**% Cart and Pendulum**

**% main calling routine**

**X = zeros(4,1);**

**dX = zeros(4,1);**

**Ref = 1;**

**dt = 0.01;**

**t = 0;**

**m1 = 1;**

**m2 = 4;**

**R = 1;**

**Ts = 8; MOS = 0.05;**

**[Kx, Kr] = ObtainCartFeedback(m1,m2,R,Ts,MOS);**

**% Kx = [-1.0714, -78.5964, -2.5230, -12.5230];**

**% Kr = -1.0714;**

**pause;**

**U = 0;**

**y = [];**

**dim = [0.3 0.6 0.2 0.15];**

**an = annotation('textbox', dim, 'String', '', 'FitBoxToText', 'on');**

**while(t < Ts\*2)**

**U = Kr\*Ref - Kx\*X;**

**dX = CartDynamics(X, U, m1, m2, R);**

**X = X + dX \* dt;**

**t = t + dt;**

**CartDisplay(X, Ref);**

**y = [y ; X(1), X(2), Ref];**

**str = sprintf('Time = %.2f s', t);**

**an.String = str;**

**drawnow;**

**end**

**t = linspace(0,Ts\*10,length(y));**

**plot(t,y);**

**xlabel('Time (s)'); title('Nonlinear System Model: Step Response');**

**function [Kx, Kr] = ObtainCartFeedback(m1,m2,R, Ts, MOS)**

**% m1 = 1; m2 = 4; R = 1;**

**[A,B] = linearizedCartPend(m1,m2,R) %#ok<NOPRT>**

**sig = getSigForTs(Ts);**

**[zeta, th, w] = getForOS(MOS,sig); %#ok<ASGLU>**

**dom\_poles = [sig+1j\*w, sig-1j\*w];**

**des\_poles = [dom\_poles, 5\*sig, 5\*sig-1] %#ok<NOPRT>**

**C1 = [1 0 0 0]; % Position of cart**

**C2 = [0 1 0 0]; % Angle of bar**

**C = C1;**

**% olPoles = flip(eig(A));**

**[Kx,Kr] = placePoles(A,B,C,des\_poles) %#ok<NOPRT>**

**G1 = ss(A-B\*Kx, B\*Kr, C1, 0);**

**G2 = ss(A-B\*Kx, B\*Kr, C2, 0);**

**G = G1;**

**U = ss(A-B\*Kx, B\*Kr, -Kx, Kr);**

**step(G);**

**hold on;**

**step(G2);**

**step(U);**

**legend('x(t)','\theta(t)','F(t)');**

**xlabel('Time (s)'); title('Linearized System Model: Step Response');**

**hold off;**

**end**

**function [A,B] = linearizedCartPend(m1, m2, R)**

**g = 9.8;**

**A = [0 0 1 0; 0 0 0 1; 0 (-m2\*g/m1) 0 0; 0 ((m1+m2)\*g/m1) 0 0];**

**B = [0;0;1/m1;-1/(m1\*R)];**

**end**

**function [sig] = getSigForTs(Ts)**

**tau = Ts/4;**

**sig = -1/tau;**

**end**

**function [zeta, th, w] = getForOS(desired\_OS, sig)**

**MOS = @(z) exp(-pi \* (z./sqrt(1-z.^2)));**

**E = @(z) abs(MOS(z) - desired\_OS);**

**[zeta,err] = fminsearch(E, 0.5);**

**th = acosd(zeta);**

**w = abs(sig)\*tand(th);**

**end**

**function [ dX ] = CartDynamics( X, F, m1, m2, R )**

**%cart dynamics (Sp21 version)**

**% X = [x, q, dx, dq]**

**g = 9.8;**

**x = X(1); %#ok<NASGU>**

**q = X(2);**

**dx = X(3);**

**dq = X(4);**

**M = [(m1+m2) (m2\*R\*cos(q)); (m2\*R\*cos(q)) (m2\*R^2)];**

**A = [m2\*R\*dq\*dq\*sin(q); m2\*R\*g\*sin(q)];**

**B = [1;0];**

**d2X = inv(M) \* (A + B\*F); %#ok<MINV>**

**dX = [dx; dq; d2X];**

**end**

**function [] = CartDisplay(X, Ref)**

**% Cart Display**

**% ECE 463 Lecture #7**

**x = X(1);**

**q = X(2);**

**% cart**

**xc = [-0.2,0.2,0.2,-0.2,-0.2] + x;**

**yc = [0,0,0.2,0.2,0];**

**xm = x + sin(q);**

**ym = 0 + cos(q);**

**% ball**

**q = [0:0.1:1]' \* 2\*pi;**

**xb = 0.05\*cos(q) + xm;**

**yb = 0.05\*sin(q) + ym;**

**plot([-3,3],[0,0],'b-',xc,yc,'r-',[x,xm],[0,ym]+0.2,'r-',xb, 0.2+yb, 'r-',[Ref, Ref],[-0.1,0.1],'b')**

**ylim([-0.5,1.5]);**

**pause(0.01);**

**end**