ECE 376 - Homework #11

z-Transforms and Digital Filters.   Due Monday, November 20th

Please email to jacob.glower@ndsu.edu, or submit as a hard copy, or submit on BlackBoard

1) Assume X and Y are related by the following transfer function

$$Y = \left(\frac{3s+6}{(s^2+10s+30)}\right)X$$

a) What is the differential equation relating X and Y?

b) Find y(t) assuming

$$x(t) = 6 + 5\sin(4t)$$

2) Assume X and Y are related by the following transfer function

$$Y = \left(\frac{0.1(z+1)}{(z-0.9)(z-0.8)}\right)X$$

a) What is the difference equation relating X and Y?

b) Find y(t) assuming a sampling rate of T = 0.01 second

$$x(t) = 6 + 5\sin(4t)$$

3) Assume G(s) is a low-pass filter with real poles:

$$G(s) = \left(\frac{2000}{(s+5)(s+10)(s+20)}\right)$$

3) Design a digital filter, G(z), which has approximately the same gain vs. frequency as G(s). Assume a sampling rate of T = 0.01 second.

Plot the gain vs. frequency for both filters from 0 to 50 rad/sec.

4) Assume G(s) is the following band-pass filter:

$$G(s) = \left(\frac{30s}{(s+3+j10)(s+3-j10)}\right)$$

Design a digital filter, G(z), which has approximately the same gain vs. frequency as G(s). Assume a sampling rate of T = 0.01 second.

Plot the gain vs. frequency for both filters from 0 to 50 rad/sec.

5) Write a C program to implement the digital filter, G(z)

Filters & Range Measurement

6) Collect 1000 range measurements using your ultrasonic range sensor (from homework #10).
   - Plot the raw data (Matlab recommended)

7) For your raw data, compute
   - The mean and standard devation
   - The 90% confidence interval for your data.

8) Filter your data with a median filter to remove glitches

In Matlab:

```
DATA = raw data (1000x1 array)
D2 = DATA;
for n=2:length(DATA)-1
   Y = sort(DATA(n-1:n+1));
   D2(n) = Y(2);
   end
k = [1:length(D2)]';
plot(k,D2);
```

For the filtered data,

- Plot the data (D2)
- Compute the mean and standard deviation of D2
- Compute the 90% confidence interval of D2

9) Filter your data with a FIR filter (average of the last five data points). In Matlab:

```
D3 = D2;
for n=5:length(D2)
   D3(n) = mean(D2(n-4:n));
   end
k = [1:length(D3)]';
plot(k,D3);
```

For the filtered data,

- Plot the data (D3)
- Compute the mean and standard deviation of D3
- Compute the 90% confidence interval of D3

10) Filter your data with a IIR filter (2nd-order Butterworth low-pass filter). In Matlab:

$$Y = \left(\frac{4}{s^2+4s+4}\right)X$$ s-plane, poles at $s = -2 \pm j2$

$$Y = \left(\frac{0.0008}{z^2-1.9600z+0.9608}\right)X$$ same filter in the z-plane with T = 10ms

For the filtered data (y), determine

- The mean of y
- The standard deviation of y
- The 90% confidence interval for the next value of y

Also plot the filtered data, y(k)

```
x = D2;
y(1:2) = mean(x);
for k=3:1000
    y(k) = 1.9600*y(k-1)-0.9608*y(k-2)+0.0008*x(k-2);
    end
k = [1:1000]';
plot(k,y)
```

note: You can do a lot better than just taking the average of the last five data points.