EE 473 HW 2 (Fall 2019)

- Homework is due **October 31, Thursday!**

1: *Reading.* So far we have covered Chapters 2 and 3, and we are about to complete Chapter 4 in Oppenheim and Schafer, 2e. We will proceed fast with new material from now on. Please make sure that you keep up with the class by reading the related sections.

2: *Sine Wave and Matlab.*

a) Use Matlab to plot the continuous-time signal $x(t) = \cos(\Omega t)$ for $\Omega = 0, \pi/2, \pi, 3\pi/2, 2\pi$.

b) Use Matlab to plot the discrete-time signal $x[n] = \cos(\omega n)$ for $\omega = 0, \pi/2, \pi, 3\pi/2, 2\pi$. (Sketch these signals as a sequence of vertical lines.)

c) Comment on the signals obtained in (a) and (b) in terms of basic properties like time-frequency relationship, periodicity, etc. Are they alike?

3: *Echo Cancellation.* In this problem, you will need to load the speech file `lineup.mat` from the site
https://github.com/sharrajesh/signals-and-systems/tree/master/buck
You will work with the data stored in `y`. The speech was recorded with a sampling rate of 8192 Hz. You should hear the phrase "line up" with an echo. In fact, we should be able to model this signal (let's call it $y[n]$) as

$$y[n] = x[n] + \alpha x[n - N] \tag{1}$$

where $x[n]$ is the uncorrupted speech signal, which has been delayed by N samples and superimposed back on itself with its amplitude scaled by $\alpha < 1$. Thus, the first term on the right-hand side of eq. (1) is the line-of-sight signal captured directly by the microphone whereas the second one is an echo reflected off a wall. The echo travels a longer path before it reaches the microphone, hence the delay N. Moreover, some of its energy is absorbed by the wall, and hence the attenuation, α. For simplicity, we ignore further reflections, as well as other echo sources.

(a) Derive the impulse response of the echo system described by eq. (1).

(b) Let $N = 1000$ and $\alpha = 0.5$. Using Matlab, generate and plot the impulse response that corresponds to eq. (1) in the range $n = 0, \ldots, 1000$.

(c) Consider the echo removal system described by the difference equation

$$z[n] + \alpha z[n - N] = y[n], \tag{2}$$

where now $y[n]$ is the input and $z[n]$ is the output which has the echo removed. Does the system in eq. (2) have an infinite-length or a finite-length impulse response?

(d) Show that eq. (2) is indeed the inverse of eq. (1) by deriving the overall difference equation that relates $z[n]$ to $x[n]$. Is $z[n] = x[n]$ a valid solution to the overall difference equation?

(e) Implement the echo removal system of eq. (2) on Matlab. Plot the output in response to the speech in `lineup.mat`. When you listen to the output, do you still hear the echo, or is it gone?

(f) In Matlab, find and plot the overall impulse response of the cascaded echo system by convolving the two impulse responses. Is the result a unit impulse? If not, why not?