Creative Computing I

Lecture 4: Sound and Music

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Sound and Music

Session plan

- What is sound?
- Installing *Processing* libraries (Sonia / JSyn).
- Making sound in *Processing*.
- Digital audio file formats.
- Mixing and synthesis.
- Introduction to music.

Sound

The nature of sound

- pressure waves propagating through a medium;
- (medium is usually air or water);
- wave hits the eardrum;
- eardrum causes the bones in the middle ear (hammer, anvil, stirrups) to move;
- movement causes fluid motion in the inner ear;
- fluid brushes against receptors, which send electrical impulses to the brain.

Sound

The Ear's Response

Frequency response:

- 20Hz – 20kHz approximately;
- high-frequency response decreases with age;
- most sensitive around 1kHz – 3kHz;
- responsible for sensation of *pitch* or *height*.

Sound

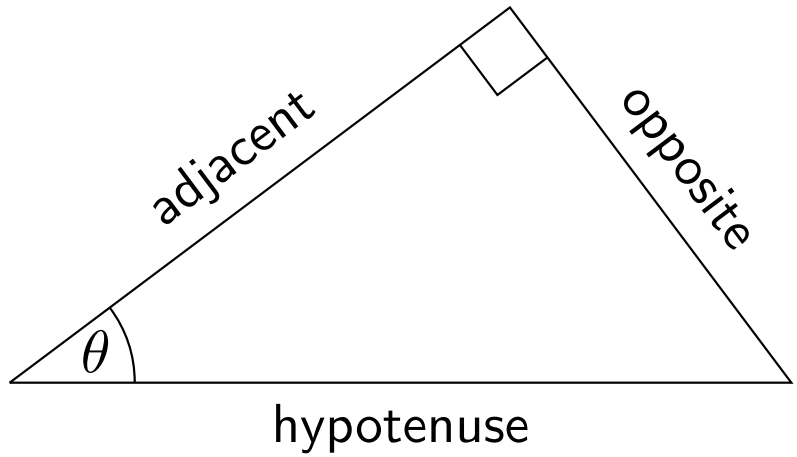
The Ear's Response

Amplitude response:

- amplitude correlates with loudness on a logarithmic (deciBel) scale
- $\lambda_{\text{dB}} = 20 \log(\text{amplitude})$
- approximate deciBel levels:
  - 0dB: threshold of hearing
  - 10dB: leaves rustling;
  - 50dB: office noise;
  - 85dB: damage from long-term exposure;
  - 110dB: nightclub dance floor;
  - 120dB: damage from short-term exposure;
  - 130dB: threshold of pain.

Trigonometric Functions

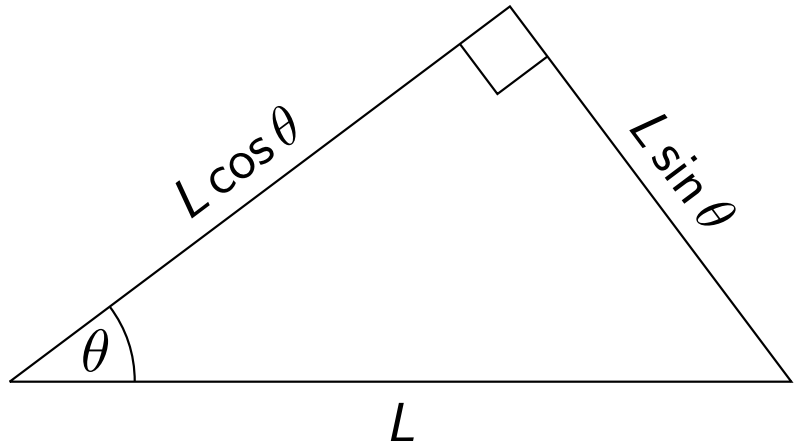
Right-angled triangles



Pythagoras' Theorem: $\text{hypotenuse} = \sqrt{\text{adjacent}^2 + \text{opposite}^2}$

Trigonometric Functions

Right-angled triangles

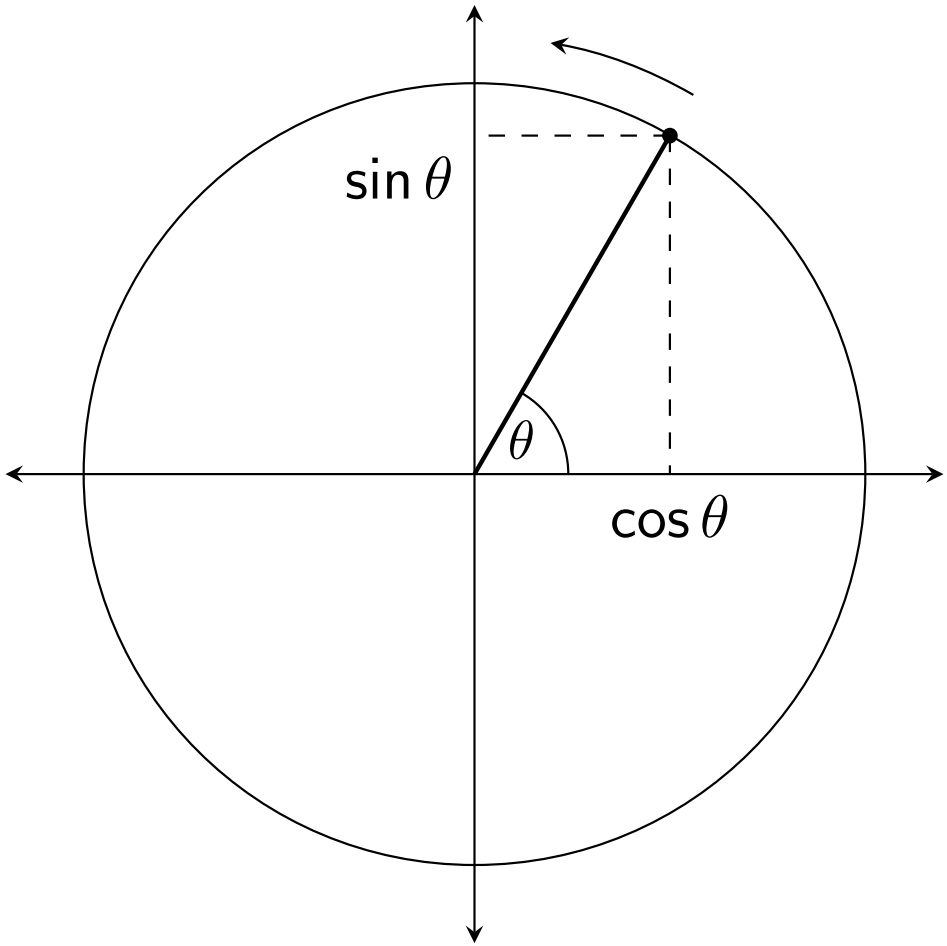


Mnemonic: *SOHCAHTOA*

- **s**in $= \dfrac{\textbf{o}\text{pposite}}{\textbf{h}\text{ypotenuse}}$
- **c**os $= \dfrac{\textbf{a}\text{djacent}}{\textbf{h}\text{ypotenuse}}$
- **t**an $= \dfrac{\textbf{o}\text{pposite}}{\textbf{a}\text{djacent}}$

Trigonometric Functions

Circles



Trigonometric Functions

Building block of sound

$$x(t) = C\sin(2\pi ft + \phi)$$

- t is time;
- x is *displacement* or *excess pressure*;
- f is wave *frequency*;
- ϕ is the initial *phase*.

$$x(t) = A\cos(2\pi ft) + B\sin(2\pi ft)$$

$$x(t) = C\cos(2\pi ft - \frac{\pi}{2} + \phi)$$

Digital Audio

Representation: Pulse-Code Modulation

Pulse-Code Modulation:

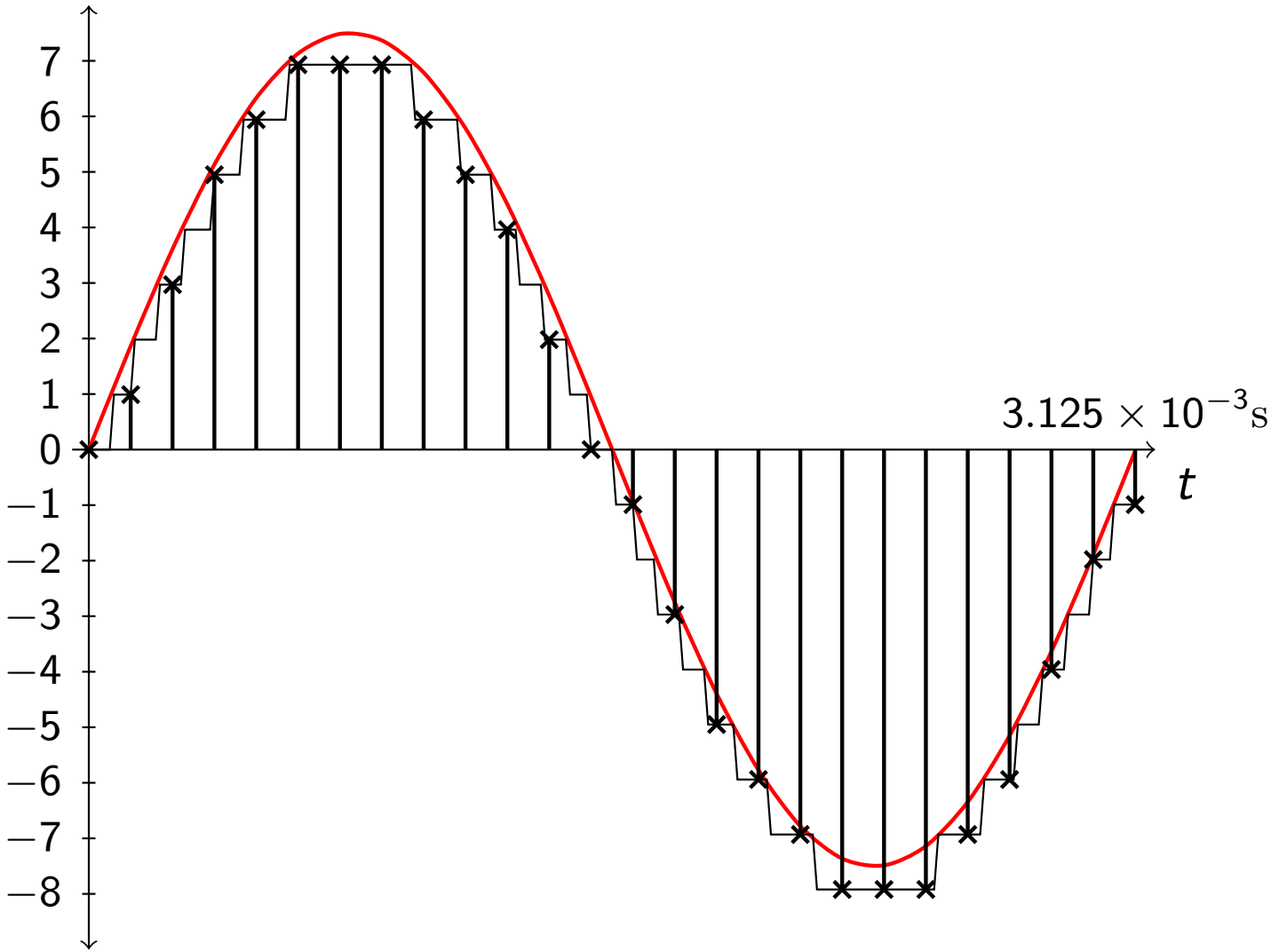
- *digital* representation of *analogue* signal;
- standard form for audio in
  - computer systems;
  - compact-disc players.

Digital-to-analogue parameters:

- bit-depth (typically 8 or 16; sometimes 20, 24);
- sample rate (usually 44.1kHz);
- channels (2 for stereo; 6 for 5.1 ‘surround’).

Pulse-Code Modulation

Sampling and Quantization



Digital Audio

Compact Disc and Recording Quality

Compact disc parameters:

- sample rate: 44.1 kHz;
- 16 bits per sample;
- 2 channels (left and right).
- (bitrate: 1411.2 kb/s)

Typical digital recording parameters:

- sample rate: 88.2 kHz – 176.4 kHz;
- over 20 bits per sample;
- one channel per microphone.

Digital Audio

File Formats: ‘lossless’

Advantages:

- fidelity (What You Encode Is What You Get Back).

Disadvantages:

- large file size;
- impractical to stream / transfer.

Examples:

- Pulse-Coded Modulation (`.pcm`, `.wav`);
- Audio Interchange File Format (`.aif`, `.aiff`);
- Free Lossless Audio Codec (`.flac`).

Note: ‘lossless’ does not necessarily mean ‘high quality’.

Digital Audio

File Formats: 'lossy'

Advantages:

- small(er) file size;
- faster Internet transfer.

Disadvantages:

- loss of fidelity;
- decoding needs processing power.

Examples:

- MPEG 1 Layer 3 (`.mp3`);
- Advanced Audio Coding (`.aac`);
- Ogg Vorbis (`.ogg`).

Note: Ogg Vorbis is intended to be 'patent-free'.

Processing support for sound

The Sonia Library

```
import pitaru.sonia_v2_9.*;

Sample sample;

void setup() {
  Sonia.start(this);
  sample = new Sample("scale.wav");
  sample.play();
}
void draw() {
  if(!sample.isPlaying())
    exit();
}
public void stop() {
  Sonia.stop();
  super.stop();
}
```

Synthesis

Mixing

Mixing:

- creates sound that is a combination of existing sounds;
- addition (linear combination) of existing waveforms;
- care required in addition: must not exceed allowed range;

Processing/Sonia support:

- multiple `Sample` objects can play simultaneously;
- `Sample.write()` method.

Synthesis

Additive Synthesis

Additive Synthesis:

- use sinusoids as building blocks of sound;
- add multiple sinusoids to get desired signal;
- can produce *any* signal in this way.

Processing/Sonia support:

- `Sample.write()` method;
- `LiveOutput` class.

Music

Equal Temperament

Western music: 12 equal-sized divisions to the octave.

- NB: not a cross-cultural Universal.

Each note has a frequency a factor of $\sqrt[12]{2}$ above the previous one.

- Note names: C, C♯, D, E♭, E, F, F♯, G, G♯, A, B♭, B.
- Beware: labels different in different countries.
- Interval between notes: *semitone*.

Conventionally: A above 'middle C' is 440Hz

Music

Harmonic Series

Sound production by instruments:

- production of *harmonics* as well as the *fundamental*;
- instruments based on lines produce harmonics at integer multiples of the fundamental frequency.

Perception of harmony and consonance:

- preference for small-integer frequency ratios;
- e.g. $\frac{3}{2}$, $\frac{4}{3}$, $\frac{5}{4}$, $\frac{5}{3}$.

Music

Rhythm

Organization of musical events in time

- scaffold for musical structure;
- hierarchical: beat, bar, phrase.