COSC 4P98 Lecture notes: **Synthesis**
Feb 21, 2014
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1. Wavetable synthesis

- big in mid-80's (Korg M1 keyboard in 1988)
- aka "sample playback"; difference with samplers is that user cannot record/load samples
- sounds are pre-recorded and burned into ROM
- libraries of artificial, natural sounds
- pitch alteration:
    - table lookup indexing – "munchkin" if too drastic
    - pitch shift and time compression: FFT analysis, granular reconstruction
- other processing
    - filtering: send sample through filters to change its harmonic composition
    - alter amplitude/filter strength over time: ADSR
        - attack, decay, sustain, release
        - "wave shaping"
    - LFO: low-frequency oscillators
        - drive amplitude and filters with auto-generated waves, which have very slow frequencies (sub-audible)
        - sine, square, sawtooth, random, …
        - spread, width, frequency, etc., are all user-controllable
- mixing: mix 2+ signals
    - can "cross fade" with various waves, envelopes: "wave programming"
    - famous hardware: Korg Wavestation

2. Subtractive synthesis

- filter-based synthesis that boosts or attenuates (weakens) regions of waveform's harmonic frequencies
- 1960/70's style "analog" synthesis (Moog, ARP)
- if source wave is harmonically rich, filters can create reasonable approximations of many real sounds
- note: analog means the wave is a voltage, whereas digital means digitally-denoted wave (binary numbers)
    - subtractive synthesis can be done in both. Analog requires special circuits, while digital requires DSP versions of filters algorithms
- source waves in original analog synthesizers: sine, saw, square, random,…
    - pro: rich, thick, phat, unique
    - con: circuits heat up and drift, hard to tune, very expensive, can burn out

3. Additive synthesis

- combining signals to create new ones
- note: harmonic reconstruction via Fourier series is additive, because you combine harmonics to create overall wave
- Many techniques and effects (table 4.1 Roads)

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5. Modulation synthesis

- 2 signals: carrier and modulator
- carrier is altered by modulator
- a) acoustic modulation:
    - vibrato: slow frequency modulation
    - tremolo: slow amplitude modulation
- b) Ring modulation
    - bipolar: signal varies between -1 and 1
    - unipolar: signal varies between 0 and 1
    - RM: multiply two bipolar signals together
    - signals can be wave tables
    - if M is below 20Hz, amplitude of C varies at frequency M: tremolo
    - but if M is an audible frequency, timbre of C changes
    - sidebands created: sum of difference of frequencies C and M (C disappears)
    - if C and M are integer ratios, the sidebands are harmonic; else inharmonic
    - Uses: colour signals, create new signals (bells, gongs)
- c) Amplitude modulation (AM, as in AM radio)
    - like RM, except M is unipolar (C is bipolar)
    - result: sum and difference around C
    - carrier bands like RM, but C is included
- d) Frequency modulation (FM, as in FM radio)
    - C's frequency is modulated by M oscillator
    - series of sidebands
    - popularized with Yamaha DX7 keyboard (early 80's)
    - C:M ratio: if integer, then harmonic sidebands; else inharmonic
    - modulation index: "Depth"
        - I = D / M, where D = freq deviation from carrier
    - can envelope D to vary the bandwidth over time
    - Uses: better simulation of real instruments than subtractive synthesis, especially horns, brass, metallic percussion effects
    - Unfortunately, not very intuitive to use. Many musicians would experiment and dabble until something interesting arises.

6. Granular synthesis (covered earlier, separate lecture notes)

7. Wave Terrain Synthesis
- An exotic synthesis technique.
- different variants
- conventional wave table: wave(x), index x
- wave terrain: wave(x, y), indices (coords) x, y
    - wave is the "z" --> 3D surface
- 2D function conditions:

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    - 1) both x, y functions and partial derivatives are continuous
    - 2) x, y functions are 0 on terain boundaries
    - eg. wave(x,y) = (x-y)(x-1)(y-1)(y+1)
- Orbits
    - scan over terrain
    - determine final shape of audio wave via orbit (trajectory)
    - periodic orbits: periodic waves
    - aperiodic orbits: time-varying waves