(w_0, L(1).I*w_0);

tau = [tau_1(3) tau_2(3) tau_3(3)];
end
```