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ECE413 – Music and Engineering

Homework 2: Synthesizing Instruments

With Regards to Coding (1-5):

General: All the functions were written to take in n different frequencies and perform the synthesis for each simultaneously and then sum at the end. Allows the same code to be used for a chord or just a single base frequency. To do this I also added an instrument mode called 'Note' that only takes one base frequency.

1. The bell from Figure 4.28 of Jerse was implemented. First a bunch of exponential (2^{-n}) waveforms of various amplitudes and frequencies (specified by ratios of the duration). Each of these waveforms was then modulated by a sine wave at frequencies that were related to the base frequency (input by user). These modulated signals were then summed to produce the resulting bell sound.

2. In order to implement subtractive synthesis, a second order filter with moving poles was implemented. The poles (z-plane) would start at $re^{j\theta}$ and $re^{-j\theta}$ for r = 0.9 (any r < 1 works) and θ would vary from π at t = 0 to 0 at the end of the duration. The transfer function for this has the form

$H(z)=\frac{1}{(z-re^{(j\theta)})(z-re^{(-j\theta)})}$. To scale this so that at the resonant frequency it has unity gain (0dB) plug in $z = e^{j\theta}$ for the theta currently in use and then find the magnitude of H for this z. Then divide by this value to get a 0dB gain at the resonant frequency. The form of the filter was thus

$H(z)=\frac{|(e^{(j2\theta)}-2r\cos(\theta)e^{(j\theta)}+r^2)|}{(z-re^{(j\theta)})(z-re^{(-j\theta)})}$. This causal version of this system corresponds to the difference equation $y[n]=|(e^{(j2\theta[n])}-2r\cos(\theta[n])e^{(j\theta[n])}+r^2)|x[n]+2r\cos(\theta[n])y[n-1]-r^2y[n-2]$. This was the implemented in MATLAB using a for loop.

3. The bell from Figure 5.9 of Jerse was implemented. The implementation was similar to that of number 1.

4. The clarinet of Figure 5.28 of Jerse was implemented. The envelope was created by by finding indexes of the times corresponding to the end of the Rise and the beginning of the Decay. With the indexes known it easy to linearly interpolate from 0 to 255 and vice versa. To implement F(x), the function was decomposed into three linear functions. The slope (m) of and offset (b) (y = mx+b) were found. Then the incoming was put through the proper portion of the function (in the code the three portions correspond to F1, F2, and F3) and were then summed back together and scaled by the desired amplitude.

5. The code written for (1-4) was written to abuse broadcasting when possible so that multiple frequencies can be in less lines of code. Three ‘base’ frequencies show up for the major and minor chord. Results for each of the frequencies were summed together to create the chord.

<u>Discussion (6):</u>

Additive:

A. The just tempered major chord seems to have more of a ring to it at its height. I can hear the the different frequencies. For the equal tempered the major chord seems more together. The separate frequencies are much less evident.

B. I prefer the equal tempered version as it sounds more like an authentic bell.

C. Just as for the major chord, the different frequencies can be heard more clearly for the just tempered version. However for the minor chord, the equal temperament has more evident frequencies than its major chord counterpart but it is still less evident than the just tempered version.

D. Again I prefer the equal tempered as it sounds more realistic.

Subtractive:

A. The just tempered seems to be out of phase in a way and sounds like its jumping back and forth really suddenly. The equal tempered sounds a lot more coherent and doesn’t have these sound spikes.

B. I prefer the equal tempered version as it sounds more coherent.

C. Again the comments for A apply here. Just has these spikes that aren’t present in the equal version.

D. Again the equal sounds better as it is overall more smooth.

FM:

A. The just tempered version sounds like it has a single high point while the equal version sounds like it has a second peak that’s lower and after the first one.

B. I prefer the just tempered version as the second peak in the equal tempered sounds a tad unnatural.

C. For the just tempered minor chord you can hear underlying frequencies more prominently than the equal tempered version.

D. I prefer the equal tempered version for the minor chord as you don’t hear the underlying frequencies as clearly.

Wave Shaping:

A. In the equal tempered version you can hear the beats more obviously than in the just tempered version. The just tempered version thus sounds more constant in the sustain region.

B. I prefer the just tempered version since the beats in the equal tempered version are annoying to listen too.

C. Honestly these sound the same to me and I can’t tell the difference. They both seem to have beats going on in the sustain region.

D. They both sound the same so they’re either equally good or equally bad (depends on your viewpoint). I would not want to listen to either again.