21M.380 Music and Technology
Sound Design

Lecture №14
Additive synthesis

Monday, March 28, 2016

1 Review

1.1 ED assignment

- Award for liveliest script in terms of sound design goes to [redacted], [redacted], and [redacted]
- Let's listen to some submissions:
  - Group A
  - Group B
  - Group C
  - Group D
  - Group E

1.2 QZ1

- Let's listen to Pd patch from p.1
- A harmonic spectrum tends to be perceived as a single source (key point!)
- `[vline~]` can also control frequency (not just amplitude)
- Input to `[osc~]` *always* controls frequency!
- Let's build that counter from question 4.1 together!

2 Overview of synthesis techniques

- Additive (Farnell 2010, ch. 17)
- Wavetables (ibid., ch. 18)
- Waveshaping (ibid., ch. 19)
- Modulation (AM and FM) (ibid., ch. 20)
- Granular (ibid., ch. 21)

3 Additive synthesis

- Fourier series: Any periodic signal can be reconstructed as a sum of (co)sine signals
- Question: Which limitations might this synthesis approach have?
  - Periodic sounds are by definition harmonic; what about inharmonic sounds?
  - Static spectrum
  - Requires lots of control data (amplitudes, frequencies, but also *phase* of all partials!)
- Phase-alignment of partials can be important (demo Farnell 2010, fig. 17.2)
- Generalize to dynamically changing sounds via STFT and resynthesis with envelopes
- Generalize to inharmonic sounds through *frequency* envelopes over time (in addition to amplitude envelopes)
- Demo: Partial-tracer in Pd: Help » Browser… » 4.data.structures » 14.partialtracer.pd
  - Try with `voice.wav` (inharmonic dynamic spectrum)
  - Re-synthesis at different speeds
  - Re-drawing traced partials
- Trick to reduce amount of control data needed: Discrete summation synthesis
- Using additive synthesis to create a band-limited *impulse*
  - Impulse is an important archetypal signal
  - Contains all frequencies (like white noise), but instantaneously
  - E.g., impulse response of a room (like in everyday life: hitting something to learn what it sounds like)
  - E.g., impulse train as sound source (e.g., car engine)

4 Application: Bell synthesis

- Dicuss concept of *modes* (string, pipes, membranes, bars, bells)
- Which frequencies occur? Are they harmonic?
- What about the envelopes? Do they relate?

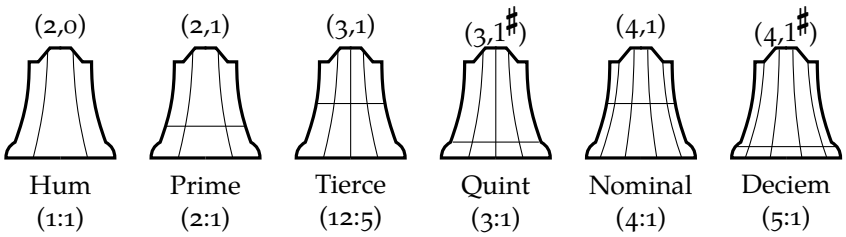

Figure 1. Characteristic modes of a bell (after Benson 2008, p. 130)

5 Exercise: Railroad crossing warning bell for train drive-by

- Farnell (2010, ch. 29) determines partial frequencies by spectral analysis of a recording.
- We'll try to do it by assuming the characteristic modes of a bell (fig. 1).
- Make the fundamental frequency adjustable

References and further reading

Benson, Dave (2008). *Music: a Mathematical Offering*. URL: https://homepages.abdn.ac.uk/mth192/pages/html/music.pdf (visited on 03/07/2015).

Farnell, Andy (2010). *Designing Sound*. Cambridge, MA and London: MIT Press. 688 pp. ISBN: 978-0-262-01441-0. MIT LIBRARY: 001782567. Hardcopy and electronic resource.

21M.380 Music and Technology: Sound Design
Spring 2016