Assignment 1

General Info

- The work can be done anywhere where MATLAB and the related toolboxes are available.
- A **written report** is required. The report is free form but should include results, figures, and any code you wrote, as well as discussions of what you observe.
- Reports should be submitted in **hard copy** in class on the **due date**.
- Late submissions will not be accepted.
- Better documentation and clearer discussions of your work improves our ability to fairly mark your report. Make sure your report is well structured, organized, and clear. Your report has to follow the order of questions. Give all relevant code right before the results and discussion of each part, not in an appendix.

1. Waveform Generation and Visualization

Here you will learn how to generate, plot, and add noise to 1D, discrete-time sinusoidal signals.

(a) Generate the following sequence:

$$x(n) = 2\sin\left(\frac{\pi}{17}n\right)$$

Plot the signal in a stem plot. The horizontal axis should extend over the range *-20<n<20*, and the axes should be labeled.

(b) Generate a zero-mean white Gaussian noise (WGN) sequence with variance 1. Plot the noise sequence, the signal sequence of (a), and the result of adding the two signals on the same figure (use different line types to distinguish the signals). Provide a legend on the figure describing the figure's contents.

(c) Repeat the steps in (b) but for a WGN signal of mean 0.5 and variance of 0.5. To double check, use MATLAB to calculate the variance and mean of your generated noise signal.

(d) Generate and plot the following two signals:

$$x_1(n) = \cos(0.4\pi n)$$

$$x_2(n) = \cos(0.4n)$$

Are the signals periodic (if necessary, check the signal values numerically)? Explain why/why not?

2. Sampling and Quantization

Here you will learn about the effects of sampling and quantization on 1D signals.

Consider the following continuous-time sinusoidal signal:

$$x_a(t) = \sin 2\pi F_0 t, \quad -\infty < t < \infty$$

The sampled signal is:

$$x(n) = x_a(nT) = \sin 2\pi \frac{F_0}{F_s} n, \quad -\infty < n < \infty$$

where $F_s = 1/T$ is the sampling frequency.

(a) Plot the signal $x(n)$, $0 \le n \le 99$ for F_s = 5 kHz and F_o = 0.5, 2, 3, and 4.5 kHz. Explain your observations about the different cases.

(b) Suppose that F_o = 2 kHz and F_s = 50 kHz

- Plot the signal $x(n)$. What is the frequency f_o of the signal $x(n)$?
- Plot the signal *y*(*n*) created by taking the even-numbered samples of *x*(*n*) . Is this a sinusoidal signal? Why? If so what is its frequency?

(c) Write a computer program that quantizes the signal $x(n)$ (from part (b)) into $x_q(n)$ using b bits or equivalently into $L = 2^b$ levels by using rounding. Plot the quantized signal using = 1, 2, 4 and 8 bits.

3. 2D Signal Representation, Display, and Manipulation

Here you will learn about the effects of different sampling strategies when geometrical operations are applied to images.

(a) Generate a binary valued image of a box (e.g. a l0xl0 white box centred in a 30x30 image, with the background set to black). The idea behind this is to have a small number of pixels in the image, so after performing some geometrical operation say rotation, the distortions at the edges of the box are more clear.

(b) Rotate the image by 25 and by 45 degrees, respectively. How does the result look like? Any visible artefacts?

(c) Try to improve the rotated image quality by applying the following interpolation methods: nearest neighbour, bilinear, and bicubic. Display and discuss your results while comparing the different methods. Too see the difference, make sure that the matrix type is not logical or integer.

(d) For a grey-level image of your choice, resize the image to twice the size using the three mentioned interpolation methods. Discuss and compare the results.

4. Audio Effects

Here you will learn about amplitude and frequency modulation of sound waves.

Audio effects[1] are tools to generate beautiful variations of the sounds. Example effects include echoes, tremolo, vibrato, flanging, chorus etc. In this exercise we will learn about tremolo and vibrato, two effects that sound similar but are produced in different ways.

Tremolo is defined as a change in volume at a frequency that is itself audible.[2] This effect can be simulated on MATLAB by multiplying the incoming signal by a slowly varying sinusoid (i.e. using signal modulation).

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[1] For more info, check out: http://en.wikipedia.org/wiki/Effects_unit.
[2] See example videos: https://www.youtube.com/watch?v=oOCNB1izw8A.

(a) Write a MATLAB code that generates 1 second of a 440 Hz signal with a sampling frequency of 11,025 Hz. Modulate the **amplitude** of this signal with a cosine wave of 4 Hz.
   (i) Using two horizontal subplots in one figure, plot the first 0.25 seconds of the original signal and the modulated signal (with the tremolo effect).
   (ii) Play the audio of both signals in MATLAB. Explain what you observe.
   (iii) Plot the magnitude of the frequency components of both signals (use the 'fft' and 'abs' functions in MATLAB). Explain the differences. Hint: zoom around 440 Hz.
   (iv) Load 'guitar.mat' and apply the tremolo affect using a 4 Hz cosine wave. Plot and play the audio before and after the effect is introduced.

For **vibrato**, we need to modulate the frequency of the signal (not the amplitude).

(a) For the 1 second signal at 440 Hz with sampling frequency of 11,025 Hz, write a MATLAB code to modulate the **frequency** of this signal with a sine wave at 4 Hz.
   (i) Using two horizontal subplots in one figure, plot the magnitude of the frequency components of both the original and the modulated signal (vibrato effect). Explain the differences.
   (ii) Play the audio (vibrato) in MATLAB. Explain what you observe.

5. Image Display and Colormaps

Here you will learn about the different colormaps used to display images. Run the following MATLAB code:

```
clear X map;
load('flujet','X','map');
imagesc(X);colormap(map);
axis off
```

(a) Show the image displayed in the resulting figure.
(b) What is the size of the matrices X and map?
(c) Explain what X and map contain and what they represent.
(d) Change the map matrix such that the color of the background becomes black. Display the new image with your new colormap.

<u>End of assignment 1</u>