**Assignment 5 Yufeng Sun**

**The plots reproduced with my code.**

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| **Figure 1: The histories of quaternions and control torque** | **Figure 2: Time histories of angular rate, and qi vs qj plots** |
|  |  |

From figure 1, we can find

* all 4 cases have similar result of Q4;
* case 1 have the largest overshot in Q1, Q2, U1, and U2;

From Figure 2, we can find

* case 1 have the largest angular velocity change in W1;
* case 3 have the largest angular velocity change in W3;
* case 3 and 4 have the similar angular velocity change in W2;
* case 4 have the shortest maneuver as the Qi vs Qj plot appears to be a nearly straight line;
* case 1 have the longest maneuver.

Code:

%--------------------------------------------------------------------------

% AEEM6036 Spacecraft Dynamics

% Assignment 5 Reproduce the simulation in paper "Quaternion Feedback

% Regulator for Spacecraft Eigenaxis Rotations"

% Author: Yufeng Sun

% Date: Nov 19, 2020

%--------------------------------------------------------------------------

**Parameters**

global J mu D

J = [1200 100 -200;

100 2200 300;

-200 300 3100];

% initial quaternion

q0 = [0.57 0.57 0.57 0.159]';

% initial angular velocity of spacecraft

w0 = [0.01 0.01 0.01];

mu = 0.9;

% gain matrix

D = 0.316\*[1200 0 0;

0 2200 0;

0 0 3100];

K1 = [201 0 0;

0 110 0;

0 0 78];

K2 = [110 0 0;

0 110 0;

0 0 110];

K3 = [72 0 0;

0 110 0;

0 0 204];

K4 = [60 0 0;

0 110 0;

0 0 155];

**Quaternion Feeback Regulator**

T = 100; % time

init\_y = zeros(7,1); % init value of angular velocity and quaternion

init\_y(1:3) = w0;

init\_y(4:7) = q0;

qd = [0 0 0 1]'; % desired quaternion

[t1,ws1,qs1,us1,es1] = Simulation([0,T],init\_y, K1);

[t2,ws2,qs2,us2,es2] = Simulation([0,T],init\_y, K2);

[t3,ws3,qs3,us3,es3] = Simulation([0,T],init\_y, K3);

[t4,ws4,qs4,us4,es4] = Simulation([0,T],init\_y, K4);

draw\_history\_q\_and\_u(t1,t2,t3,t4,qs1,qs2,qs3,qs4,us1,us2,us3,us4);

draw\_history\_w\_and\_qi(t1,t2,t3,t4,qs1,qs2,qs3,qs4,ws1,ws2,ws3,ws4,es1,es2,es3,es4);

**Supporting functions**

function draw\_history\_w\_and\_qi(t1,t2,t3,t4,q1,q2,q3,q4,w1,w2,w3,w4,es1,es2,es3,es4)

hold on

figure(2)

h1 = subplot(4,2,1);

draw\_subplot(h1,t1,t2,t3,t4,w1(:,1),w2(:,1),w3(:,1),w4(:,1),"W1 RAD/SEC");

h2 = subplot(4,2,2);

draw\_subplot(h2,t1,t2,t3,t4,w1(:,2),w2(:,2),w3(:,2),w4(:,2),"W2 RAD/SEC");

h3 = subplot(4,2,3);

draw\_subplot(h3,t1,t2,t3,t4,w1(:,3),w2(:,3),w3(:,3),w4(:,3),"W3 RAD/SEC");

h4 = subplot(4,2,4);

draw\_subplot(h4,t1,t2,t3,t4,es1,es2,es3,es4,"EIGEN ANGLE DEG");

h5 = subplot(4,2,5);

draw\_qi\_plot(h5,q1,q2,q3,q4,1,2,"Q1","Q2");

h6 = subplot(4,2,6);

draw\_qi\_plot(h6,q1,q2,q3,q4,2,3,"Q2","Q3");

h7 = subplot(4,2,7);

draw\_qi\_plot(h7,q1,q2,q3,q4,1,3,"Q1","Q3");

legend("Case 1: K=kJ^-1","Case 2: K=kI","Case 3: K=(\alpha J+\beta I)^-1","Case 4: K=kJ");

hold off

end

% plot angular velocity

function draw\_history\_q\_and\_u(t1,t2,t3,t4,q1,q2,q3,q4,u1,u2,u3,u4)

hold on

figure(1)

h1 = subplot(4,2,1);

draw\_subplot(h1,t1,t2,t3,t4,q1(:,1),q2(:,1),q3(:,1),q4(:,1),"Q1");

h2 = subplot(4,2,2);

draw\_subplot(h2,t1,t2,t3,t4,q1(:,2),q2(:,2),q3(:,2),q4(:,2),"Q2");

h3 = subplot(4,2,3);

draw\_subplot(h3,t1,t2,t3,t4,q1(:,3),q2(:,3),q3(:,3),q4(:,3),"Q3");

h4 = subplot(4,2,4);

draw\_subplot(h4,t1,t2,t3,t4,q1(:,4),q2(:,4),q3(:,4),q4(:,4),"Q4");

h5 = subplot(4,2,5);

draw\_subplot(h5,t1,t2,t3,t4,u1(:,1),u2(:,1),u3(:,1),u4(:,1),"U1 Nm");

h6 = subplot(4,2,6);

draw\_subplot(h6,t1,t2,t3,t4,u1(:,2),u2(:,2),u3(:,2),u4(:,2),"U2 Nm");

h7 = subplot(4,2,7);

draw\_subplot(h7,t1,t2,t3,t4,u1(:,3),u2(:,3),u3(:,3),u4(:,3),"U3 Nm");

legend("Case 1: K=kJ^-1","Case 2: K=kI","Case 3: K=(\alpha J+\beta I)^-1","Case 4: K=kJ");

hold off

end

function draw\_subplot(h,t1,t2,t3,t4,v1,v2,v3,v4,y\_label)

hold on

plot(t1, v1);

plot(t2, v2);

plot(t3, v3);

plot(t4, v4);

xlabel(h, "TIME (SEC)");

ylabel(h, y\_label);

hold off

end

function draw\_qi\_plot(h,q1,q2,q3,q4,xi,yi,x\_label,y\_label)

hold on

plot(q1(:,xi), q1(:,yi));

plot(q2(:,xi), q2(:,yi));

plot(q3(:,xi), q3(:,yi));

plot(q4(:,xi), q4(:,yi));

xlabel(h, x\_label);

ylabel(h, y\_label);

hold off

end

% simulation with a specificed K gain

function [t,ws,qs,us,es] = Simulation(t\_span,init\_y,K\_gain)

global K J D mu

K = K\_gain;

[t,y] = ode45(@SpacecraftDynamics,t\_span,init\_y);

ws = zeros(length(t),3);

qs = zeros(length(t),4);

us = zeros(length(t),3);

es = zeros(length(t),1);

for i = 1:length(t)

w = y(i,1:3)';

ws(i,1:3) = w(1:3);

q = y(i,4:7)';

qs(i,1:4) = q(1:4);

u = -mu\*(-skew(w))\*J\*w-D\*w-K\*q(1:3);

us(i,1:3) = u(1:3);

es(i,1) = (2\*acos(q(4)))\*(180/pi);

end

end

function dy = SpacecraftDynamics(t, y)

w = [y(1) y(2) y(3)]';

q = [y(4) y(5) y(6)]';

q4 = y(7);

global J mu D K

% dynamics with a closed-loop control

% where the control torque is

% u = -mu\*skew(w)\*J\*w-D\*w-K\*q;

dw = J^-1\*((1-mu)\*(-skew(w))\*J\*w-D\*w-K\*q);

dq = 0.5\*(-skew(w))\*q+0.5\*q4\*w;

dq4 = -0.5\*w'\*q;

dy = zeros(7,1);

dy(1:3)=dw(1:3);

dy(4:6)=dq(1:3);

dy(7) = dq4;

end