Digital Music

Music and how she is played on the computer

Digital Music (overview)

- Background
  - Sound
  - Storage of sound
  - Use of electronics (amplification)
- Physical nature of sound: frequencies
- Digitization of sound
- File Formats
  - Compression
  - MIDI

Background: Sound

- Compression of air
- Interpreted by the human ear
- Ear responds to frequencies in range 15-20,000Hz

Background: Storage

- Phonograph
- Newer analog (http://arts.ucsc.edu/EMS/Music/tech_background/TE-19/teces_19.html)
  - Record
  - Tape
  - See also http://en.wikipedia.org/wiki/Sound_recording

Background: Electronics

- Electronics was used mostly to amplify sound.

Physical nature of sound

- Main characteristics
  - Frequency (oscilloscope + speakers)
  - Amplitude
  - Waveform (See Java Sound Demo)+applet
- Perception
  - Frequency (pitch)
  - Amplitude (loudness)
  - Waveform (quality or timbre)

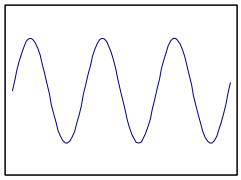
Applets

- http://www.ac-nice.fr/physique/Fourier/fourier.htm
- http://www.univ-lemans.fr/enseignements/physique/02/divers/syntfour.html
- http://www.physics.gatech.edu/academics/tutorial/phys2121/Java%20Applets/ntnujava/sound/sound.html
- http://homepages.gac.edu/~huber/fourier/index.html
- http://mapageweb.umontreal.ca/hamamh/Electro/SignComb/SigComb.htm

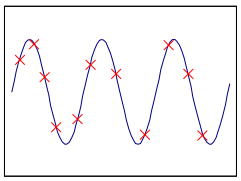
Digitalization of Sound

- Can the richness of sound really be represented by a sequence of numbers?
- Sound is a waveform ... so, reproduce the waveform using numbers.

Here's the analog signal



And the digital Samples



- Can we recreate the original waveform from these samples?

- Astonishingly, the answer is yes...
  - if we sample at twice the max frequency in the signal

Sampling

- The max frequency in a sound waveform is 20,000 Hz, so we need to sample at over 40,000Hz.
- CDs use 44KHz.
- Each sample needs to be stored as a number. For CD audio, 16 bits are used to store each number

Terminology

- Sampling frequency
  - How rapidly we sample (e.g. 44KHz)
- Sampling precision
  - How accurately we measure one particular sample (e.g. 16 bits)

Example

- Measure how the temperature varies over a day, accurate to one degree.
- How frequently might you measure it?
  - 1000 times a second?
- How precise would it have to be?

But (CD only 4 samples for a 10khz wave)

Web information

- HowStuffWorks

The Digital Advantage

- Does not degenerate as it gets older
- Can be perfectly copied
- Can be transmitted over a network without error.
- Can be edited.
- Can have meta-information; information about the music (e.g. artist)

File Formats

- No Compression
  - .wav
- Compression
  - Lossy: mp3
  - Lossless: ADPCM

Other formats

- MIDI
  - .mid (Musical Instruments)

Compression

- Lossy
  - The original cannot be retrieved
  - High compression rates (5-12 times smaller)
  - Example: mp3
  - Not good if converting 'tween formats/editing
- Lossless
  - The original can be restored
  - Compression rate 2-4 times smaller.

Lossless

- One technique (ADPCM):
- Note the first sample, only note the differences in subsequent samples.
- The left and right channels may be similar
  - record one channel
  - simply record the differences of the other channel

Lossy

- The human ear isn't perfect and simply can't hear some sounds. (Psychoacoustics.)
- Lossy compression, detects these sounds and simply removes them.

Psychoacoustics

- Temporal Masking
- Can't hear a quiet sound just after a loud sound.
- Spectral Masking
  - If two frequencies are very close together and one is much loader than the other, then only the louder one can be heard. E.g.

MP3

- MP3
  - analyses the sound mathematically
  - detects frequencies that can't be heard
  - removes them.

how stuff works

Comparison between formats

MIDI

- Replicates the effect of a music synthesizer.
- Records instrument, note played and time it was played.
- MIDI files are very short.