Signals and Systems project: Convolution and audio processing

This project explores the basic applications of convolution in audio signal processing. Create a new project and load **`main.m`**. Complete each task in order to produce different audio effects such as echo and cross synthesis.

Task 1: Loading audio file

For the first part, your task is to load the audio file **`voice.wav`** and plot the signal. Notice that the audio file has 2 channels, one for each ear.

```
[audio, Fs] = audioread("voice.wav");

% TODO: Plot the audio signal

% TODO: Double the sampling rate and save the audio

audiowrite("./out_doubled.wav", audio, Fs_2);
```

Where Fs is the sampling rate. Double the sampling rate and save the audio file. Explain what happened.

Task 2: Changing volume

Now create a decreasing exponential signal (like e^{-x}) with the same length as your input signal. Then multiply them together and plot the result. At the end, save the modified audio signal.

Task 3: Simulating echo effect

In this part, your task is to create an echo filter using the properties of the convolution operator.

Recall that:

$f(t) * \delta(t) = f(t)$

$f(t) * \delta(t - T) = f(t - T)$

$f(t) * h_1(t) + f(t) * h_2(t) = f(t) * (h_1(t) + h_2(t))$

Using these properties, create a signal that when convolved with the audio, it adds to the audio 2 echoes of itself. First echo starts after a 1 second delay and with 80 percent intensity. The second one starts after a 2 second delay with 50 percent intensity.

Convolve the filter that you created with the audio and save the output.

```
first_echo_delay = 1.0;
second_echo_delay = 2.0;

first_echo_intensity = 0.8;
second_echo_intensity = 0.5;

% TODO: Create the echo filter

% TODO: Convolve with the audio and save the result
```

Task 4: Applying cross-synthesis

Cross synthesis is a technique in digital audio processing where the characteristics of one sound are imposed onto another. This technique blends the features of two distinct sounds to produce a new and unique output that often retains elements from both source sounds.

An impulse response is a record of how an acoustic or electrical system reacts to an impulse (a short, sharp sound or electrical spike). For example, the file **`concert_hall_IR.wav`**, contains the impulse response of a concert hall. This represents the characteristics of the concert hall space.

Convolving this with any audio signal, confers these characteristics onto the audio.

Load the **`concert_hall_IR.wav`** and plot the signal. Convolve it with the loaded audio and save the result.

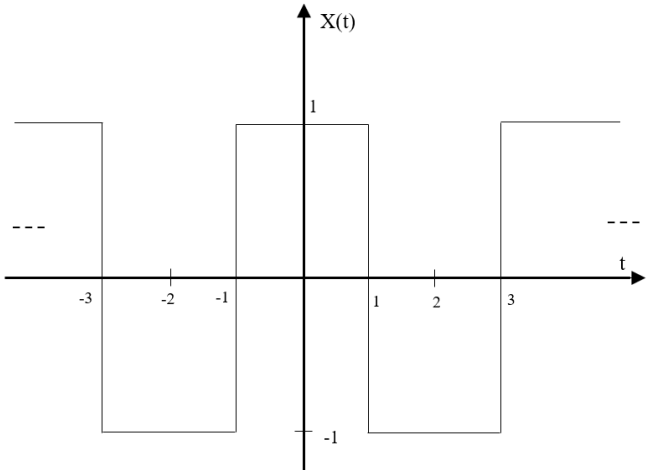
Repeat this for **`iron_bucket_IR.wav`** impulse response.

Task 5: Fourier series

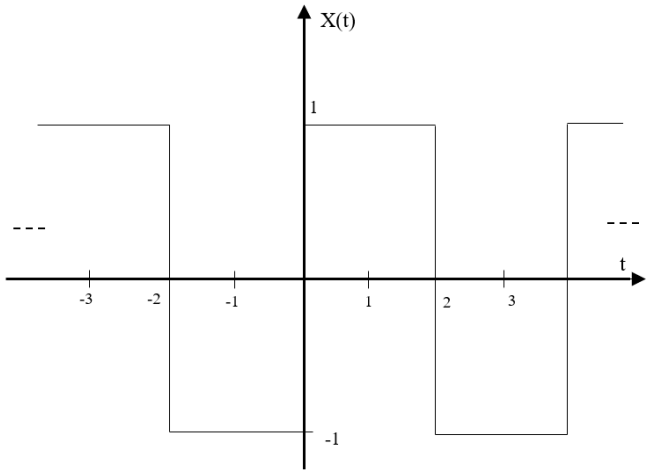
Use function `trapezoidal_rule.m` which approximates the integral of a function over a specified interval using two files called: `upper_riemann.m` & `lower_riemann.m`

Calculate the Fourier series coefficients a_k of a given $x(t)$ and then find the Fourier series for $k \in$ [−20 20], [−100 100] and [−500 500] harmonics.

What happens when you increase the number of harmonics? Explain the results.



Calculate the new Fourier series coefficients c_k and the Fourier series for the new $x(t)$ shown below for $k \in$ [−500 500]. Theoretically show the relation between the old coefficients and the new coefficients in your report and show that the relation is correct for a_3 and c_3 in MATLAB.



Task 6: 360 Audio(Optional)

We want to make a 360° audio file! It simply means that we want to make the feeling that the audio source is circling around the listener's head. An mp3 file has been sent to you. Read the audio file called `original_audio.wav` with MATLAB. For each channel (left and right) define a sinusoidal wave with the right amount of phase shift to create this feeling.

About submission:

- ✓ File's naming format:
  - ❖ For MATLAB Project: "PRJ_StudentNo." E.g.: PRJ_401613198.rar
  - ❖ Make sure to include all your m-files in the rar file.
- ✓ Your submission should include a report file and the rar file.
- ✓ Late submissions will result in a 10% daily reduction from your Project mark.
- ✓ Clean codes will receive a slight extra mark.