

**ECE 366 Fall 2008**  
**MATLAB Mini-Project 2**  
**Due 11/21/08**

- **Office Hours for the Instructor:** 3:30-5:00 pm Monday and Wednesday in 2210 EB. If you cannot make either of these times, send an e-mail to make an appointment.
- **Office Hours for the Grader:** 1:00-3:00 pm Monday and 2:00-5:00 pm Thursday in 2226 EB.
- Include all of your MATLAB code, plots and printouts.

1. [50] In this problem, you will analyze and manipulate an audio signal in the frequency and the time domains. You are given an audio file named 'splat.mat' that contains the samples of a continuous-time audio signal sampled at 8192 Hz. The function `sound` can be used to play the signal on your computer's speaker. First load the sample audio signal by typing:

```
load splat
y=y(1:8192);
```

The function `fft` takes the sampled representation and computes the Discrete Fourier Transform, an approximation to the continuous-time Fourier transform  $Y(\omega)$  at samples of  $\omega$ .

a) [12] Type `Y=fftshift(fft(y))` to calculate the Fourier transform. You can generate a corresponding vector of frequency values by `w=[-pi:2*pi/N:pi-pi/N]*fs`, where `fs=8192` and `N=8192`. Use `w` and `Y` to plot the magnitude and the phase of the Fourier transform.

b) [12] Create a new vector `Y1` to be the complex conjugate of `Y` and compute its inverse Fourier transform to get the time domain vector, `y1` (Use `ifft`). Show analytically what happens to a signal in the time domain if you take its complex conjugate in the frequency domain. Play `y1`, what do you observe?

c) [16] Define two new signals with Fourier transforms,  $Y_2(\omega) = |Y(\omega)|$ ,  $Y_3(\omega) = e^{j\angle Y(\omega)}$ .

Demonstrate analytically that  $y_2(t)$  and  $y_3(t)$  are real signals, whenever  $y(t)$  is real.

Generate `Y2` and `Y3` in MATLAB and compute their inverse Fourier transforms `y2` and `y3`. Play both of them. Based upon the two signals you just heard, which component of the Fourier transform is more crucial for representing an audio signal: the magnitude or the phase?

d) [10] Now assume that  $y_4(t) = y(2t)$ . Show analytically the effect of sampling in the time domain on the Fourier transform. Create a vector `y4` by sampling `y` and find its Fourier transform. Play `y4`, can you explain the change in pitch by comparing the Fourier transform of `y4` with that of `y`?

2. [50] In this exercise, we will explore discrete-time convolution and obtaining impulse response from difference equations. Consider the following difference equation for a second order system:

$$y[n] - 0.9y[n-1] + 0.81y[n-2] = x[n] - x[n-2]$$

- a) [6] Find the impulse response  $h[n]$  for  $n = 0, 1, 2$  using recursion.
- b) [10] Find the impulse response  $h[n]$  using MATLAB command `filter` similar to Example C3.5 in the book. Plot the impulse response for  $n = 0:32$ .
- c) [6] Determine whether this system is stable or not using  $h[n]$  found in part c and MATLAB.
- d) [8] Use the MATLAB command `freqz` to obtain the magnitude and phase response for this system, i.e.  $|H(\Omega)|, \angle H(\Omega)$ . Determine the type of filter this system corresponds to.
- e) [10] Compute the zero-state response  $y[n]$  when the input is  $x[n] = \sin\left(\frac{\pi}{3}n\right)$  using `conv` command in MATLAB. Plot the output signal for  $n = 0:32$ .
  - i. Obtain an analytical expression for the output signal by reading the values of  $|H(\pi/3)|$  and  $\angle H(\pi/3)$  from the graph.  
Hint: When the input to a LTI system is a sinusoid, the output is also a sinusoid at the same frequency with an amplitude change and phase shift.
  - ii. Verify your answer by comparing with  $y[n]$  obtained from convolution.
  - iii. Compare the input signal to the output signal and explain the effect of the filter on the input signal's magnitude and phase.
- f) [10] Assume that the sinusoid in part e is contaminated by noise, which is modeled by a high frequency sinusoid,  $\sin\left(\frac{2\pi}{3}n\right)$  added onto the original signal. Repeat part e) for this contaminated signal.