Digital Signal Processing

Laboratory 2 Basic Signals

2.1 Introduction

The purpose of this lab[1] is to generate and represent basic signals in OCTAVE . The basic signals used in digital signal processing are the unit impulse, exponentials, sine waves, their generalization to complex exponentials, speech and 2-D signals.

2.2 Impulses

The (shifted) unit impulse signal is defines as:

$$\delta(n - n_0) = 1 \tag{2.1}$$

The following code will generate an impulse:

```
L = 32;
n = 0:L-1;
imp1 = zeros(L,1);
imp1(1) = 1;
```

2.2.1 EXERCISE

1. Generate and plot the following sequences. In each case the horizontal (n) axis should extend only over the range indicated and should be labelled accordingly. Plot each sequence as a discrete-time signal using **stem**.

$$\begin{aligned}
x_1(n) &= 0.9\delta(n-5) && 1 \le n \le 20 \\
x_2(n) &= 0.8\delta(n) && -15 \le n \le 15 \\
x_3(n) &= 1.5\delta(n-222) && 200 \le n \le 250 \\
x_4(n) &= 3.5\delta(n+7) && -15 \le n \le 0
\end{aligned}$$

[1] S. Burrus, etal., *Computer-Based Exercises for Signal Processing using Matlab*, Englewood Cliffs, NJ: Prentice-Hall, 1994, pp.2-8

2. The following code will produce a repetitive signal in the vector x:

```
x = [0 1 1 1 0 0]' * ones(1,7);
x = x(:);
size(x)
```

Plot x then give a mathematical formula to describe this signal.

3. The shifted impulse, $\delta(n - n_0)$, can be used to build weighted impulse train, with period P and total length MP:

$$s(n) = \sum_{l=0}^{M-1} A_l \delta(n - lP) \tag{2.2}$$

Generate and plot a periodic impulse train whose period $P = 5$ and whose length is 50. Start the signal at $n = 0$. Use vector operations rather than `for` loops. How many impulses are contained within the finite-length signal?

2.3 Sinusoids

Three parameters describe a real sinusoid: amplitude (A), frequency (ω_0), and phase (ϕ).

$$x(n) = A\cos(\omega_0 n + \phi) \tag{2.3}$$

The following code will generate 32 points of a discrete-time sinusoid:

```
n = 0:31;
sin1 = sin(n/2);
```

2.3.1 EXERCISE

1. Generate and plot the following sequences. Use OCTAVE's vector capability by taking the cosine (or sine) of a vector. In each case the horizontal (n) axis should extend only over the range indicated and should be labelled accordingly. Plot each sequence as a discrete-time signal using `stem`.

$$\begin{aligned} x_1(n) &= \sin \tfrac{\pi}{17} n & 0 &\le n \le 25 \\ x_2(n) &= \sin \tfrac{\pi}{17} n & -15 &\le n \le 25 \\ x_3(n) &= \sin(3\pi n + \tfrac{\pi}{2}) & -10 &\le n \le 10 \\ x_4(n) &= \cos\left(\tfrac{\pi}{\sqrt{23}} n\right) & 0 &\le n \le 50 \end{aligned}$$

Give a simpler formula for $x_3(n)$ that does not use trigonometric functions. Explain why $x_4(n)$ is not a periodic function.

2. Write an OCTAVE function that will generate a finite-length sinusoid. The function will need a total of five input arguments: three for the paramenters and two more to specify the first and the last n index of the finite-length signal. The function should return a column vector that contains the values of the sinusoid. Test this function by plotting the results for various input parameters. Generate the signal:

$$x_5(n) = 2\sin(\tfrac{\pi}{11}n) \qquad\qquad -20 \leq n \leq 20$$

2.4 Sampled Sinusoids

A continuous-time sinusoid is given by the following equation:

$$s(t) = A\cos(2\pi f_0 t + \phi) \tag{2.4}$$

where A is the amplitude, f_0 is the frequency, ϕ is phase. Sampling $s(t)$ at a rate of $f_s = 1/T$:

$$\begin{aligned} s(n) &= s(t)|_{t=nT} && (2.5)\\ &= A\cos(2\pi f_0 nT + \phi) && (2.6)\\ &= A\cos\left(2\pi\frac{f_0}{f_s}n + \phi\right) && (2.7) \end{aligned}$$

2.4.1 EXERCISE

Write a function that will generate samples of $s(t)$ to create a finite-length discrete-time signal. This function will require six inputs: three for the signal parameter, two for the start and stop times, and one for the sampling rate (in hertz). Set the units of start and stop times in seconds. Use this function to generate a sampled sinusoid with:

```
Amplitude = 50              Signal freq = 1200 Hz
Initial Phase = 45 deg      Sampling freq = 8 kHz
Starting time = 0 sec       Ending time = 7 millisec
```

Make two plots of the resulting signal: one as a function of time t (in milliseconds), and the other as a function of the sample index n.

2.5 Exponentials

The following function generates a discrete-time exponential signal.

```
function y = genexp(b, n0, L)
%GENEXP  generate an exponential signal: b^n
%  usage:  Y = genexp (B, N0, L)
%    B   input scalar giving ratio between terms
%    N0  starting index (interger)
%    L   length of generated signal
%    Y   output signal Y(1:L)
if( L <= 0 )
  error('GENEXP: length not positive')
end
n = n0 + [1:L]' - 1;
y = b .^ n;
end
```

2.5.1 EXERCISE

1. Use the function to plot the exponential $x(n) = (0.9)^n$ over the range $n = 0, 1, 2 \ldots 20$.
2. The exponential sequence $a^n u(n)$ can be summed over a finite range. This sum is known in closed form as:

$$\sum_{n=0}^{L-1} a^n = \frac{1-a^L}{1-a} \qquad \text{for} \qquad a \neq 1 \tag{2.8}$$

   Use the function from exercise 1 to generate an exponential, get the sum and compare the result to that using Eq. 2.8.

2.6 Speech Signals

Digital signal processing is used in processing speech with applications ranging from compression, transmission, recognition and speaker identification.

2.6.1 EXERCISE

Use `wavread` to load the file `speech1.wav` into OCTAVE . Plot the signal.

Play the signal using the function `sound`.

2.7 2-D Signals

2-D signals may be visualized as images or as 2-D surfaces.

2.7.1 EXERCISE

1. Use the `meshgrid` command to generate the 2-D signal

$$f(m,n) = 255|sinc(0.1m)sin(0.1n)|$$

   for $-50 \leq m \leq 50$ and $-50 \leq n \leq 50$. Plot the signal as a surface plot using `mesh`.

2. Plot the 2-D signal as an image using the `image` command.