FINAL PROJECT IN DIGITAL SIGNAL PROCESSING

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SUBMISSION POLICY

The project must be submitted by February 11, 2022. The project must be submitted by pairs of students. You must submit the programing assignments as a code in single Jupiter file.

1. Introduction to musical signal

Audio signals generated by musical instruments typically have a harmonic structure. For our purposes we will us A simplified mathematical model of musical signal:

$$x(t) = \sum_{m=1}^{\infty} c_m \cos(2\pi m f_0 t + \phi_m)$$

Where:

f_0 is the fundamental frequency

c_m is amplitude and ϕ_m is the phase of the mth harmonic.

The frequency f_0 is determined by the note being played. In western music, the frequencies of musical instruments obey a geometric series formula.

$$f_i = f_{ref} q^i \, , q = 2^{\sqrt{12}}$$

Where f_{ref} is a reference frequency. The standard reference frequency historically was chosen to be 440Hz, and the corresponding note is called A (also known as la). The ratio $2^{\sqrt{12}}$ is called a semitone. The notes A#, B, C, C#, D, D#, E, F, F#, G, G# are 2, 3, 4, 5, 6, 7, 8, 9 and 10 semitones above A. The note 12 semitones above A is again called A, and is said to be an octave higher. The ratio between two notes an octave apart is exactly 2.

Note	Octave1	Octave2	Octave3
A	110.00	220.00	440.00
A#	116.56	233.08	466.16
B	123.47	246.94	493.88
C	130.81	261.63	523.25
C#	138.59	277.18	554.37
D	146.83	293.66	587.33
D#	155.56	311.13	622.25
E	164.81	329.63	659.26
F	174.61	349.23	698.46
F#	185.00	369.99	734.99
G	196.00	329.00	783.99
G#	207.65	415.3	830.61

The harmonic structure of a musical instrument is the series of amplitudes of the various harmonics relative to the fundamental frequency. The harmonic structure depends on the type of the instrument, the individual instrument, the note played, and the way it is played. Different instruments have their typical harmonic structures. It is the differences in harmonic structure make different instruments sound differently. The relative phases of the various harmonics are of little importance, since the human ear is almost insensitive to phase.

2. programing assignments

1. Write program that for given input (wav file) prints the matching note name.
    a. Use the provided sound recorded files of trumpet to write and check your program, the pitch frequency is provided for each file:
    trumpet-G3.wav the pitch is 196 Hz
    trumpet-C5.wav, the pitch is 523 Hz
    b. Find the note that played on the sound recorded file trumpet.wav.
2. Write program that for a given input (wav file) prints the matching instrument (piano or trumpet).
    a. Use the provided sound recorded files of trumpet and piano to write and check your program, the pitch frequency is 523Hz: piano-C5.wav ,trumpet-C5.wav.
    b. Find the instrument that playing on the sound recorded file instrument.wav.

* use the function scipy.io.wavfile.read to open the wav files, the function returns data and sampling rate of a wav file.