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Research on Pitch Perception using Complex Tones based on Tempered Perfect Fifths

This document is a brief summary of my technical contributions to the ongoing research project.

Contributions

I began volunteering for Professor Diana Deutsch (Professor of Psychology at University of California, San Diego) as a software engineer in the spring of 2021 on the study of Tritone Paradox. I created Pure Data patches that streamlined the process of generating complex tones for the experiment by allowing a user to specify the number of components and the width of the spectral envelope. As we studied the effect further, we discovered that the pitch circularity was obtained when seven complex tones were played sequentially with a semitone interval. The ongoing research in collaboration with Professor Diana Deutsch and Professor Kevin Dooley (Psychology Lecturer at California State University Dominguez Hills) explores the study of pitch perception using complex tones that consist of six sinusoidal components that are separated by tempered perfect fifths. As a student researcher, I have been creating pure data patches, generating audio stimuli for the experiment, and collecting some informal data.

Technical Overview

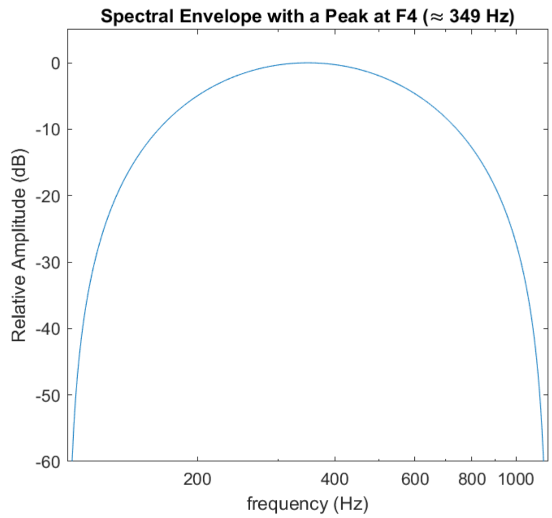
Spectral Envelope

The relative amplitudes of the sinusoidal components are determined by a bell-shaped spectral envelope based on the equation defined by Deutsch *et al.*[1]:

$$A(f) = 0.5 - 0.5cos(\frac{2\pi}{\gamma}\log_\beta \frac{f}{f_{min}}), \qquad f_{min} < f < \beta^\gamma f_{min}$$

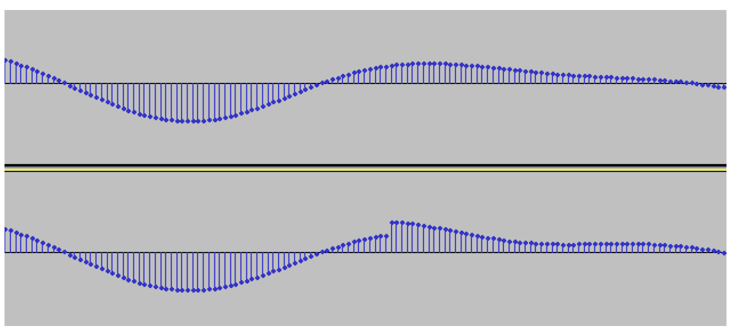
where β is the frequency ratio between adjacent components, γ is the number of components, and f_{min} is the minimum frequency for the lowest component. In the experiment, the frequency ratio was set to a tempered perfect fifth (≈ 1.498), and the number of components was set to 6.

[1] Deutsch et al.: The perceived height of octave-related complexes. Journal of the Acoustical Society of America, VoL 80, No. 5, November 1986



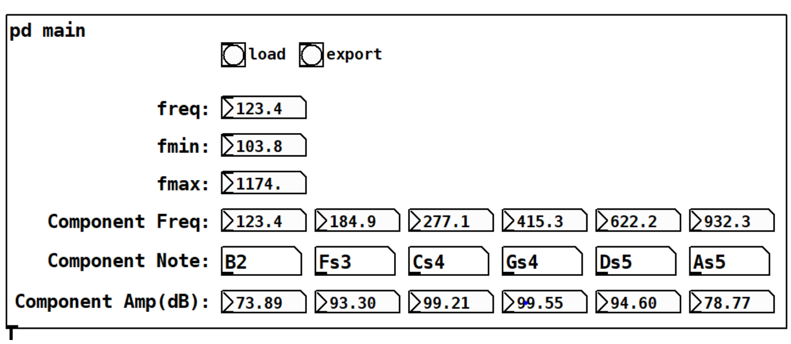
Wave Continuity

Playing sinusoidal components with different amplitudes successively results in a wave discontinuity. In order to avoid this issue, a low-pass filter with the cutoff frequency at 100 Hz is used to smooth the change of amplitude for each sinusoidal component in a complex tone.



With a low-pass filter (above) vs. Without a low-pass filter (below)

Pure Data Patches and Text Files



The complex tones are sequenced in text files, which are loaded inside the main Pure Data patch. In addition to notes, a user is able to specify the peak and width of the spectral envelope as well as the ratio between adjacent sinusoidal components. The generated audio is exported as wav files with the bit depth at 16 and the sample rate at 44,100 Hz. The patch utilizes two abstractions from a Pd library that I created: a symbol to MIDI converter and a MIDI to symbol converter. The use of these abstractions allows a user to type a musical note rather than a MIDI note number for the peak of the spectral envelope. It also enables a real-time visual representation of the musical note for each sinusoidal component inside the main patch.

perfect5th_F4_0-3.txt - Notepad

File Edit Format View Help

```
gain 3.5;
peak F4;
compnum 6;
compratio 1.49830707688;
ratio 1.49830707688;

rest -;
1000 note 0;
1000 note 3;
1000 rest -;
1000 note 0;
1000 note 3;
1000 rest -;
1000 note 0;
1000 note 3;
1000 rest -;
6000;
```

A text file example where a pair of complex tones is played three times with a 1000ms pause in between.