Lecture 16

Game Audio
The Role of Audio in Games

Engagement

- **Entertains** the player
  - Music/Soundtrack

- Enhances the **realism**
  - Sound effects

- Establishes **atmosphere**
  - Ambient sounds

- Other reasons?
The Role of Audio in Games

Feedback

- **Indicate** off-screen action
  - Indicate player should move

- **Highlight** on-screen action
  - Call attention to an NPC

- **Increase reaction** time
  - Players react to sound faster

- **Other reasons?**
History of Sound in Games

Basic Sounds

• Arcade games
• Early handhelds
• Early consoles
Early Sounds: *Wizard of Wor*
History of Sound in Games

Basic Sounds ➔ Recorded Sound Samples

- Arcade games
- Early handhelds
- Early consoles
- Starts with MIDI
- 5th generation (Playstation)
- Early PCs
History of Sound in Games

- Arcade games
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- Sample selection
- Volume
- Pitch
- Stereo pan
History of Sound in Games

- Basic Sounds
- Recorded Sound Samples
- Some Variability of Samples
- More Variability of Samples

- Arcade games
- Early handhelds
- Early consoles
- Starts w/ MIDI
  - 5th generation (Playstation)
  - Early PCs
- Sample selection
  - Volume
  - Pitch
  - Stereo pan
- Multiple samples
  - Reverb models
  - Sound filters
  - Surround sound
The Technical Challenges

• Sound **formats** are not (really) cross-platform
  • It is not as easy as choosing MP3
  • Android, iOS favor different formats

• Sound playback **APIs** are not standardized
  • Cocos2d is a layer over many different APIs
  • So behavior is not the same on all platforms

• Sound playback crosses **frame boundaries**
  • Mixing sound with animation has challenges
# File Format vs Data Format

**File Format**
- The data storage format
  - Has data other than audio
- Many have many encodings
  - .caf holds MP3 *and* PCM
- **Examples:**
  - .mp3, .wav
  - .aac, .mp4, .m4a (Apple)
  - .flac, .ogg (Linux)

**Data Format**
- The actual audio encoding
  - Basic audio codec
  - Bit rate (# of bits/unit time)
  - Sample rate (digitizes an analog signal)
- **Examples:**
  - MP3, Linear PCM
  - AAC, HE-AAC, ALAC
  - FLAC, Vorbis
## Data Formats and Platforms

<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
<th>iOS</th>
<th>Android</th>
</tr>
</thead>
<tbody>
<tr>
<td>MP3</td>
<td>You know what this is</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>(HE-)AAC</td>
<td>A lossy codec, Apple’s MP3 alternative</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Linear PCM</td>
<td>Completely uncompressed sound</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MIDI</td>
<td><strong>NOT SOUND</strong>; Data for an instrument</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Vorbis</td>
<td>Xiph.org’s alternative to MP3</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>ALAC</td>
<td>Apple’s lossless codec (but compressed)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>FLAC</td>
<td>Xiph.org’s alternative lossless codec</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>iLBC</td>
<td>Internet low bit-rate codec (VOIP)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>IMA4</td>
<td>Super compression for 16 bit audio</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>$\mu$-law</td>
<td>Like PCM, but optimized for speech</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
The Associated File Formats

<table>
<thead>
<tr>
<th>Format</th>
<th>File Types</th>
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<tr>
<td>MP3</td>
<td>.mp3</td>
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<td>(HE-)AAC</td>
<td>.aac, .mp4, .m4a</td>
</tr>
<tr>
<td>Linear PCM</td>
<td>.wav</td>
</tr>
<tr>
<td>MIDI</td>
<td>.mid</td>
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</table>

- Any other file format is **not cross-platform**
- Apple/iOS is pushing the .caf file
  - Stands for Core Audio Format
  - Supports MP3, (HE-)AAC, PCM, ALAC, etc…
  - But not cross-platform
Which Format is Best?

- **MP3** is *not free* to use in games!
  - Patent holders charge a license is on file usage
  - Only free if you sell less than 5000 games

- **Linear PCM** is *completely uncompressed*
  - The file size is huge for music, long sounds
  - Makes it unreasonable for portable use

- **AAC** is (believe it or not) the best
  - Apple charge the license only to the hardware maker
  - But you need iTunes to create the file
Cross-Platform Sound APIs

- **OpenAL**
  - Created in 2000 by Loki Software for Linux
  - Was an attempt to make a sound standard
  - Loki went under; last stable release in 2005
  - Apple supported, but HARD deprecated in iOS 9

- **FMOD**
  - Industry standard for game development
  - Mobile support is possible but not easy
  - Not free; but no cost for low-volume sales
Proprietary Sound APIs

- **Apple AVFoundation**
  - API to support modern sound processing
  - Mainly designed for music/audio creation apps
  - But very useful for games and playback apps

- **android.media**
  - A horrible API that proves there is no God
  - Missing significant basic functionality
  - Has many bad implications for Cocos2d
Solution: Cross-Platform Wrappers

- **SimpleAudioEngine**: The oldest Cocos audio engine
  - **Android**: Uses newer AudioEngine (was android.media)
  - **OS X**: OpenAL for sound effects, CoreAudio for music

- **AudioEngine**: New engine in cocos2d::experimental
  - **Android**: Uses OpenSL ES (sort-of cross-platform)
  - **OS X**: OpenAL for everything (and hence distortion)

- **SoundEngine**: Our custom class for CS 4152
  - **Android**: Uses OpenSL ES (sort-of cross-platform)
  - **OS X**: Uses AVFoundation for everything
Managing Sound Assets

- Sounds can be read from **file** or **preloaded**
  - Preloaded sounds will play immediately
  - Files will *stream* and have a slight playback delay

- Preloading uncompresses the file into **PCM format**
  - Okay (and preferred for) sound effects
  - Inappropriate for music or very large sounds

- This is motivation for SimpleAudioEngine API
  - It separates assets into *sound effects* and *music*
  - Only sound effects can be preloaded
Managing Sound Assets

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  • Preloaded sounds will play immediately
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Android cannot preload sounds!
Playing a Sound

• Playback may include **multiple sounds**
  • Sounds may play simultaneously (offset)
  • Simultaneous sounds may be same asset
  • **Asset (source) vs. Instance (playback)**

• Playback crosses **frame boundaries**
  • It may span multiple animation frames
  • Need to know when it stops playing
  • May need to stop (or pause) it early
Sound Engines are **Mixers**

Diagram showing a mixer connected to multiple sound instances.
Classic Model: Channels

Channel
Channel
Channel
...
Channel
Channel

Mixer
Classic Model: **Channels**

Engine has fixed number of channels (historically 24)
Classic Model: Channels

- Engine has fixed number of channels (historically 24)
  - Load sound into channel to play it

Diagram:
- Channel
- Channel
- Channel
- ...
Classic Model: Channels

Engine has fixed number of channels (historically 24)

Load sound into channel to play it
Playing a Sound with Channels

- **Request** a sound channel for your asset
  - If none is available, sound fails to play
  - Otherwise, it gives you a id for a channel

- **Load** asset into the channel (but might stream)

- **Play** the sound channel
  - Playing is a property of the channel, not asset
  - Channel has other properties, like volume

- **Release** the channel when the sound is done
  - This is usually done automatically
Application Design

Channel
Channel
Channel
...
Channel

Need to remember channel id

Mixer

Sound

Game Audio
AudioEngine API

- /**
  * @return channel id for sound playback
  *
  * If no channel is available, returns INVALID_AUDIO_ID
  *
  * @param file The source of the sound (may be preloaded)
  *
  * @param loop Whether to loop indefinitely
  *
  * @param volume The sound volume
  */
  int play2d(const string& file, bool loop, float volume);

- void stop(int audioID);

- void setLoop(int audioID, bool loop);

- void setVolume(int audioID, float volume);

- bool setCurrentTime(int audioID, float time);

Need to remember channel id
Why This is Undesirable

- Tightly couples architecture to sound engine
  - All controllers need to know this channel id
  - Playback must communicate the id to all controllers

- Instances usually have a *semantic meaning*
  - **Example**: Torpedo #3, Ship/crate collision
  - Meaning is independent of the channel assigned
  - Would prefer to represent them by this meaning

- **Solution**: Refer to instances by *keys*
The SoundEngine Alternative

- /**
  * Plays given sound as a sound effect (paging out as necessary)
  *
  * @param key the reference key for the sound effect
  * @param sound the sound effect file to play
  * @param loop Whether to loop indefinitely
  * @param volume The sound volume
  */
  
  void playEffect(string key, Sound* sound, bool loop, float volume);

- void stopEffect(string key);

- void setEffectLoop(string key, bool loop);

- void setEffectVolume(string key, float volume);

Refer to instance logically
Problem with the Channel Model

• All controls are embedded in the channel
  • **Example**: Volume, looping, play position
  • Restricted to a *predetermined* set of controls

• Modern games want *custom sound-processing*
  • User defined sound filters (low pass, reverb)
  • Advanced equalizer support
  • Support for surround and 3D sound
  • Procedural sound generation
DSP Processing: The Mixer DAG
DSP Processing: The Mixer DAG

Channel model is a special case of this DAG
Example: UDK Kismet

Warehouse section

Turn on power?
  Trigger: Used

Already On?
  Boolean

WAREHOUSE AREA ON
  Play Sound
  Play Out

Bool
  In
  Out
  Value
  Target

WAREHOUSE AREA OFF
  Play Sound
  Play Out

Bool
  In
  Out
  Value
  Target

Delay (6.03)
  Start
  Finished

Toggle
  Turn On
  Turn Off
  Target

rattle 1
  music
  Ambience 1

rattle 2
  bass
  Ambience 3

rattle 3
  Ambience 5

rattle 4
  rattle 4

rattle 5
  rattle 5

Ambience 2
  rattle 3

Ambience 4
  rattle 4

Ambience 5
  rattle 5
AVFoundation Implementation

Load with file or PCM data

**AVAudioPlayerNode**

**AVAudioNode**

**AVAudioPlayerNode**

**AVAudioNode**

**AVAudioMixerNode**
Provided AVAudioNodes

• **AVAudioUnitEQ**
  • Support for equalizer and low pass/high pass filters

• **AVAudioUnitDistortion**
  • Support for custom distortion effects

• **AVAudioUnitReverb**
  • Support for custom reverb effects

• **AVAudioEnvironmentNode**
  • Support for *positional* and 3D audio
Stopping Sounds

- Would like to know when a sound is finished
  - To free up the channel (if not automatic)
  - To stop any associated animation
  - To start a follow-up sound

- Two main approaches
  - **Polling**: Call an `isPlaying()` method
  - **Callback**: Pass a function when play

- `SoundEngine` only allows polling approach
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- `SoundEngine` only allows polling approach
Positional Audio: Surround Sound

Sub

Left Front

Center

Right Front

Left Surround

Center

Right Surround

Left Rear Surround

Player

Right Rear Surround

Game Audio
Positional Audio: Surround Sound

Sub
Left Front
Center
Right Front
Left Surround
Left Rear Surround
Game Audio
Right Rear Surround
Positional Audio: Surround Sound

Original source must be mono to work properly

- Sub
- Left Front
- Center
- Right Front

- Left Surround
- Right Surround

- Left Rear Surround
- Right Rear Surround

Game Audio
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</tr>
<tr>
<td>listenerPosition</td>
<td>Location of the listener</td>
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<tr>
<td>listenerVectorOrientation</td>
<td>Facing orientation of the listener</td>
</tr>
<tr>
<td>obstruction</td>
<td># decibels to reduce sound from source (Affects direct sound, but not reverb)</td>
</tr>
<tr>
<td>occlusion</td>
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<td>Amount reverb to add to scene</td>
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## AVAudioEnvironmentNode API

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- **obstruction** and **occlusion**: Do **not** compute physics.
Modeling Sound Environments

Must compute the obstacle/occlusion values separately.
Advanced: Reverb Calculations

- Uses audio raytracing
- Also material reflection
- No AVFoundation support
Advanced: Reverb Calculations

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Area of active development in AAA games
### AVAudioEnvironmentNode API

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So what does this actually do?
AVAudio3DMixingRenderingAlgorithm

- AVAudio3DMixingRenderingAlgorithmStereoPassThrough
  - **Turns off positional** rendering and uses source encoding

- AVAudio3DMixingRenderingAlgorithmEqualPowerPanning
  - Pans the volume across **two stereo channels**

- AVAudio3DMixingRenderingAlgorithmSoundField
  - Positional audio for **surround sound**

- AVAudio3DMixingRenderingAlgorithmSphericalHead
  - **Binaural synthesis** assuming a spherical head

- AVAudio3DMixingRenderingAlgorithmHRTF
  - **Binaural synthesis** with the Head Related Transfer Function
Binarual Synthesis

• Positional sound is fakey
  • Essentially volume control
  • Cannot pinpoint source

• **Goal**: realistic perception
  • Track the sound parallax
  • Account for shape of head

• Limited to headphones
  • Cannot do speakers (yet)

• **Example**: Papa Sangre

---

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- **Goal**: realistic perception
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- **Example**: Papa Sangre
Example: Papa Sangre

SEE WITH YOUR EARS.
MOVE WITH YOUR FEET.
Summary

- Audio design is about creating soundscapes
  - Music, sound effects, and dialogue
  - Combining sounds requires a sound engine

- Cross-platform support is a problem
  - Licensing issues prevent a cross-platform format
  - Very little standardization in sound APIs

- Best engines use digital signal processing (DSP)
  - Mixer graph is a DAG supporting sound effects
  - Some limited support for positional audio