EEE 391 Fall 2024-2025
MATLAB Assignment 1: Musical Signal Analysis and Synthesis
Deadline: November 14, 2024 by 23.59 on Moodle

1 Introduction

The goal of this assignment is to use MATLAB to create, analyze, and manipulate musical signals through sinusoidal synthesis and harmonic addition. The focus will be on signal synthesis, harmonic enrichment, and understanding aliasing effects in the time and frequency domains.

2 Signal Generation

Use the list below to see which minor chord you should choose. A chord is 3 notes played together in unison. Check the frequencies corresponding to these notes in the 4th octave. For example, note A is 440 Hz. Choose a sufficiently large sampling frequency and an appropriate signal duration ($f_s = 8000$ Hz and $t = 1$ is reasonable).

You can find the corresponding frequencies in www.engineeringtoolbox.com

- Create sinusoidal signals at these frequencies corresponding to musical notes. You can round the frequencies to a whole number. First choose the amplitude and phase values a constant and listen to each note's sound. Amplitude of 1 and phase of 0 degrees will work. Then add the sinusoidal signals and listen to the corresponding sound. Use the "sound" command to play the notes and the chord. You can use the "pause" command to separate the sounds.
- Plot the individual notes and the resulting chord signal in the time domain using the "subplot" command. When plotting, restrict the time interval so that a clear view of the signals is possible.
- Use the digits of your ID (`d1d2d3d4d5d6d7d8`) to select the amplitudes and the phase values of the signals using the rule below:

Last digit of your ID	**Chord**	**1st Note**	**2nd Note**	**3rd Note**
0	Cm	C	E♭	G
1	C♯m	C♯	E	G♯
2	D♭m	C♯	E	G♯
3	Dm	D	F	A
4	D♯m	E♭	F♯	B♭
5	E♭m	E♭	F♯	B♭
6	Em	E	G	B
7	Fm	F	G♯	C
8	F♯m	F♯	A	C♯
9	G♭m	F♯	A	C♯

Table 1: Chord selection based on ID

– Amplitude values:

$$A_1 = d_6$$
$$A_2 = d_7$$
$$A_3 = d_8$$

– Phase values:

$$\varphi_1 = d_4 d_5 d_6\,^\circ$$
$$\varphi_2 = d_5 d_6 d_7\,^\circ$$
$$\varphi_3 = d_6 d_7 d_8\,^\circ$$

If `d6`, `d7` or `d8` is 0, choose 1 for amplitudes.

- Add the resulting signals and listen to the new sound. Compare it with the sound before. Plot the individual notes and the resulting chord signal in the time domain using the "subplot" command. When plotting, restrict the time interval so that a clear view of the signals is possible.

3 Adding Harmonics

- Again, consider the original notes and the chord you used in the first part. Add the second, third and fourth harmonics of each note to the original signal. This means that you should create new sinusoidal signals of which the frequencies correspond to integer multiples of the original frequency. (Create new signals with $f = 2f_0, 3f_0, 4f_0$). Experiment with different amplitudes for the harmonics. Choosing diminishing weights would be one way.

- Compare this sound with the previous sound.

- Plot the harmonics and the resulting signal in time domain using the “subplot” function. When plotting, restrict the time interval so that a clear view of the signals is possible.

4 Fourier Analysis

- In this section we will employ the Fourier Transform. Although we did not yet study it in class, its interpretation is similar to Fourier series coefficients. You may use the Matlab command ”fft” to computer the Fourier transform of a signal represented by a vector and “abs” to get the magnitudes.
- Compute the Fourier transform of the chord signal when the harmonics are added. Plot the spectrum into another figure.
- Observe how the harmonic components appear in the frequency domain and discuss how they affect the sound quality.

5 Aliasing & Reconstruction

- Intentionally reduce the sampling frequency below the Nyquist criteria for the highest note in the chord. Try to create the original chord and the second, third and fourth harmonics.
- MATLAB won’t play the sound as there is aliasing in the sound. Use “interp1” command to upsample the sound before playing. This way, the sound will still be aliased. You can use the MATLAB documentation for ”interp1” command.
- Listen to the resulting chord. How does it compare with the original chord? Can you hear any difference?
- Add the new harmonics and listen to the resulting sound. How does it compare with the original sound? Can you hear any difference?
- Plot the chords frequency spectrum using the “fft” function. Also plot the frequency spectrum of the chord with the harmonics added. Compare the resulting frequency values with the original values.

Submit the results of your own work in the form of a well-documented report on Moodle. Borrowing full or partial code from your peers or elsewhere is strictly forbidden and will be punished. Please include all evidence (plots, screen dumps, MATLAB codes, MATLAB command window print-outs, etc.) as needed in your report. Append your MATLAB code at the end of your assignment, do not upload it separately. The axes of all plots should be scaled and labeled. Typing your report instead of handwriting some parts will be better. Please do not upload any photos/images of your report. Your complete report should be uploaded to Moodle as a single good-quality pdf file by the given deadline. Please DO NOT submit any files by e-mail.