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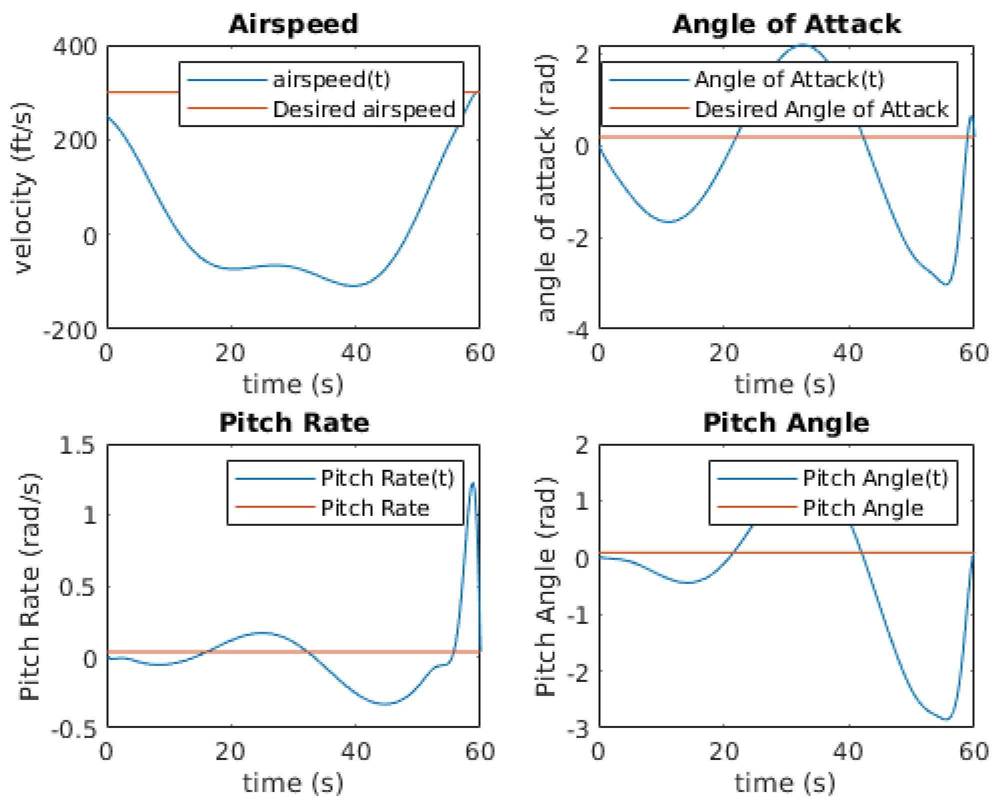
Question 6

```
A = [-0.038   18.984   0       -32.174;...
     -0.001  -0.632    1        0;...
      0        -0.759   -0.518   0;...
      0         0        1        0];

B =   [10.1       0;...
        0        -0.0086;...
        0.025    -0.011;...
        0         0];

be = B(:,2);
% a) Show that the longitudinal dynamics are completely controllable
 with
% just an elevator.

rank(ctrb(A,B(:,2)))

% b) Can you control the system from xo = [250 0 0 0]' to x60 = [300
 10 2
% 5]' with only a constant elevator input?
% x60 = expm(A60)xo + integral expm(At)*be*delta_e dt

xd = [300 10*pi/180 2*pi/180 5*pi/180]';   % Desired state after 60
 seconds
xo = [250 0 0 0]';    % Initial state at trim
z = xd - expm(A*60)*xo;
y = inv(A)*(expm(A*60)-eye(4))*B(:,2);

% c) Find a time varying delta_e to control xo to xd

% Construct the grammian
% syms t

temp = @(x) expm(A*x)*be*be'*expm(A'*x);
Wr_d = integral(temp,0,60,'ArrayValued',true)

% If xd - expm(A*60)*xo is in the range of the grammian Wr_d such
% that xd-expm(A*60)*xo = Wr_d*zeta then we can
% find a control law delta_e(t) = be'*expm(A'(60-t))*zeta that
 transforms
% xo to xd in sixy seconds.

% Find zeta
```

```
zeta = inv(Wr_d)*(xd - expm(A*60)*xo);



% d) Simulate your results from part c to verify you achieved the
 desired
% end state after 60 seconds.

[t,x] = ode45(@(t,x) aircraftDynamics(t,x,A,be,zeta),[0 60],xo);

error = norm(xd - x(end,:)')


ans =

     4


Wr_d =

    0.2460    0.0007    0.0005    0.0001
    0.0007    0.0001    0.0000    0.0001
    0.0005    0.0000    0.0001    0.0000
    0.0001    0.0001    0.0000    0.0001


error =

    0.0041


figure(1),clf;
subplot(2,2,1)
plot(t,x(:,1));
hold on
plot(t,xd(1)*ones(length(t),1));
xlabel("time (s)")
ylabel("velocity (ft/s)")
title("Airspeed")
legend("airspeed(t)","Desired airspeed")

subplot(2,2,2)
plot(t,x(:,2));
hold on
plot(t,xd(2)*ones(length(t),1));
xlabel("time (s)")
ylabel("angle of attack (rad)")
title("Angle of Attack")
legend("Angle of Attack(t)","Desired Angle of Attack")

subplot(2,2,3)
plot(t,x(:,3));
hold on
plot(t,xd(3)*ones(length(t),1));
```

```
xlabel("time (s)")
ylabel("Pitch Rate (rad/s)")
title("Pitch Rate")
legend("Pitch Rate(t)","Pitch Rate")

subplot(2,2,4)
plot(t,x(:,4));
hold on
plot(t,xd(4)*ones(length(t),1));
xlabel("time (s)")
ylabel("Pitch Angle (rad)")
title("Pitch Angle")
legend("Pitch Angle(t)","Pitch Angle")
```

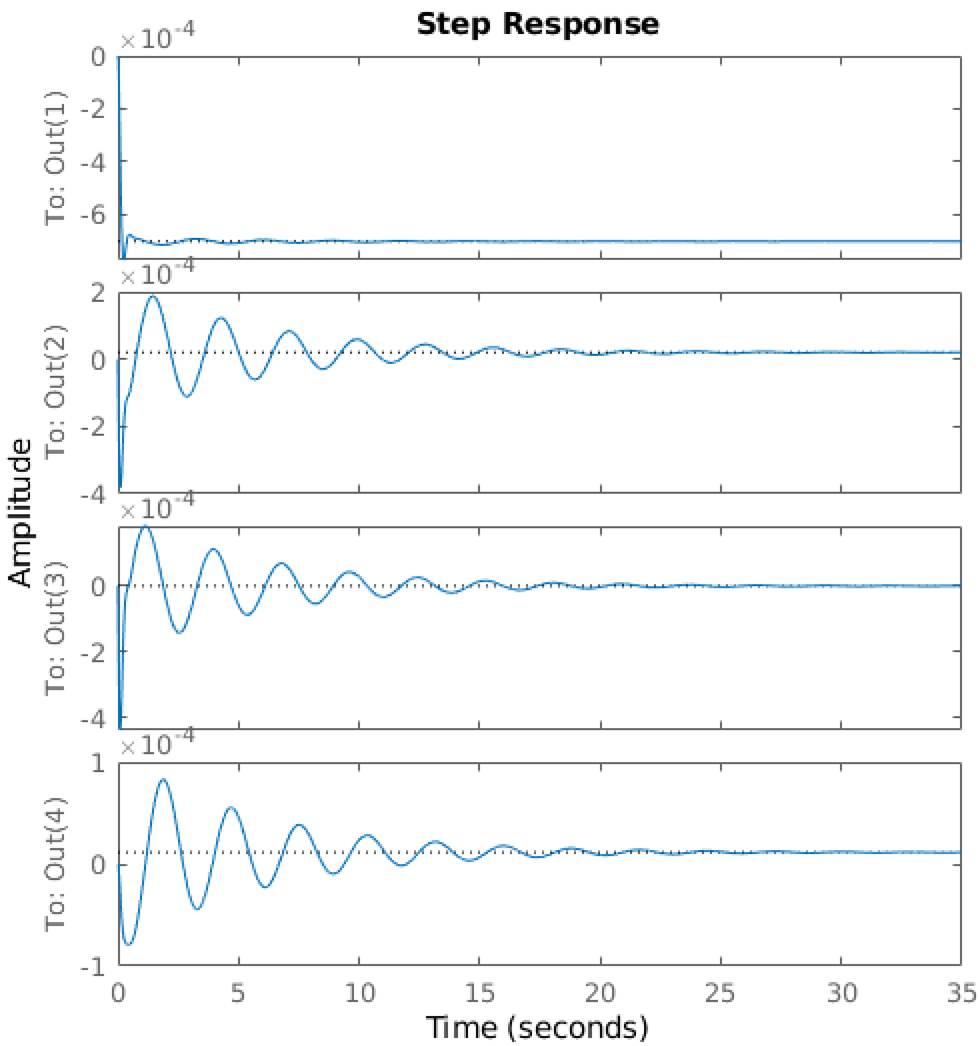


e)

```
A*xd

ans =

  -10.8944
   -0.3754
   -0.1506
    0.0349
```

Question 7

```
% Find a state feedback control u = -kx that puts the poles 15x
 further to
% the left i nthe complex plane. Pick poles that will maintain the
 original
% ratio.

lambda = eig(A);     % Get the original eigen values of A
K = place(A,B,15*lambda);

SYS = ss(A-B*K,be,eye(4),0);
figure(2)
step(SYS)
```



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