EE 521 Digital Signal Processors Lab

Assignment 1

12 January 2021

This assignment is the prerequisite assignment for DSP lab. Being good at Signals and Systems will be essential to complete this lab efficiently. This assignment has to be done using Python. You can also use MATLAB for this purpose, but its recommended that you use Python. Resources will be updated soon in the Slack channel. For plotting the functions you can use numpy and matplotlib. Try taking a range in which at least 3-4 periods are visible for the signals.

1. **Continuous signals** Each section will be on a single subplot. Plot the following continuous time signals:

   - **Basic signals**

     Consider the following signal with basic transformations of the form: $y(t) = Ax(Bt+C)$ where A is the amplitude scaling factor, B is the time scaling factor, C is the time shift.

     Plot the following signals: $x_1(t) = u(t)$, $x_2(t) = r(t) = tu(t)$, $x_3(t) = p(t) = \frac{t^2 u(t)}{2}$, $x_4(t) = rect(t/\tau)$, $x_5(t) = tri(t/\tau)$, $x_6(t) = sinct = \frac{\sin \pi t}{\pi t}$ where $u(t)$ is the unit impulse signal, $r(t)$ is the ramp signal, and $p(t)$ is the parabolic signal, $rect(t/\tau)$ is a rectangular pulse between $-\tau/2$ to $\tau/2$, similarly $tri(t/\tau)$ is triangular pulse from $-\tau/2$ to $\tau/2$. Also draw the amplitude scaled and time shifted versions of these 3 signals with amplitude scaling factor $A = 5$ and shift $C = 2$ sec. Finally, plot the time scaled versions of the original signals $x_1(t), x_2(t), x_3(t)$ with time scaling factor as $B = 0.5, 2$

   - **Exponentials**

     Consider the signals of the form: $x(t) = Ae^{Bt}$. Plot $x(t)$ for different values of A and B. Take $A = -5$ and 5 and B in range $[-5, -2, -0.5, -0.25, 0, 1, 2]$. Plot all possible combinations to get a taste of how exponentials behave.

- **Sinusoids**
  $x_1(t) = 5\sin 2\pi t$, $x_2(t) = 2\sin\frac{2\pi}{3}t$, $x_3(t) = 4\cos\frac{\pi}{3}t$, $x_4(t) = 3\cos(2\pi t + \frac{\pi}{3})$, $x_5(t) = x_1(t) + x_2(t)$, $x_6(t) = x_3(t) + x_4(t)$, $x_7(t) = x_1(t) + x_3(t)$, $x_8(t) = x_1(-t)$, $x_9(t) = x_3(-t)$.
- **Complex Exponentials**
  Consider the signals of form: $y(t) = Ae^{Bt}\cos\omega t$. Plot the signals, where $A = 0.1, 0.5, 1, 2$ and $b = -0.25, -0.5, -1, 0.5, 1$ and $\omega = 2\pi, \frac{\pi}{6}, \frac{5\pi}{3}$
  A special type of complex exponential is $y(t) = Ae^{st}$, where $s = \sigma + j\omega$. Consider, a phases shift introduced to the signal $y(t)$ with phase θ . The resultant signal becomes, $y(t) = Ae^{j(\omega t+\theta)}$. Plot the real and imaginary parts ($\mathrm{Re}(y(t))$ and $\mathrm{Im}(y(t))$) of the following signals, with the following parameters (A, ω, θ): $(1, 0.14\pi, 0)$, $(1, 0.14\pi, \pi)$, $(2, 0.34\pi, 0.5\pi)$, $(2, 0.75\pi, \pi/3)$.

2. **Discrete Signals**

   Plot the following signals: $x_1[n] = \delta[n]$, $x_2[n] = 3\delta[n]$, $x_3[n] = 3\delta[2n]$, $x_4[n] = 3\delta[2n-5]$, $x_5[n] = 3\delta[n^2+3n+2]$, $x_6[n] = x_1[n]+x_2[n]+x_3[n]$, $x_7[n] = \delta[n]$, $x_8[n] = \sum_{k=-\infty}^{\infty}\delta[n-k]$ (Impuse Train), $x_9[n] = \delta[n]$

   Plot the discrete counter parts of all the signals given in the Continuous Signals section. Replace $x(t)$ by $x[n]$ and plot them. You can use the discrete impulse train to sample continuous signals in intervals of 1 sec.

   The impulse function, unit step function, ramp function and parabolic function in continuous time are related by the differentiation operation. If we differentiate unit step we get impulse and so on. Is there any relation between the discrete counterparts? If yes how will you implement ramp function from parabolic function, unit step from ramp and impulse function from unit step in the discrete time domain.

   Plot an alternating discrete periodic square wave using impulse train.

3. **Systems (Time domain approach)**

   Every discrete LTI system is characterized by its impulse response. The output of a discrete LTI system in terms of the impulse response is given by the equation:

$$y[n] = x[n] * h[n] = \sum_{k=-\infty}^{\infty} x[k]h[n-k] \tag{1}$$

   This is the convolution sum. Write a function for performing convolution.

```
// Signature of Convolution.py
## Function for computing convolution of 2 sequences
def convolution(inputSeq, impulseResponse):
    inputSeq = np.array()
    impulseResponse = np.array()
    ## Do something with inputSeq and impulseResponse
    ## Both are numpy arrays or list of numbers
    .
    .
    return outputSeq
```

Use this function to calculate the output for the following system: $x[n] = 2, 4, 5, 2, 7$, $h[n] = 8, -5, 4$.

Calculate the impulse response for $y[n] = 2x[n-3]$ and find the response of the system to the following inputs: unit step function $u[n]$, ramp function $r[n]$, parabolic function $p[n]$, the complex exponential e^{sn} where $s = 2+j3$.

Plot the input signals and their responses. Plot the real and imaginary part of the response for complex exponential input. Do you see some pattern in the input and response of complex exponential signal?