IAT 380: Sound Design

Sound Synthesis

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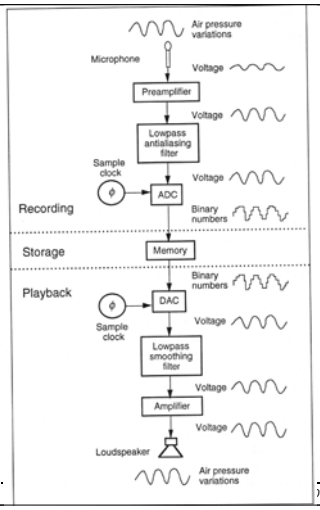
Digitalising sound

- **Overview of the audio digital recording and playback chain**



Sound Design for Moving Images

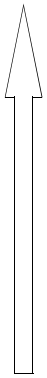
- **Sound design for moving images can be divided into three domains:**
  - **Speech:**
    - **Naration: Direct, Indirect, Contrapunctual**
    - **Dialogue**
  - **Sound effects:**
    - **Contextual**
    - **Narrative**
  - **Music:**
    - **Production source music**
    - **Source music**
    - **Underscore music**

Techniques of Sound Spatialisation

- The various types of spatial sound reproduction techniques developed over the years can be classified as either:
  - Perception simulation:
    - Aim to reproduction of what the ears would hear in a natural situation
    - Examples: Binaural sound, n-channel stereophony, Dolby surround, etc.
  - Sound-field simulation:
    - Aims to reproduce the actual sound field.
    - Examples: Beam forming, wave field synthesis, Ambisonic surround, etc.

Ontology of Media Art

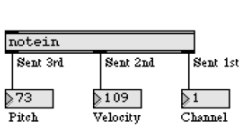
- Meta-creation:
  - Engineering machines endowed with a creative behavior: improvising automata
  - AI-art, a-life art, …
- The artist-engineer:
  - MAX-MSP/Jitter, Pure Data/Gem, Performer, EyesWeb, …
  - Micro-controllers, sensors, …
- The artist and the technician:
  - Classical practices: music, painting, drawing, …

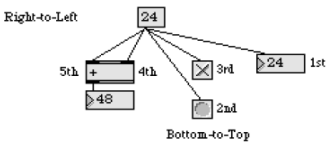


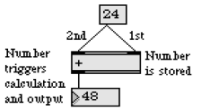
- Influences/creates the content:
  - FightPod, the future of DJing
  - Machine Motor, the future of VJing
  - Kino, YouTube, Current TV, …
- The user interacts with the content:
  - Interactive devices (HCI, Sensors)
  - Video games, Karaoke, interactive installations, …
- The user is a passive receptor:
  - Television, Cinema
  - Books, Journal, Music,…

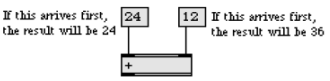
MAX / MSP

- Graphical programming environment
- Perfect for real-time digital signal processing
- A must in the artist/designer's tool box









MSP

- MSP is the collection of audio signal processing objects associated with MAX (control objects)
- The basic objects are:
  - DAC~ : digital to analog converter
  - ADC~ : analog to digital converter
  - +~ : audio sum (mixer)
  - *~ : audio multiplication (amplifier)
  - Cycle~ : use a a 512 sample table (a sine wave by default) and play it as a loop as a given frequency. Inputs are frequency and phase and buffer name is an optional parameter.
- All you need to know is covered in the MSP tutorials (31 short tutorials).

Sound Synthesis

- We have seen various ways of getting sounds:
  - Recordings: field recording, Foley, ADR, ...
  - Sound Library: at the library, on-line, ...
  - Sampling: from recorded music, ...
- We have seen ways to represent and store sounds as sequences of numbers
- Sound synthesis is the process of generating new sounds from scratch (generating directly a sequence of numbers or an audio signal).
- It basically revolves around the use of mathematical functions and algorythms

Sound Synthesis

- Several goals are possible:
  - Mimicking existing instruments, electrical or physical
  - Create something completely original
- Different families of approaches have been proposed
  - Physical modeling:
    - How to model a violin?
    - What if the cords are 12 meters long and made of cristal?
  - Approaches that rest on basic electronic components functions:
    - Oscillators
    - Filters
    - Amplifiers

Sound Synthesis Methods

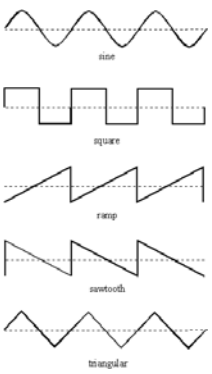
- Sound synthesis methods (by decreasing order of popularity):
  - Sampling based synthesis and wavetable lookup
  - Subtractive Synthesis
  - Additive Synthesis
  - Frequency modulation (FM), phase modulation and phase distortion
  - (Nonlinear) waveshaping
  - Decomposing time—granular synthesis, FOF and VOSIM
  - Physical modelling—waveguides and controlled nonlinearity
  - Time-domain and graphical synthesis
  - Analysis–resynthesis
  - Hybrid methods

Additive Synthesis

- The timbre of an instrument is composed of multiple harmonics or partials, in different quantities, that change over time.
- Additive synthesis emulates such timbres by combining numerous simple waveforms pitched to different harmonics, with a different amplitude envelope on each, along with inharmonic artifacts (noise, ...).
- Additive synthesis has a direct link with Fourrier theorem (when the waveforms are sines)
- This involves a bank of oscillators (tuned to multiples of the base frequency in the case of harmonics sounds). Often, each oscillator has its own customizable volume envelope, creating a realistic, dynamic sound that changes over time.

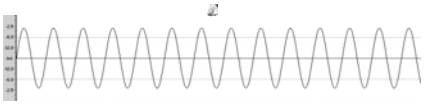
Additive Synthesis

- The generators or ocsillators provide the most common source signals: square waves, pulse waves, sawtooth waves and triangle waves.
- Modern digital and software synthesizers may include other, more complex waveforms or allow the user to upload arbitrary waveforms.
- Some synthesizers may use a form of pulse width modulation which dynamically alters the source for a richer, more interesting, more organic tone.



Additive Synthesis

Sine 100Hz



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Ramp 102Hz

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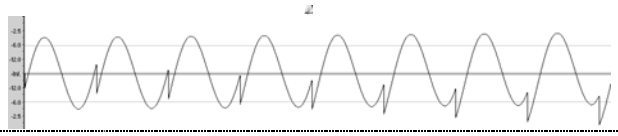
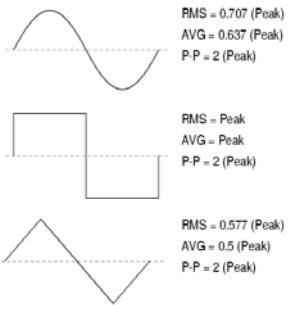


Additive Synthesis

- **Remember that loudness is not only determined by amplitude:**



⇨ **Demonstration of additive synthesis (Tutorial 7)**

Subtractive Synthesis

- **Subtractive synthesis is a method of subtracting harmonic content from a sound via the application of audio filters to the audio signal.**
- **For example, taking the output of a sawtooth generator and using a low-pass filter to dampen its higher partials generates a more natural approximation of a bowed string instrument than using a sawtooth generator alone.**
- **Typically, the complexity of the source signal and the cut-off frequency and resonance of the filter are controlled in order to simulate the natural timbre of a given instrument.**

Subtractive Synthesis

- Example: the human voice
  - The vocal folds are acting as the generator of:
    - Basic waveshapes with rich harmonic content,
    - White noise
  - The mouth and throat act as filters
  - The air colone acts as the enveloppe generator
- When saying or singing “oooh” and “aaah” at the same pitch:
  - The vocal folds roughtly generate the same waveforms
  - The mouth and throat is acting as a low pass filter and filters more harmonics in the case of the “oooh”

Amplitude modulation

- Amplitude modulation is when a signal is modulating the volume of another signal
- While additive synthesis rest on addition, amplitude modulation ring modulation rests on multiplication (*~)
- The modulation can be at:
  - Non-audio frequency:
    - Tremolo is an example of amplitude modulation using a sine wave.
  - Audio frequency (25Hz+):
    - It is then called ring-modulation
    - This changes the nature of the sound and creates new partials, …
    - Any audio signal can be modulated by any other signal

⇨ Demonstration of AM (Tutorial 8)

Frequency modulation

- The same way that one can modulate the amplitude of the audio signal, one can modulate the frequency (left input of the cycle~)
- Here again the modulation can occur at:
  - Non audio frequency level:
    - When is is reasonable amplitude (in terms of frequency) it is called a vibrato
  - Audio frequency level:
    - It is then called FM synthesis

Frequency Modulation

- FM synthesis was very popular in the 80s

Pulse Width Modulation

- There are numerrous variants of the two preceding families:
  - Instead of modulating the frequency of the whole waveform, one can modulate the relative durations of its various parts (possibilities are infinite)
  - Pulse Width Modulation is a well known (and quite common) example of such modulation

Sound Synthesis: Example

- In most of the case a combination of techniques are sued
- First, two oscillators produce relatively complex and harmonic-rich waveforms:
  - Waveform #1
  - Waveform #2
- In this case we will use pulse-width modulation for a dynamically changing tone:
  - PWM waveform #1
  - PWM waveform #2
- The two sounds are mixed. In this case they are combined at equal volume, but any ratio could be used.
  - Combined waveforms

Sound Synthesis: Example

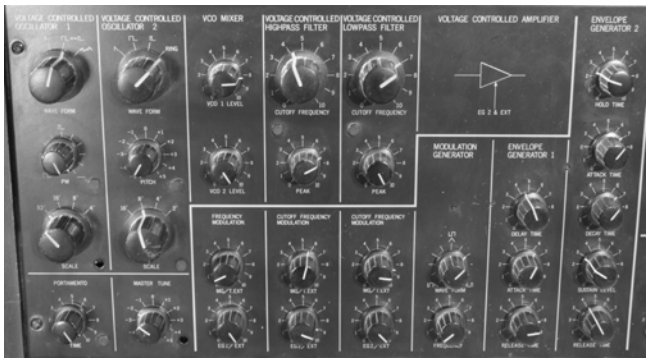
- The combined wave is passed through a voltage controlled amplifier connected to an ADSR envelope. In this case, we attempt to emulate the envelope of a plucked string:
  - Enveloped sound
- We then pass the sound through a shallow low-pass filter:
  - Low-passed sound
- In this case, to better emulate the sound of a plucked string, we want the filter cutoff frequency to start in the mid-range and move low. The effect is similar to an electric guitar's wah pedal.
  - Some arpeggios
  - Filtered with a LFO

Sound Synthesis

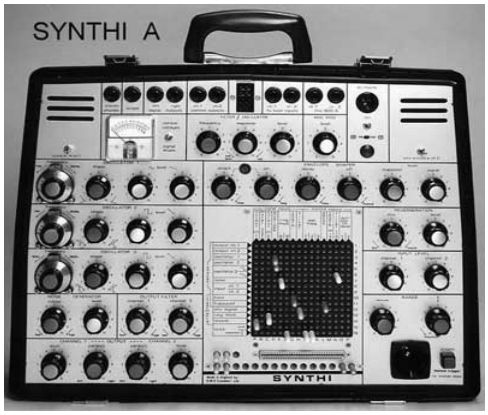
- All these technics are the basics of sound synthesis:
  - They are inherited from a long history of analog synthetisers
  - In particular, modular synthetizers were offering all these functions separately:
    - Ocsillators
    - Filters
    - Envelop generator (ADR, ADSR)
    - Amplitude modulator
    - Envelop follower
    - LFO (Low frequency oscillator) for non audio frequency modulations
  - A lot of this can be applied to any audio signal (samples and sound files).

Sound Synthesis

Sound Synthesis

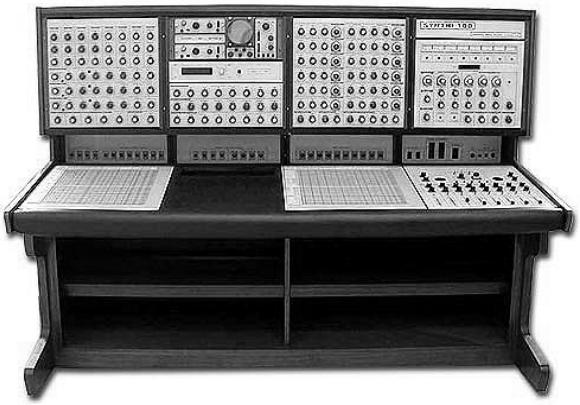


Sound Synthesis



Sound Synthesis

Sound Synthesis



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"Since light travels faster than sound, people appear bright until you hear them speak."