Sound synthesis and sound effects

- Sound synthesis: generating sounds starting from scratch, using math, etc...
- Manipulating sounds and making them more interesting.
- Applications: electronic music, computer games, HCI, interactive performances, installations, new musical instruments design, sound effects for movies...
MIDI (http://www.midi.org/)

- When talking about music synthesizer the word MIDI comes up quite often. But what is MIDI?
- MIDI stands for Musical Instrument Digital Interface.
- It is a protocol widely accepted and utilized by composers and musicians since its conception in 1982.

MIDI

- MIDI was initially conceived to connect synthesizers together.
- Now it is used to supplement digitized audio in games and multimedia applications.
- One advantage of storing files in MIDI format is space: MIDI files are extremely small when compared to regular .wav files.
- This is because a MIDI file does not contain the sampled audio data, it only contains the instructions needed by a synthesizer to play the data.
Problems with MIDI

- It is too slow: there is a delay between the time a command is sent and a note is produced.
- It was meant mostly for keyboard controllers.
- There are only 128 values for each command.

MIDI in Max/MSP

- Notein and noteout messages
- kslider
- Max/MSP is connected to the MIDI devices installed in the computer, and allows to send and receive data to and from such devices (either physical devices such as synthesizers and controllers, or software packages).
Beginning of sound synthesis

- In 1963 Max Mathews, then a researcher at the Bell Laboratories in New Jersey, published a paper in which he predicted that the computer would become the ultimate musical instrument. "There are no theoretical limits," Mathews wrote, "to the performance of the computer as a source of musical sounds."

Sound synthesis versus sampling

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<td>Sound synthesis</td>
<td>Parametric sound effects!</td>
<td>Hard to code realistic sounds</td>
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<td>Sampling</td>
<td>Easy to get sonic material</td>
<td>Nothing/little to control!</td>
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Overview of synthesis techniques

- Additive synthesis (MED3)
- Subtractive synthesis (MED3)
- Modulation and distortion synthesis (AM, RM, FM).
- Granular synthesis
- Spectral models, source-filter models, physical models (advanced techniques left for the Master).

Today and next lecture

- Additive synthesis (brief review)
- Amplitude modulation
- Ring modulation
- Frequency modulation
- Subtractive synthesis (review)
- Plus exercises
Additive synthesis

- Additive synthesis refers to a number of related synthesis techniques, all based on the idea that complex tones can be created by the summation, or addition, of simpler ones.
- It is possible to **break up** any complex sound into a number of simpler ones, usually in the form of sine waves (Fourier).
- In additive synthesis, we use this theory in reverse.

- Additive synthesis uses combinations of **harmonics** or **partials** to create the basic tone colours or 'timbres' and on more sophisticated systems several of these timbres can be combined to make the overall sound.
This organ has many pipes, and they're used exactly like an additive synthesis algorithm.

Each pipe is a sinusoid (or almost)

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**Modulation**

- Modulation is the *alteration* of the characteristics of a sound by using another sound.
- Ring modulation (RM)
- Amplitude modulation (AM)
- Frequency modulation (FM)
Ring modulation: applications

- Examples: guitar sound
- Example: Mantra by Stockhausen
- The ring modulation effect is used to produce a sort of electronic piano.

Ring modulation: how does it work?

- Ring modulation is the multiplication of two signals.
- Usually one of them is a sinewave.
- Ringmod = C * M
- What happens in the case of two sinusoids?

  - Using trigonometry:
  - $\cos(a)\cos(b) = 0.5 \ [\cos(a+b) + \cos(a-b)]$
Ring modulation math

- \( y_1 = \cos(w_1 t) \)
- \( y_2 = \cos(w_2 t) \) where \( w_1 \) and \( w_2 \) are the frequencies, \( t \) is time.

- \( y = y_1 y_2 = \cos(w_1 t) \cos(w_2 t) = \)
- \( y = 0.5 \left[ \cos(w_1 + w_2) t + \cos(w_1 - w_2) t \right] \)

Example

- \( w_1 = 500 \text{ Hz}, w_2 = 200 \text{ Hz} \)
- \( Y = y_1 y_2 = \cos(500 t) \cos(200 t) = \)
- \( = 0.5 \left[ \cos(700) t + \cos(300) t \right] \)

So when two signals with amplitude 1 and frequency \( w_1 \) and \( w_2 \) are multiplied, the result is the sum of two signals with amplitude 0.5 and frequencies \( w_1 + w_2 \) and \( w_1 - w_2 \).

Notice that the original frequencies are lost!
Parameters

- In ring modulation, Output = C*M where C is known as the carrier frequency, while M is the modulator.
- When M<20 Hz we obtained the so called \textit{tremolo} effect, where tremolo is a variation of the amplitude of a signal.
- Example in Max/MSP

Amplitude modulation

- The amplitude of a waveform varies in accordance with a modulator wave.
  \[ y = [1 + \cos(w_1 \ t)] \cos(w_2 \ t) = \]
  \[ = \cos(w_2 \ t) + \cos(w_1 \ t)\cos(w_2 \ t) = \]
  \[ = \cos(w_2 \ t) + 0.5 [\cos (w_1 +w_2) \ t + \cos(w_1 -w_2) \ t] \]
- In amplitude modulation, the frequency of the modulated signal is not lost.
To summarize

- When you multiply two sinusoids you obtain two partials, one at the sum of their frequencies, the other at the difference.
- These new components are called sidebands.

Implementing modulation

- Creating a digitally based ring modulator comes down to simply multiplying two numbers each sampling interval which is very easy to accomplish.
- Very simple to implement in Max/MSP
Ring modulation

Frequency modulation (FM)

- History: Frequency modulation is a synthesis technique discovered by John Chowning in the late 60s, while he was a student at Stanford University.
- Bought by Yamaha who released the DX7 synthesizer.
Math

- $y = A \cos(w_1 t)$ equation of a sinewave
- $y = y_1 y_2 = \cos(w_1 t) \cos(w_2 t)$ ring modulation
- What if we try to modulate the frequency of the sinewave instead?
  - $y = A \cos(w_1 t) = A \cos (\cos(w_2 t) t)$
  - In this case $w_1 = \cos(w_2 t)$

Advantages

- Computational cost very low.
- Possibility to create complex sounds with only two sinusoids.
Examples

- Microsoft sound by Brian Eno
- The thing from the agency said: “We want a piece of music that is inspiring, universal, blah-blah, da-da-da, optimistic, futuristic, sentimental, emotional, this whole list of adjectives, and then at the bottom it said and it must be 3 1/4 seconds long.”