I547: Audio Music Processing
Homework 3

1. In the following examples suppose we are given $x(n)$ for $n = 0, \ldots, N-1$ where $N = 1024$ and suppose X is the finite Fourier transform of x, $x \overset{FFT}{\leftrightarrow} X$. Give the modulus and argument of the complex numbers $X(0) \ldots X(N/2)$ when

   (a) $x(n) = \cos(2\pi 5n/N + 1)$

   (b) $x(n) = 4\sin(2\pi 5n/N) + 3\sin(2\pi 6n/N) + 2\cos(2\pi 8n/N)$

   (c) $x(n) = 4\sin(2\pi 5n/N) + \cos(2\pi 5n/N)$

   (d) $x(n) = 3\cos(2\pi 8n/N - 1) + 3\cos(2\pi 8n/N + 1)$

   No coding is necessary or desirable.

2. Download the Bass Oboe data from the class website and examine using the program spectrum_movie.r.

   (a) Describe the effect of varying the FFT length in this program.

   (b) Window a representative (non-silence) piece of the audio data before computing the FFT using a Hann (raised cosine) window. Compare the spectra with and without this window and submit your plots.

   (c) Identify *through visual inspection alone* the locations (eg. frames 10 - 20) and musical pitches (eg. "middle c") of the first 5 notes. By "frame" I mean an individual analysis segment or Fourier transform.

3. Using approximately 1 second of sound starting 64000 samples into the bass oboe data, create a Hann-windowed fft of $N = 8192$ data points. Reconstruct the sound as a sum of sine waves (as in **sawtooth.r**) using

   (a) all N/2 sines — okay to ignore the "DC" (non-oscillating) component

   (b) the N/4 sine waves having the biggest amplitude

   (c) the N/4 sine waves having the smallest amplitude

   (d) the N/10 sine waves having the biggest amplitude

   (e) the N/100 sine waves having the biggest amplitude

   Listen to each sound and describe what you hear. Submit your R code for each of the examples.

4. Using the idea of the timbre_copy.r example, create a 16 sinusoid model of bass oboe note. You might want to "page through" the sound using spectrum_movie.r to find a suitable location.

   (a) Using your timbre model, recreate "Amazing Grace" starting on $C = 4402^{-21/12}$.

   (b) Using your timbre model, recreate the expressive octave leap of the previous assignment.

   Submit your code and be prepared to play your examples in class.

5. From a single note on the "octaves" data compute two representative timbre models from two different spectra, as you did in the previous problem. Call these a^1, a^2 where $a^1 = (a^1_1, \ldots, a^1_{16})$, and similarly for a^2. Create a timbral vibrato by oscillating back and forth smoothly between the two timbres defined by a^1 and a^2 for a given frequency.

6. Suppose we create a sound signal, x, in the following way: Begin by create n samples of white noise. Then for the remaining samples let $x(i) = \frac{x(i-L)+x(i-L-1)}{2}$, $i = n+1, n+2, \ldots$.

   (a) Perform this experiment and listen to the sound while varying the parameters L.

   (b) Describe how L relates to the sound you hear.

   (c) Explain why the sound has the characterisitics it does.