Robotics Lab 1 Team Members

30 Sep 2020

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Lab 1b

Devin Dalton
21 Sep 2020

In order to generate trajectories I need to find coefficients

Identify Constraints

$x_1(0)$	$\dot{x}_1(0)$	$\ddot{x}_1(0)$	$x_1(t_1)$	$\dot{x}_1(t_1)$	$\ddot{x}_1(t_1)$	$x_2(t_1)$	$\dot{x}_2(t_1)$	$\ddot{x}_2(t_1)$
X_1	0		X_2	$\dot{x}_2(t_1)$	$\ddot{x}_2(t_1)$	X_2		

$x_2(t_2)$	$\dot{x}_2(t_2)$	$\ddot{x}_2(t_2)$
X_3	0	

8 constraints → 2 cubic polynomials

$x_1(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 = X_1$

$\dot{x}_1(t) = a_1 + 2a_2 t + 3a_3 t^2$

$\ddot{x}_1(t) = 2a_2 + 6a_3 t$

$x_2(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3 = b_0 + b_1(t-t_1) + b_2(t-t_1)^2 + b_3(t-t_1)^3$

$\dot{x}_2(t) = b_1 + 2b_2 t + 3b_3 t^2 = b_1 + 2b_2(t-t_1) + 3b_3(t-t_1)^2$

$\ddot{x}_2(t) = 2b_2 + 6b_3 t = 2b_2 + 6b_3(t-t_1)$

Apply constraints

~~$x_1(0) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 = X_1$~~

eq 1 $\quad x(0) = a_0 = X_1$

eq 2 $\quad \dot{x}(0) = a_1 = 0$

eq 3 $\quad x_1(t_1) = X_1 + a_2 t_1^2 + a_3 t_1^3 = X_2 = b_0$

eq 4 $\quad x_2(t_1) = b_0 = X_2$

eq 5 $\quad \dot{x}_2(t_1) = \dot{x}_1(t_1) = \cancel{a_1} + 2a_2 t_1 + 3a_3 t_1^2 = b_1$

eq 6 $\quad \ddot{x}_1(t_1) = \ddot{x}_2(t_1) = 2a_2 + 6a_3 t_1 = 2b_2$

eq 7 $\quad x_2(t_2) = \cancel{b_0}\ X_2 + b_1(t_2-t_1) + b_2(t_2-t_1)^2 + b_3(t_2-t_1)^3 = X_3$

eq 8 $\quad \dot{x}_2(t_2) = b_1 + 2b_2(t_2-t_1) + 3b_3(t_2-t_1)^2 = 0$

eqs : 5 unknowns $(a_2, a_3, b_1, b_2, b_3)$

Solve eq 3 for a_2: $a_2 = \dfrac{x_2 - x_1 - a_3 t_1^3}{t_1^2} = \dfrac{x_2 - x_1}{t_1^2} - a_3 t_1$

$$\boxed{a_2 = c_1 - a_3 t_1}$$

($\dfrac{x_2 - x_1}{t_1^2}$ is just a number for ease of calc's I will create a new constant term

$c_1 = \dfrac{x_2 - x_1}{t_1^2}$)

Solve eq 5 for a_3

$$2a_2 t_1 + 3a_3 t_1^2 = b_1$$

$$2t_1(c_1 - a_3 t_1) + 3a_3 t_1^2 = b_1$$

$$2t_1 c_1 - 2a_3 t_1^2 + 3a_3 t_1^2 = b_1$$

$$2t_1 c_1 + a_3 t_1^2 = b_1 \qquad a_3 = \frac{b_1 - 2t_1 c_1}{t_1^2} = \frac{b_1}{t_1^2} - \frac{2t_1 c_1}{t_1^2} = \frac{b_1}{t_1^2} - \frac{2c_1}{t_1}$$

$$\boxed{a_3 = \frac{b_1}{t_1^2} - c_2}$$

($c_2 = \dfrac{2c_1}{t_1}$)

put a_2 in terms of b_1

$$a_2 = c_1 - \left(\frac{b_1}{t_1^2} - c_2\right)t_1 = c_1 - \frac{b_1}{t_1} + t_1 c_2 = -\frac{b_1}{t_1} + t_1 c_2 + c_1$$

$$\boxed{a_2 = c_3 - \frac{b_1}{t_1}}$$

($c_3 = t_1 c_2 + c_1$)

b_2 in terms of b_1 from eq 6

$$b_2 = c_3 - \frac{b_1}{t_1} + 3\left(\frac{b_1}{t_1^2} - c_2\right)t_1 = c_3 - \frac{b_1}{t_1} + \frac{3b_1}{t_1} - 3c_2 t_1$$

$$= \frac{2b_1}{t_1} + c_3 - 3c_2 t_1$$

($c_4 = c_3 - 3c_2 t_1$)

$$\boxed{= \frac{2b_1}{t_1} + c_4 = b_2}$$

$b_3(b_1)$ from eq 7: $\quad t_2 - t_1 = t_m$

$$x_2 + b_1 t_m + \left(\frac{2b_1}{t_1} + c_4\right)t_m^2 + b_3 t_m^3 = x_3$$

$$x_2 + b_1 t_m + \frac{2b_1 t_m^2}{t_1} + c_4 t_m^2 + b_3 t_m^3 = x_3$$

$$b_3 = \left\{x_3 - x_2 - b_1\left(t_m + \frac{2t_m^2}{t_1}\right) - c_4 t_m^2\right\}\frac{1}{t_m^3}$$

$$= \frac{x_3 - x_2}{t_m^3} - b_1\left(\frac{1}{t_m^2} + \frac{2}{t_m t_1}\right) - \frac{c_4}{t_m}$$

$$c_5 = \frac{1}{t_m^2} - \frac{2}{t_m t_1}$$

$$b_3 = \frac{x_3 - x_2}{t_m^3} - \frac{c_4}{t_m} - b_1 c_5$$

$$\frac{x_3 - x_2}{t_m^3} - \frac{c_4}{t_m} = c_6$$

$$\boxed{b_3 = c_6 - b_1 c_5}$$

find b_1 from eq 8

$$b_1 + 2\left(\frac{2b_1}{t_1} + c_4\right)t_m + 3t_m^2(c_6 - b_1 c_5) = 0$$

$$b_1 + \frac{4b_1 t_m}{t_1} + 2c_4 t_m + 3t_m^2 c_6 - 3t_m^2 b_1 c_5 = 0$$

$$b_1\left(1 + \frac{4t_m}{t_1} - 3t_m^2 c_5\right) = -2c_4 t_m - 3t_m^2 c_6$$

$$b_1 = \frac{-2c_4 t_m - 3t_m^2 c_6}{1 + \frac{4t_m}{t_1} - 3t_m^2 c_5} = c_7$$

$$b_3 = c_6 - c_7 c_5$$

$$b_2 = \frac{2c_7}{t_1} + c_4$$

$$a_3 = \cancel{c_3 - \frac{c_7}{t_1}} \quad \frac{c_7}{t_1^2} - c_2$$

$$a_2 = c_3 - \frac{c_7}{t_1}$$

Table of Contents


```
%  Devin Dalton, Ryan Dalby, Iain Lee, Bao Thach
%  Robotics Lab 1 Trajectories
%  21 Sep 2020

% This program will take the provided starting mid and final position
% along with the given constraints for a 7 actuator robotic arm to
% create a spliced polynomial and find the position as a function of
 time

clear all
clc
close all
```

Define given starting, mid, and end position for each actuator

```
% Uppercut Punch
x1p = [-2.75771,0.879738,-0.203636,0.867466,-0.5184,-0.02646,3.04725];
x2p = [-3.0323,1.3127,-0.859796,0.333257,0.234699,1.03275,3.04725];
x3p =
 [-2.75771,0.879738,-0.203636,0.867466,-0.518486,-0.0264612,3.04725];

% Jab
x1j = [-1.94854,2.14566,0.233549,1.01856,0.552617,0.595568,3.04687];
x2j = [-2.45552,0.576393,-0.466714,0.132306,2.71285,0.137291,2.94601];
x3j = [-1.94854,2.14566,0.233549,1.01856,0.552617,0.595568,3.04687];
```

Define Time Variables

```
tf = 5 ;
t1 = tf/2;
tm = tf - t1;
```

Define Coefficients based off of solved spliced polynomial

```
% Initialize variables
c1p = zeros(1,7);
```

```
c1j = zeros(1,7);
c2p = zeros(1,7);
c2j = zeros(1,7);
c3p = zeros(1,7);
c3j = zeros(1,7);
c4p = zeros(1,7);
c4j = zeros(1,7);
c5p = zeros(1,7);
c5j = zeros(1,7);
c6p = zeros(1,7);
c6j = zeros(1,7);
c7p = zeros(1,7);
c7j = zeros(1,7);
a0p = zeros(1,7);
a0j = zeros(1,7);
a1p = zeros(1,7);
a1j = zeros(1,7);
a2p = zeros(1,7);
a2j = zeros(1,7);
a3p = zeros(1,7);
a3j = zeros(1,7);
bop = zeros(1,7);
b0j = zeros(1,7);
b1p = zeros(1,7);
b1j = zeros(1,7);
b2p = zeros(1,7);
b2j = zeros(1,7);
b3p = zeros(1,7);
b3j = zeros(1,7);

for i = 1:7

    % Define constants created for ease of calculations in spliced
    % polynomial
    c1p(i) = (x2p(i) - x1p(i))/t1^2;
    c1j(i) = (x2j(i) - x1j(i))/t1^2;
    c2p(i) = 2*c1p(i)/t1;
    c2j(i) = 2*c1j(i)/t1;
    c3p(i) = t1*c2p(i) + c1p(i);
    c3j(i) = t1*c2j(i) + c1j(i);
    c4p(i) = c3p(i) - 3*t1*c2p(i);
    c4j(i) = c3j(i) - 3*t1*c2j(i);
    c5p(i) = (1/tm^2) - 2/(tm*t1);
    c5j(i) = (1/tm^2) - 2/(tm*t1);
    c6p(i) = (x3p(i) - x2p(i))/tm^3-c4p(i)/tm;
    c6j(i) = (x3j(i) - x2j(i))/tm^3-c4j(i)/tm;
    c7p(i) = (-2*c4p(i)*tm-3*tm^2*c6p(i))/(1+(4*tm/t1)-3*tm^2*c5p(i));
    c7j(i) = (-2*c4j(i)*tm-3*tm^2*c6j(i))/(1+(4*tm/t1)-3*tm^2*c5j(i));

    % Define Polynomial Coefficients
    a0p(i) = x1p(i);
    a0j(i) = x1j(i);
    a2p(i) = c3p(i) - c7p(i)/t1;
    a2j(i) = c3j(i) - c7j(i)/t1;
```

```
        a3p(i) = c7p(i)/t1^2 - c2p(i);
        a3j(i) = c7j(i)/t1^2 - c2j(i);
        b0p(i) = x2p(i);
        b0j(i) = x2j(i);
        b1p(i) = c7p(i);
        b1j(i) = c7j(i);
        b2p(i) = 2*c7p(i)/t1+c4p(i);
        b2j(i) = 2*c7j(i)/t1+c4j(i);
        b3p(i) = c6p(i) - c7p(i)*c5p(i);
        b3j(i) = c6j(i) - c7j(i)*c5j(i);

    end
```

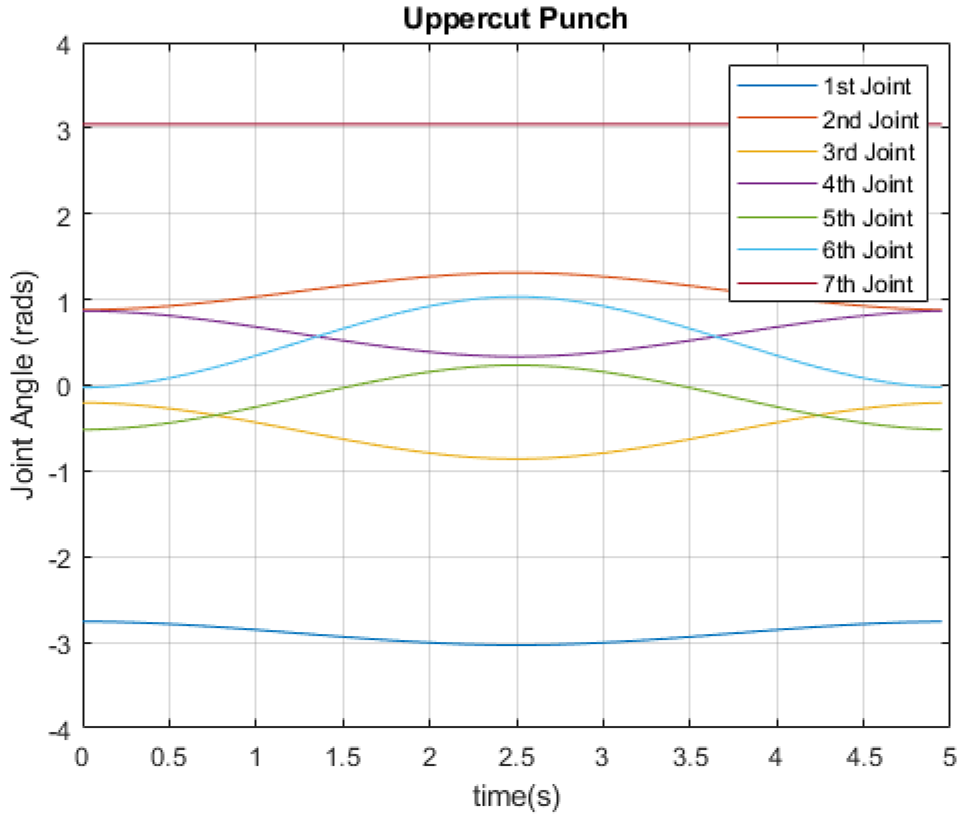
Define time intervals and calculate position at each time step

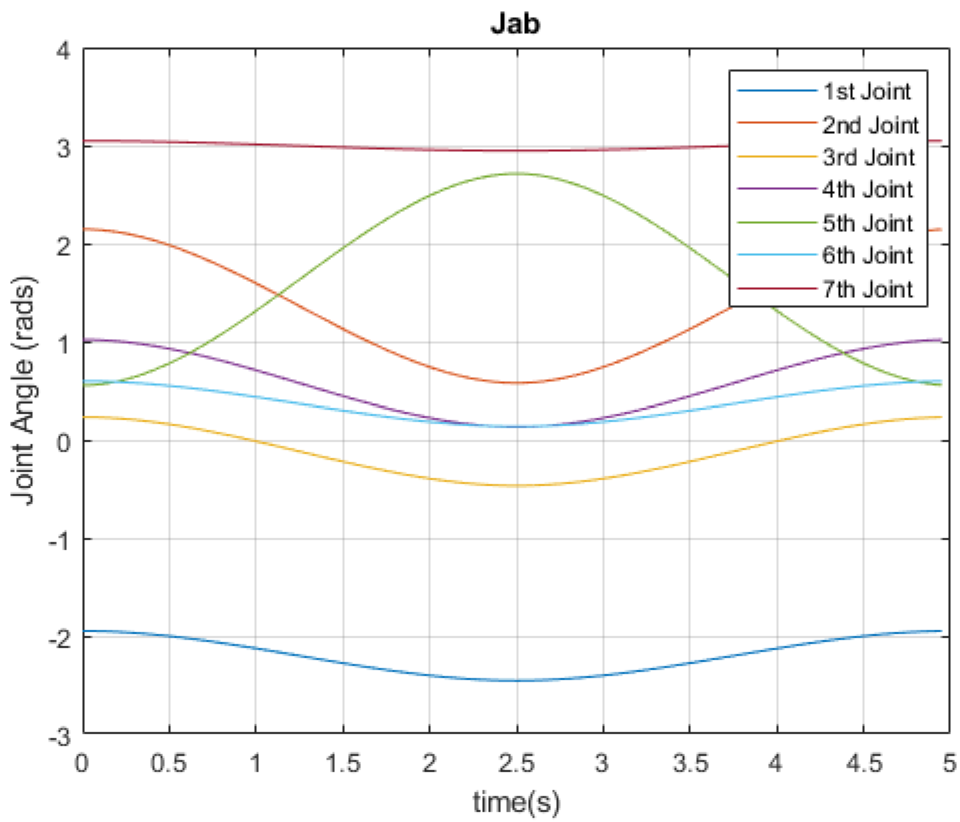
```
num_time_intervals = 100;
dt = tf/num_time_intervals;
t = 0:dt:tf;

xp = zeros(num_time_intervals,7);
xj = zeros(num_time_intervals,7);
for i = 1:7
    for j = 1:num_time_intervals
        if t(j) < t1
            xp(j,i) = a0p(i) + a1p(i)*t(j) + a2p(i)*t(j)^2 +
 a3p(i)*t(j)^3;
            xj(j,i) = a0j(i) + a1j(i)*t(j) + a2j(i)*t(j)^2 +
 a3j(i)*t(j)^3;
        else
            xp(j,i) = b0p(i) + b1p(i)*(t(j) - t1) + b2p(i)*(t(j) -
 t1)^2 + b3p(i)*(t(j) - t1)^3;
            xj(j,i) = b0j(i) + b1j(i)*(t(j) - t1) + b2j(i)*(t(j) -
 t1)^2 + b3j(i)*(t(j) - t1)^3;
        end
    end
end
```

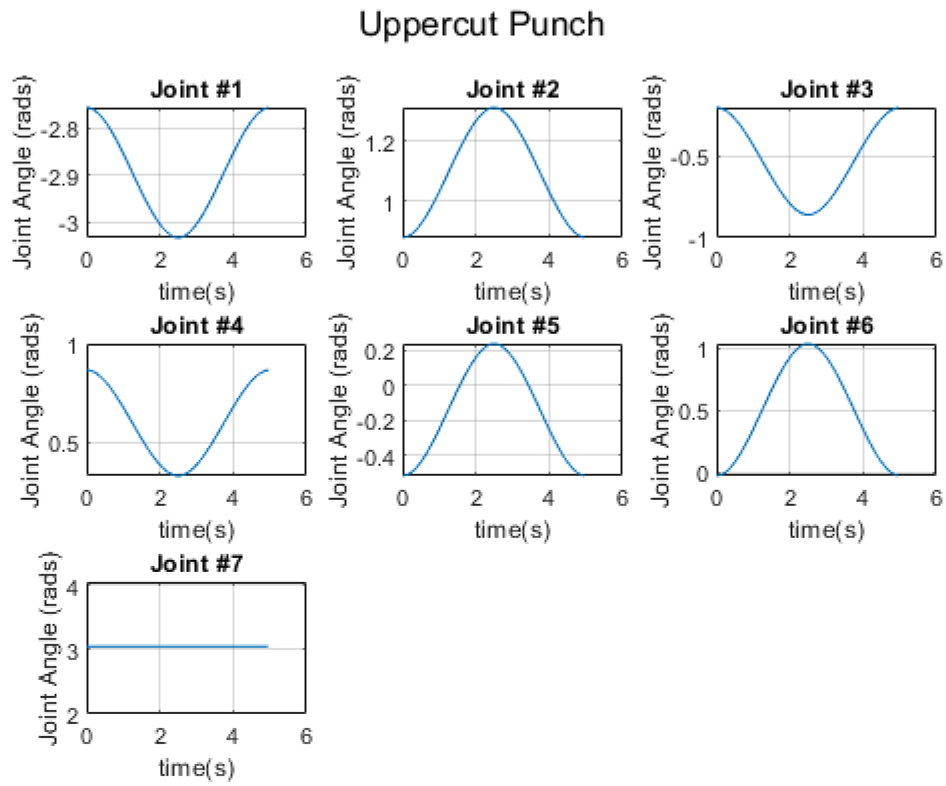
Create plots of spline functions

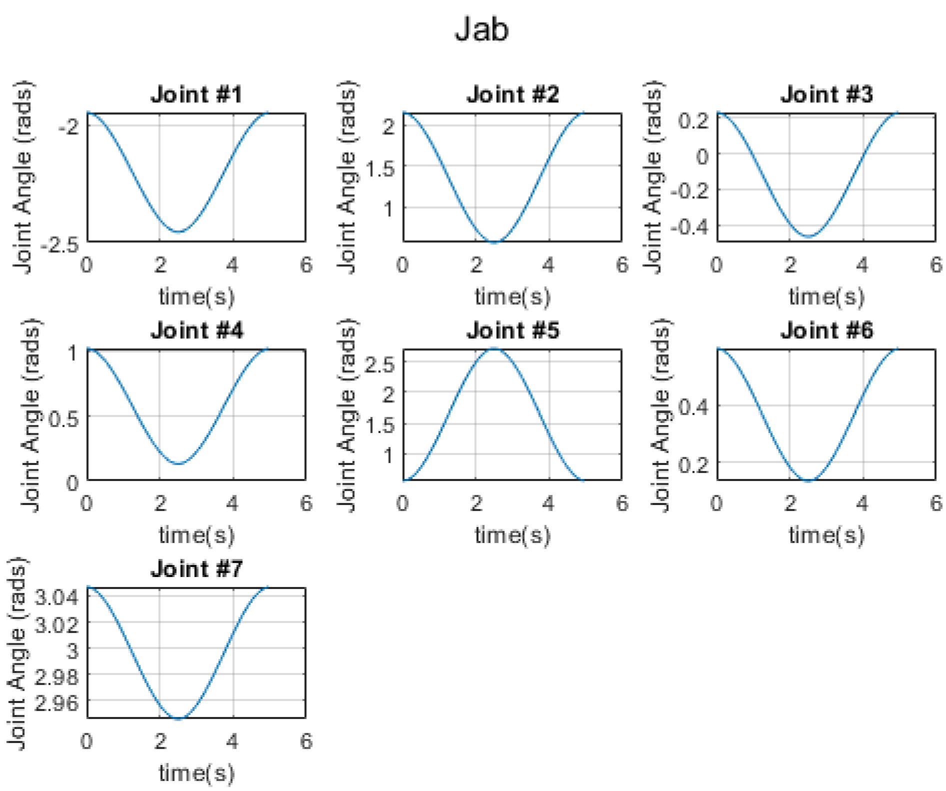
```
for k = 1:7
    plot(t(1:num_time_intervals),xp(:,k));
    hold on
    grid on
    title('Uppercut Punch')
    xlabel('time(s)')
    ylabel('Joint Angle (rads)')
    if k == 7
        legend('1st Joint','2nd Joint','3rd Joint','4th Joint','5th
 Joint'...
               ,'6th Joint','7th Joint')
    end
```

```
    %given = [x1p(k),x2p(k),x3p(k);0,t1,tf];
    %plot(given(2,:),given(1,:));
end

figure
for k = 1:7
    plot(t(1:num_time_intervals),xj(:,k));
    hold on
    grid on
    title('Jab')
    xlabel('time(s)')
    ylabel('Joint Angle (rads)')
    if k == 7
        legend('1st Joint','2nd Joint','3rd Joint','4th Joint','5th
 Joint'...
               ,'6th Joint','7th Joint')
    end
    %given = [x1p(k),x2p(k),x3p(k);0,t1,tf];
    %plot(given(2,:),given(1,:));
end

figure
for k = 1:7
    subplot(3,3,k), plot(t(1:num_time_intervals),xp(:,k));
    hold on
    grid on
    sgtitle('Uppercut Punch')
    kstring = int2str(k);
    heading = append('Joint #', kstring);
    title(heading)
    xlabel('time(s)')
    ylabel('Joint Angle (rads)')
    %given = [x1p(k),x2p(k),x3p(k);0,t1,tf];
    %plot(given(2,:),given(1,:));
end

figure
for k = 1:7
    subplot(3,3,k), plot(t(1:num_time_intervals),xj(:,k));
    hold on
    grid on
    sgtitle('Jab')
    kstring = int2str(k);
    heading = append('Joint #', kstring);
    title(heading)
    xlabel('time(s)')
    ylabel('Joint Angle (rads)')
    %given = [x1p(k),x2p(k),x3p(k);0,t1,tf];
    %plot(given(2,:),given(1,:));
end
```


Uppercut Punch
Joint Angle (rads)
time(s)
1st Joint
2nd Joint
3rd Joint
4th Joint
5th Joint
6th Joint
7th Joint


Jab
Joint Angle (rads)
time(s)
1st Joint
2nd Joint
3rd Joint
4th Joint
5th Joint
6th Joint
7th Joint


Uppercut Punch
Joint #1
Joint #2
Joint #3
Joint #4
Joint #5
Joint #6
Joint #7
Joint Angle (rads)
time(s)


Jab
Joint #1
Joint #2
Joint #3
Joint #4
Joint #5
Joint #6
Joint #7
Joint Angle (rads)
time(s)

Create .txt file for us in the lab

```
timestep = t(2) -t(1);
dlmwrite('lab1bpunch.txt',timestep);
dlmwrite('lab1bpunch.txt',xp(:,:),'-append');
dlmwrite('lab1bjab.txt',timestep);
dlmwrite('lab1bjab.txt',xj(:,:),'-append');
```

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0.05

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