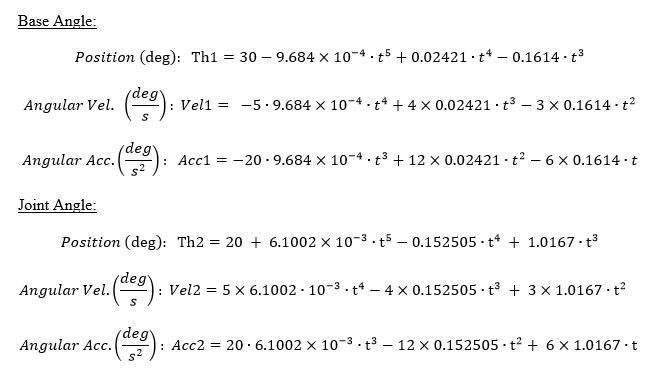
**ENED 1091 HW#4**

**Due Week of February 29th**

The following formulas will be useful for all the problems in this assignment and are taken from the 2-link robot arm problem from HW#2.



**Problem 1:**  In a script file do the following:

* Create a vector for time starting at 0, incrementing by 0.75, and ending at 9.75 seconds.
* Calculate the base angle position and joint angle position for each time using the given polynomial equations and save the results in vectors.
* Using a 2PT reverse estimate, calculate estimates for angular velocity of the base and angular velocity of the joint for each time and save the results in vectors.
* Calculate the actual angular velocities for each time using the given polynomial equations.
* Plot the estimated and actual velocities for the base and joint angles.
* Calculate the absolute value of the estimation error for each velocity (i.e., abs(Vel\_2PT – Vel)).
* Plot the absolute estimation error for the angular velocity of the base and joint angles.
* Calculate the maximum estimation error for the base angular velocity and the maximum estimation error for the joint angular velocity. Use fprintf statements to display these values.

All plots should be titled, labeled (include units), and have a legend (if appropriate).

**PLOTS OF ESTIMATED AND ACTUAL VELOCITIES (Joint and Base)**

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**PLOTS OF ABSOLUTE ESTIMATION ERROR (Joint and Base)**



**Maximum Estimation Error for Base Angular Velocity:** 0.3466

**Maximum Estimation Error for Joint Angular Velocity:** 2.1833

**PASTE MATLAB SCRIPT HERE:**

%Problem 1

t = 0:.75:9.75;

th1 = 30 - .0009684\*t.^5 + .02421\*t.^4 - .1614\*t.^3;

th2 = 20 + .0061002\*t.^5 - .152505\*t.^4 + 1.0167\*t.^3;

est\_Vth1 = zeros(1,14);

est\_Vth2 = zeros(1,14);

for k = 2:14

est\_Vth1(k) = (th1(k) - th1(k-1))/(t(k)-t(k-1));

est\_Vth2(k) = (th2(k) - th2(k-1))/(t(k)-t(k-1));

end

Vth1 = -5\*.0009684\*t.^4 + 4\*.02421\*t.^3 - 3\*.1614\*t.^2;

Vth2 = 5\*.0061002\*t.^4 - 4\*.152505\*t.^3 + 3\*1.0167\*t.^2;

err\_Vth1 = abs(est\_Vth1 - Vth1);

err\_Vth2 = abs(est\_Vth2 - Vth2);

max\_err\_Vth1 = max(err\_Vth1);

max\_err\_Vth2 = max(err\_Vth2);

figure(1)

subplot(2,1,1)

plot(t,est\_Vth1,'r\*',t,Vth1,'k\*');

xlabel('Time (s)');

ylabel('Angular Velocity (deg/s)')

title('Base Angular Velocity vs. Time');

legend('Estimate','Actual');

subplot(2,1,2)

plot(t,est\_Vth2,'b\*',t,Vth2,'k\*');

xlabel('Time (s)');

ylabel('Angular Velocity (deg/s)')

title('Joint Angular Velocity vs. Time');

legend('Estimate','Actual');

figure(2)

plot(t,err\_Vth1,'r\*',t,err\_Vth2,'b\*');

xlabel('Time (s)');

ylabel('Absolute Error')

title('Base and Joint Velocity Estimate Error');

legend('Base','Joint');

fprintf('Max error for base: %.4f\n',max\_err\_Vth1);

fprintf('Max error for joint: %.4f\n',max\_err\_Vth2);

**Problem 2:** Repeat Problem 1 to estimate the angular acceleration of the base and joint by applying the 2nd derivative estimate to the base and joint angles.

**PLOTS OF ESTIMATED AND ACTUAL ACCELERATIONS (Joint and Base)**

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**PLOTS OF ABSOLUTE ESTIMATION ERROR (Joint and Base)**



**Maximum Estimation Error for Base Angular Acceleration:** 0.2242

**Maximum Estimation Error for Joint Angular Acceleration:** 1.4126

**PASTE MATLAB SCRIPT HERE:**

%Problem 2

clear; clc; close all;

t = 0:.75:9.75;

th1 = 30 - .0009684\*t.^5 + .02421\*t.^4 - .1614\*t.^3;

th2 = 20 + .0061002\*t.^5 - .152505\*t.^4 + 1.0167\*t.^3;

est\_Ath1 = zeros(1,14);

est\_Ath2 = zeros(1,14);

for k = 2:13

est\_Ath1(k) = (th1(k+1) - 2\*th1(k) + th1(k-1))/((t(k)-t(k-1))^2);

est\_Ath2(k) = (th2(k+1) - 2\*th2(k) + th2(k-1))/((t(k)-t(k-1))^2);

end

Ath1 = -20\*.0009684\*t.^3 + 12\*.02421\*t.^2 - 6\*.1614\*t;

Ath2 = 20\*.0061002\*t.^3 - 12\*.152505\*t.^2 + 6\*1.0167\*t;

err\_Ath1 = abs(est\_Ath1 - Ath1);

err\_Ath2 = abs(est\_Ath2 - Ath2);

max\_err\_Ath1 = max(err\_Ath1);

max\_err\_Ath2 = max(err\_Ath2);

figure(1)

subplot(2,1,1)

plot(t,est\_Ath1,'r\*',t,Ath1,'k\*');

xlabel('Time (s)');

ylabel('Angular Acceleration (deg/s^2)')

title('Base Angular Acceleration vs. Time');

legend('Estimate','Actual');

subplot(2,1,2)

plot(t,est\_Ath2,'b\*',t,Ath2,'k\*');

xlabel('Time (s)');

ylabel('Angular Acceleration (deg/s^2)')

title('Joint Angular Acceleration vs. Time');

legend('Estimate','Actual');

figure(2)

plot(t,err\_Ath1,'r\*',t,err\_Ath2,'b\*');

xlabel('Time (s)');

ylabel('Absolute Error')

title('Base and Joint Acceleration Estimate Error');

legend('Base','Joint');

fprintf('Max error for base: %.4f\n',max\_err\_Ath1);

fprintf('Max error for joint: %.4f\n',max\_err\_Ath2);

**Problem 3:** The results in Problems 1 and 2 indicate that the largest estimation error occurs with joint angle. Find the largest acceptable DeltaT ***(within two places behind the decimal point***) that ensures that the maximum angular velocity estimation error will be less than 1 deg/sec.

**DeltaT =** .33

**Include your code and/or explanation of how you arrived at this value for DeltaT:**

%Problem 3

clear; clc; close all;

dt = .75;

err\_Vth2 = 1;

while max(err\_Vth2) >= 1

t = 0:dt:9.75;

th2 = 20 + .0061002\*t.^5 - .152505\*t.^4 + 1.0167\*t.^3;

est\_Vth2 = zeros(1,14);

for k = 2:length(t)

est\_Vth2(k) = (th2(k) - th2(k-1))/dt;

end

Vth2 = 5\*.0061002\*t.^4 - 4\*.152505\*t.^3 + 3\*1.0167\*t.^2;

err\_Vth2 = abs(est\_Vth2 - Vth2);

dt = dt - .01;

end

disp(dt);

**Problem 4:** This problem is designed to illustrate the effect of noise on derivative estimates. In some cases, a seemingly small amount a noise can be greatly amplified when taking derivatives of a noisy signal. As an example, consider the following signal: 0.01sin(1000t). The signal has a very small amplitude of 0.01. What happen when we take a derivative of this signal? Suddenly the amplitude grows by a factor of 1000 to an amplitude of 10! A 2nd derivative causes the amplitude to grow by a factor of 1 million to an amplitude 10,000!

For this problem, you need the data file, HW4.mat, posted on the Blackboard metasite with Homework #4. The MATLAB command: load HW4 will load the data into the MATLAB workspace. The data file has 2 vectors:

* t is a vector of times (seconds) starting at 0, incrementing by 0.34, and ending at 9.86 s.
* Th2\_n is a vector of noisy angular position measurements of the joint angle (deg) taken at the times in vector t.

1. Calculate the actual joint angular position at the times in vector t using the equation given at the beginning of this assignment. On the same plot, plot the actual angular position and the noisy angular position measurements.

**PLOT of Actual Joint Angle and the Sensor Measurements:**



**Do the measurements look very noisy to you?**

No, the measurements look quite accurate.

1. Using the noisy angular joint position measurements, calculate a 2 PT reverse estimate of the angular velocity. Plot the estimates on the same graph as the actual joint angular velocity.

**PLOT of Angular Velocity Estimate vs. Actual Angular Velocity:**



**Comment on the Accuracy of the Estimates:**

This estimated velocity data is definitely much noisier than the position data.

1. Using the noisy angular joint position measurements, calculate an estimate of the angular acceleration of the joint. Plot the estimates on the same graph s the actual joint angular acceleration.

**PLOT of Angular Acceleration Estimate vs. Actual Angular Acceleration:**



**Comment on the Accuracy of the Estimates:**

This data is not really even possible to analyze; the noise is clearly a major factor at this level.

**PASTE MATLAB CODE FOR PARTS (a) – (c):**

%Problem 4

clear; clc; close all;

load HW4.mat;

th2 = 20 + .0061002\*t.^5 - .152505\*t.^4 + 1.0167\*t.^3;

Vth2 = 5\*.0061002\*t.^4 - 4\*.152505\*t.^3 + 3\*1.0167\*t.^2;

Ath2 = 20\*.0061002\*t.^3 - 12\*.152505\*t.^2 + 6\*1.0167\*t;

est\_Vth2 = zeros(1,length(t));

est\_Ath2 = zeros(1,length(t));

for k = 2:length(t)

est\_Vth2(k) = (Th2\_n(k) - Th2\_n(k-1))/(t(k)-t(k-1));

end

for k = 2:length(t)-1

est\_Ath2(k) = (Th2\_n(k+1) - 2\*Th2\_n(k) + Th2\_n(k-1))/((t(k)-t(k-1))^2);

end

figure(1)

plot(t,Th2\_n,'r\*',t,th2,'k\*');

xlabel('Time (s)');

ylabel('Angular Position (deg)');

title('Angular Postion vs. Time');

legend('Sensor','Actual');

figure(2)

plot(t,est\_Vth2,'r\*',t,Vth2,'k\*');

xlabel('Time (s)');

ylabel('Angular Velocity (deg/s)');

title('Angular Velocity vs. Time');

figure(3)

plot(t,est\_Ath2,'r\*',t,Ath2,'k\*');

xlabel('Time (s)');

ylabel('Angular Acceleration (deg/s^2)');

title('Angular Acceleration vs. Time');

legend('Sensor','Actual');

1. What have you learned from this problem?

When dealing with certain data sets, derivative estimates may not be accurate in the slightest even though the raw data looks good. It is important to use some caution when dealing with potentially noisy data.