ELCE 705 Digital Signal Processing

Simulation Project 2

Due date: Oct. 10, 7:00 pm.
Report should be submitted via UMMoodle.

MATLAB hints:

- Use function ***stem*** to plot discrete-time signals and use function ***plot*** to plot continuous-time signals. Other useful plotting functions may include ***plot, subplot, hold on, axis, xlabel, ylabel, title.***
- When more than one signal is shown in the figure, please use different colors and symbols to distinguish them.

Problem 1: Linear Constant Coefficient Difference Equations

A causal system is given by:
y[n]-0.4y[n-1]+0.75y[n-2]+0.2y[n-3] = 2.2403x[n] +2.4908x[n-1]+2.2403x[n-2]

The impulse response of the causal discrete-time system can be calculated by matlab function ***impz***, as following:

```
num=[2.2403 2.4908 2.2403];
den=[1 -0.4 0.75];
h =impz(num, den, N);     % compute N samples of the impulse response
```

The following program can be used to calculate the output y[n]:

```
num=[2.2403 2.4908 2.2403];
den=[1 -0.4 0.75];
ic=[0 0 0]; %set zero initial conditions, number of zero is determined by the order of the difference equation
y=filter(num, den, x, ic);     % x is the input sequence
```

(a) Calculate the output of the discrete-time system by using matlab function ***filter***, when input x_1[n] =cos(2*pi*0.1*n) for n=0~30. Show the input and output sequences in your report.

(b) Calculate the impulse response h[n] with the length of 10, 20 and 30 samples respectively, by matlab function ***impz***. Show them in the report and compare the results.

(c) Using matlab function ***conv*** to calculate the convolution sum of x_1[n] and the h[n] to get the output of the given system. Use the three h[n] obtained in part (b) respectively. Show the results in your report and compare them. Comparison with the result obtained in part (a) is also necessary. Comments on your result.

Problem 2: FIR system

A causal system is given by:

y[n] = 0.9x[n] -0.45x[n-1]+0.35x[n-2]+0.002x[n-3]

(a) Calculate the output of the discrete-time system by using matlab function ***filter***, when input $x_1[n]$ =cos(2*pi*0.1*n) for n=0~30. Show the input and output sequences in your report.

(b) Generate the impulse response h[n] of the given causal LTI system and provide the results in your report. In this case, the parameter N is not necessary for using the function ***impz***. Could you explain why? Is the given system a stable system and why? Please provide your answer in the report.

(c) Using matlab function ***conv*** to calculate the convolution sum of $x_1[n]$ and h[n], compare the results with that obtained in part (a).

Problem 3: DTFT Computation

The DTFT of a sequence x[n] of the form of Eq. (1) can be computed easily by using the Matlab function **freqz**.

$$X(e^{j\omega}) = \frac{b_0 + b_1 e^{-j\omega} + \cdots + b_M e^{-j\omega M}}{a_0 + a_1 e^{-j\omega} + \cdots + a_N e^{-j\omega N}} \tag{1}$$

There are several methods to use the function freqz, one example is given as follows:

```
w= - pi:0.01 : pi;    % Assign the frequency spectrum range and step size
h=freqz(num,den,w);
```

(a) Using Matlab function ***freqz*** to obtain the discrete-time Fourier transform of Eq. (1). Show its real part, imaginary part, magnitude response and phase response in the range - 2π≤ ω ≤2π in the report.

$$X(e^{j\omega}) = \frac{0.0181 + 0.0543 e^{-j\omega} + 0.0543 e^{-j2\omega} + 0.0181 e^{-j3\omega}}{1 - 1.76 e^{-j\omega} + 1.1829 e^{-j2\omega} - 0.2781 e^{-j3\omega}} \tag{1}$$

Is the DTFT a periodic function of ω? If it is, what is the period? Explain the type of symmetries exhibited by the four figures.

(b) Modify your program to evaluate the DTFT of the following finite-length sequence:

g[n]= [0.1170 0.4132 0.7500 0.9698 0.9698 0.7500 0.4132 0.1170];

Draw its real part, imaginary part, magnitude response and phase response in the range - π≤ ω ≤ π. Is there any difference in the phase response of (b) and (a)?

Hints: You can use h=freqz(num, den, w) to obtain the DTFT, then use matlab function ***real, imag, abs, angle*** to draw the required figures. Other method to get the

DTFT of the given sequence is also acceptable.

Problem 4: z-transform

(a) Draw the real part, imaginary part, magnitude and phase response of the following z-transform when its value is evaluated on the unit circle.

$$H(z) = \frac{2 + 5z^{-1} + 9z^{-2} + 5z^{-3} + 3z^{-4}}{5 + 45z^{-1} + 2z^{-2} + z^{-3} + z^{-4}} \qquad (1)$$

(b) Computer the poles and zeros of the z-transform in (1). Express (1) in factored form with the obtained poles and zeros, and generate the pole-zero plot of (1).

*The pole-zero plot of a rational z-transform H(z) can be readily obtained using the function **zplane**. There are two versions of this function. If the z-transform is given in the form of a rational function as in (1), the command to use is **zplane**(num, den) where num and den are row vectors containing the coefficients of the numerator and denominator polynomials of H(z) in ascending powers of z^{-1}. On the other hand, if the zeros and poles of H(z) are given, the command to use is **zplane**(zeros, poles) where zeros and poles are column vectors.*

*The function **tf2zp** can be used to determine the zeros and poles of a rational z-transform H(z). The program statement to use is [z, p, k]=**tf2zp**(num, den) where num and den are row vectors containing the coefficients of the numerator and denominator polynomials of H(z) in ascending powers of z^{-1} and the output file contains the gain constant k and the computed zeros and poles given as column vectors z and p, respectively.*

(c) From the pole-zero plot generated in part(b), determine the number of regions of convergence (ROC) of H(z). Show explicitly all possible ROCs. Can you tell from the pole-zero plot whether or not the DTFT exits?

(d) Determine the partial fraction expansion using **residuez.**

(e) Determine the rational form of a z-transform whose zeros are at z_1=0.3, z_2=2.5, z_3=-0.2+0.4j, z_4=-0.2-0.4j; the poles are at p_1=0.5, p_2=-0.75, p_3=0.6+0.7j, p_4=0.6-0.7j; and the gain constant k is 3.9. Generate the corresponding pole-zero plot.

The reverse process of converting a z-transform given in the form of zeros, poles, and the gain constant to a rational form can be implemented using the function zp2tf. The program statement to use is [num,den]=zp2tf(z,p,k).

~~~ The End ~~~
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