Sound System

Design, Sources, Scene

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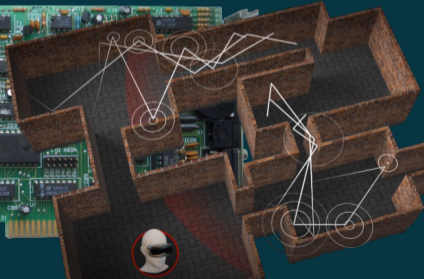DCGM, CPhoto@FIT
Faculty of Fine Arts
Game Media Studio

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INTRODUCTION

Sound in Games

- User Communication [2]
- Theme, Mood, Emotion [6]
- Movie × Game: Interaction
- Essential Part of Games [3]
  - User Interface
  - Interactive Sounds
  - Communication
  - World Immersion
- Long History
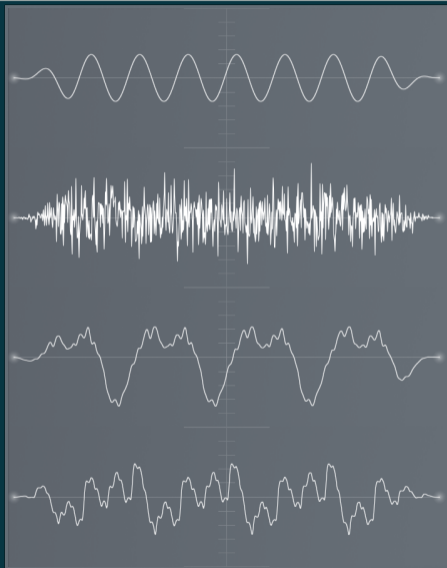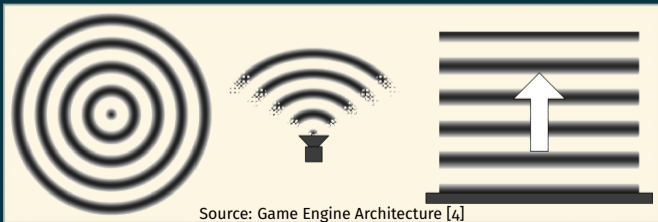- → Audio System

Sound Theory

- Compression Wave
  $p(t) = p_a(t) + p_s(t) \; [Pa]$
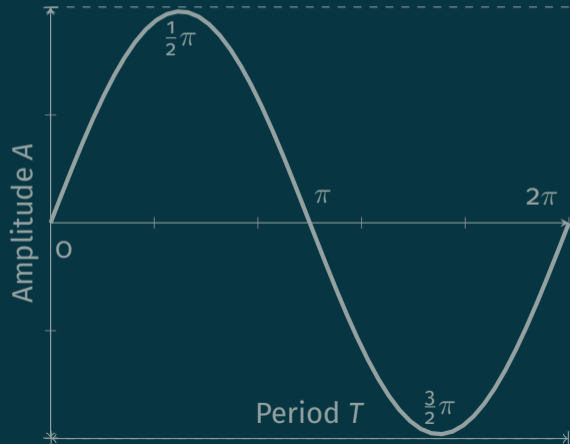- Change in Time $\rightarrow$ Signal
- Sound Sources
- Propagation in Medium
  - Wave Properties: Reflect, Refract, Diffract
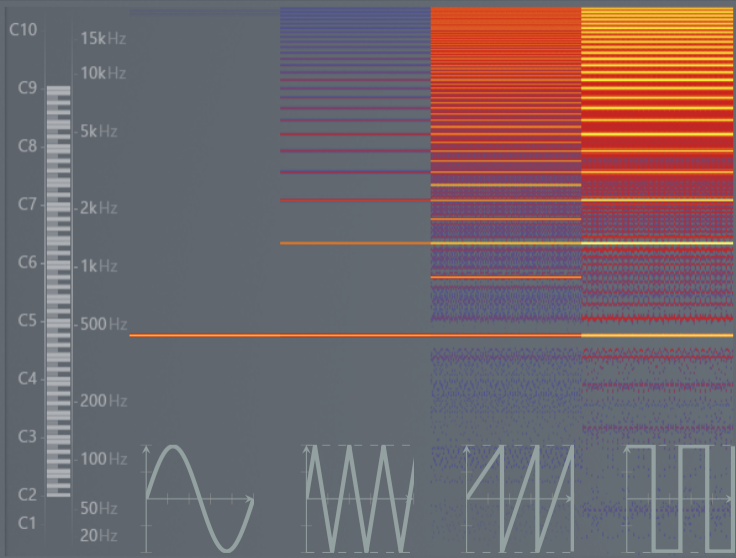 - Absorption & Falloff: $p \propto \frac{1}{r} \; I \propto \frac{1}{r^2}$

Source: Game Engine Architecture [4]

Sound Wave Attributes

- Periodic Nature

- Period T [s]
- Frequency f [Hz]
- Phase ϕ [rad]
- Speed v [ms^{-1}]
- Wavelength λ [m]
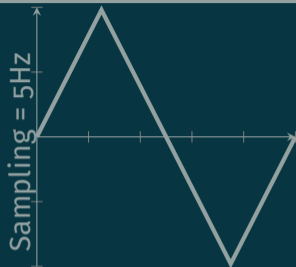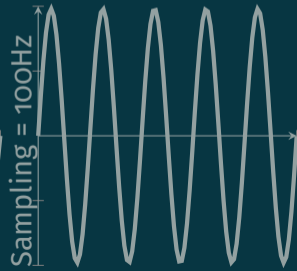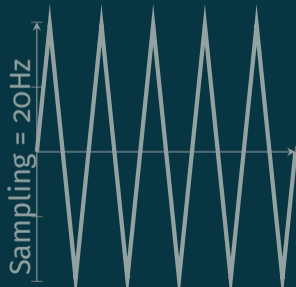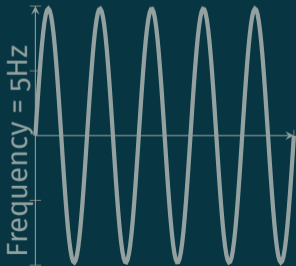
- Signal = Sinusoid Sum
- The Spectrum
- Fourier Transform
  time ⇄ frequency
- Wave Shapes
  - ‣ Sine
  - ‣ Triangle
  - ‣ Sawtooth
  - ‣ Square

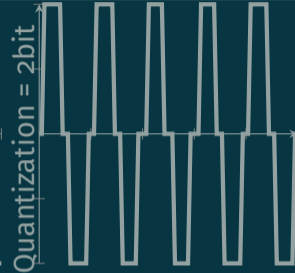- Analog → Digital
- AD & DA Converters
- Sampling Frequency
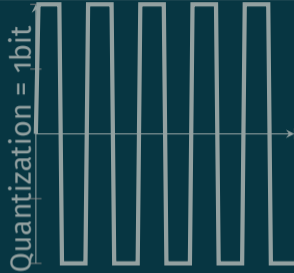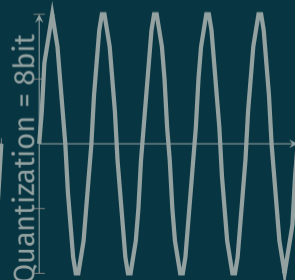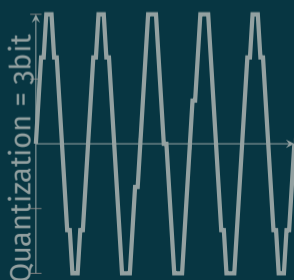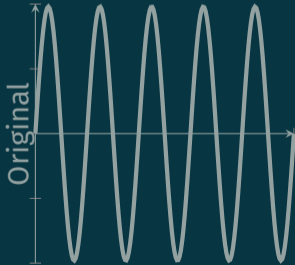 Nyquist–Shannon Theorem
- Quantization

SAMPLING

- Analog → Digital
- AD & DA Converters
- Sampling Frequency
  Nyquist–Shannon Theorem
- Quantization

- **Ear Construction [1]**
  - ‣ External Ear
  - ‣ Middle Ear
  - ‣ Internal Ear
  - ‣ Neural Encoding

- **Sound Loudness [4]**
  - ‣ Sound Pressure
  $$I \propto p_{rms}^2 = \sqrt{\frac{1}{t} \int p(t)^2 dt}$$
  - ‣ Wide Dynamic Range
  - ‣ Logarithmic → decibels [dB]
  - ‣ Sound Pressure Level (SPL)
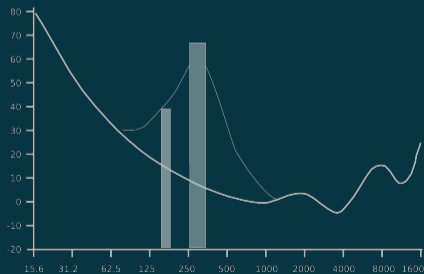 $$L_p = 10 \log_{10} \left(\frac{p_{rms}^2}{p_{ref}^2} \right)$$
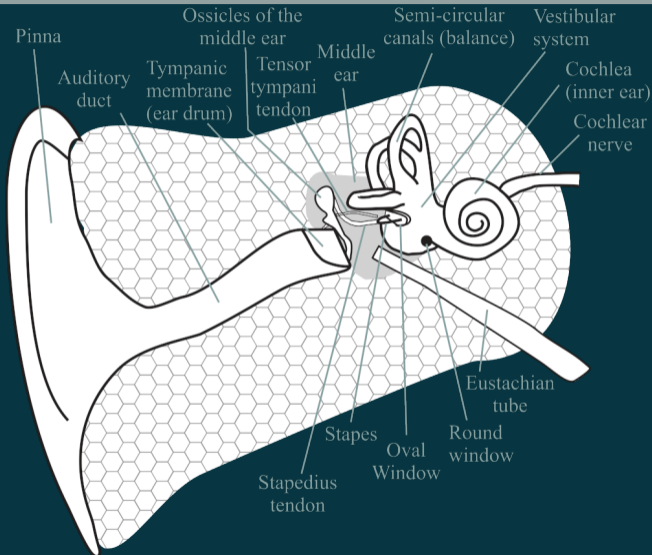
Source: Engineering Noise Control [1]
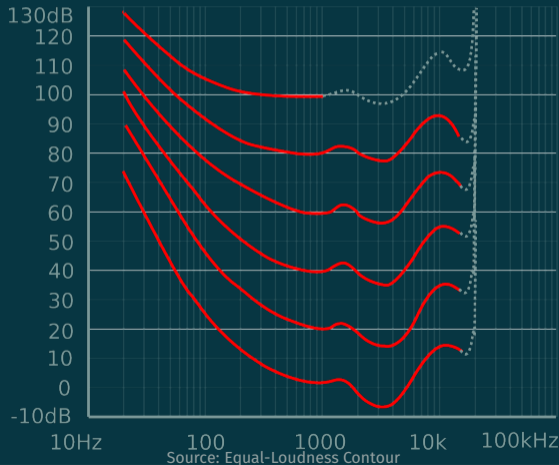
- Signal Processing → Perception
- Limits of Hearing : 20 *Hz*–20 *kHz*
- Psychoacoustics
  ‣ Fletcher-Munson Curve [5]
  ‣ Auditory Masking ⇄ [1]
- Gestalt Psychology

Source: Psychoacoustics

Source: Equal-Loudness Contour

Sound Design

HISTORICAL DEVELOPMENT: 8-BIT

- Arcade Machines [2]
  - Specialized Hardware
  - Digital Recording ⤳ DAC
  - Sound Synthesis ⤳ PSG
- Home Consoles [2]
  - Shared I/O Chip
  - Programmable Sound
  - Looping Tracks
- Personal Computers [2]
  - The Beeper
  - Programming & Memory

- **Programmable Sound Generator**
  - ‣ Voice Channels
  - ‣ Envelope & ADSR
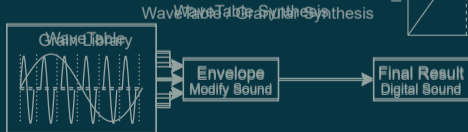- **Subtractive Synthesis 1**
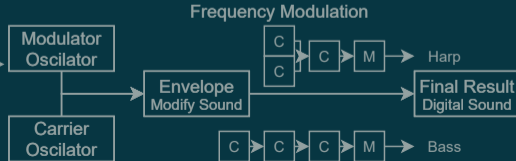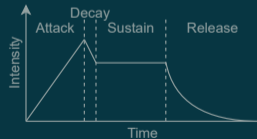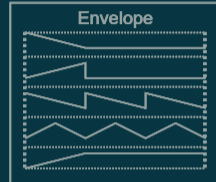- **Frequency Modulation Synthesis [2]**
  - ‣ Frequency Modulation (I) (II)
  - ‣ Synthesizer (I) (II)
- **Table-Based Synthesis**
  - ‣ WaveTable
  - ‣ Granular

Programmable Sound Generator

Channel	Frequency	Vol	Wave	Envelope
A	440	0.75	0.75	
B	293	0.50	0.50	
C	X	0.00	0.00	
...				
Noise	X	0.00	0.00	

Subtractive Synthesis

Oscillator Base Sound → Filter Cut Frequency → Amplifier Envelope → Final Result Digital Sound

Frequency Modulation

Modulator Oscillator
Carrier Oscilator
Envelope Modify Sound

C C C M → Harp

C C C M → Bass

Final Result Digital Sound

Decay
Attack Sustain Release
Intensity
Time

WaveTable and Granular Synthesis

Wave Table
Envelope Modify Sound → Final Result Digital Sound

- "Programmer-Composer"
- Sequencer → Synthesizer
- MIDI
  - ‣ Standard Format
  - ‣ Command Interface
  - ‣ Hardware Dependant Sound
- iMUSE [2] (I)
- Music Tracker (I)
- Digital Audio Workstation

- DAW → Samples & Synthesis
- Magic of Sound Design (I)
- Diegetic vs Nondiegetic [2]
- Music Track
- Sound Effects Library
- User Interface (I)
  - ‣ Digital
  - ‣ Mechanical
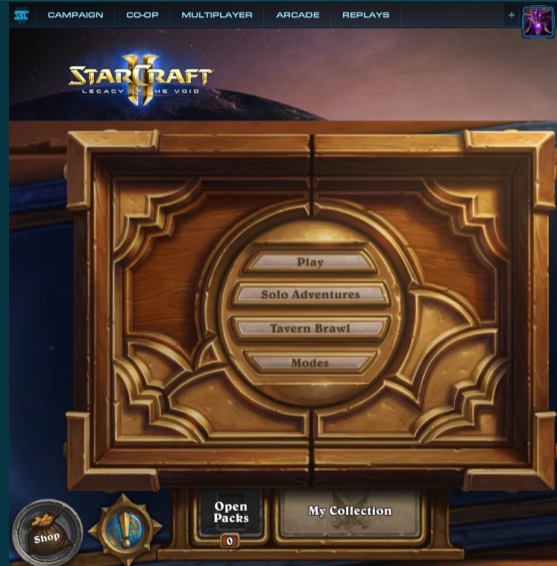
- Physical $\times$ Synthesis
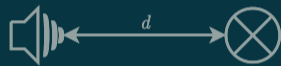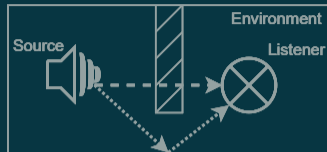- Recording + Touch Up
- Sound Effects
- Music & Voice
- Foley (I) (II)

Implementation

Rendering the Audio

- Direct PlayBack?
- Modeling the World [4]
  - ‣ Environment
  - ‣ Sound Sources
  - ‣ Listeners
- Sound Synthesis & Triggers
- Occlusion → Indirect
- Spatialization
  - ‣ Distance Attenuation $\frac{1}{d^2}$
  - ‣ Volume Panning
- Acoustic Modeling
- Doppler Shift
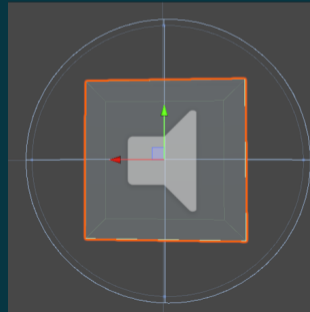- Real-Time Tricks

Source: Doppler Shift
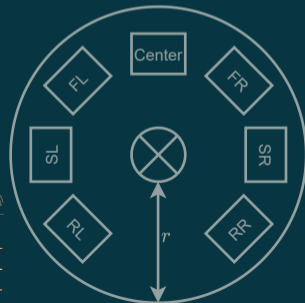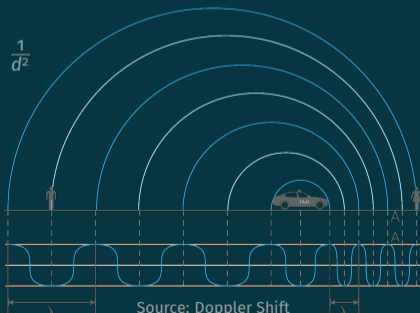
- Audio Processing Pipeline
- Sound Voices
  ‣ Degree of Polyphony
  ‣ 2D × 3D
- Voice Pipeline
- The Master Mixer
  ‣ Mixing Voices
  ‣ Depth & Rate Conversion
- Output Bus
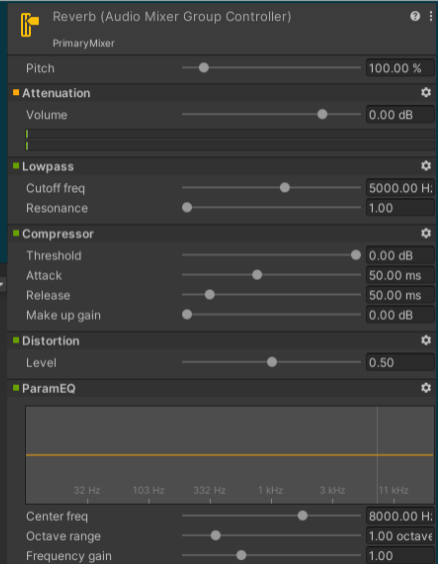- Audio Engines:
  ‣ System Audio
  ‣ FMOD
  ‣ Wwise
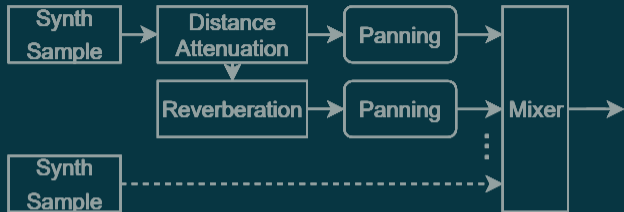
Audio in Unity

- Hierarchy Integration
- Audio Source & Listener
- 2D and Full 3D
- Audio Asset Support
- Profiler Section
- Tracker Modules

Audio Mixing

- Spatial Blending & Distance
- Equalizer → Groups
- Filters, Parametric Equalizer
- Effects: Reverb, Echo, …

ADDITIONAL RESOURCES

- [YouTube] Trackers: the sound of 16-bit
- [YouTube] Augmented Second - An Analysis of the Arabic Interval
- [YouTube] Signal Processing for Sound Design
- [YouTube] Magic of Making Sounds
- [Software] Sonic Pi

Source: Toxic Biohazard Synthesizer

Thanks For
Your Attention!

AudioSurf

[1] DAVID BIES. *Engineering Noise Control.* London: CRC Press, 2017. ISBN: 9781498724050.

[2] KAREN COLLINS. *Game sound: an introduction to the history, theory, and practice of video game music and sound design.* Mit Press, 2008.

[3] JAIME CROSS. *Game Audio and the 50% Fallacy.* https://speedyjx.com/2015/06/04/game-audio-and-the-50-fallacy/. 2015.

[4] JASON GREGORY. *Game Engine Architecture, Second Edition.* 3rd. USA: A. K. Peters, Ltd., CRC Press, 2018. ISBN: 1351974288.

[5] JARED H. *Fletcher Munson Curve: The Equal Loudness Contour of Human Hearing.* https://ledgernote.com/columns/mixing-mastering/fletcher-munson-curve/. 2021.

[6] DAVID SONNENSCHEIN. *Sound design: The expressive power of music, voice, and sound effects in cinema.* Michael Wiese Productions Studio City, 2001.