Sound in Games and Movies
Overview

• Sound in Unity
• Foley sound
• Physically based sound
  – Sound generation research
  – Sound propagation research
Unity Sound

• Sound is generated audio clips
  – Some audio clips can be found in asset store.

• Two types of sounds: Mono and Stereo
  – Mono for ambient sound
  – Stereo for music

• An audio clip is attached to a game object

• Use script to control it

• See the demo.
Foley Sound

- Foley effect, Foley sound, Foley art, Foley...
- Invented by Jack Donovan Foley in 1927
- Produce fake ambient sound in movies
  - Walking on floors
  - Cloth
  - Door noise
  - Gun fire
  - Many other sound
Foley Example

• A pair of gloves sounds like bird wings flapping
• An old chair makes a controllable creaking sound
• A heavy staple gun combined with other small metal sounds make good gun noises
• A metal rake makes a fence sound
• Coconut shells cut in half and stuffed with padding makes horse hoof noises
• A heavy phone book makes body-punching sounds
• Acorns, small apples and walnuts on wooden parquet surface can be used for bones breaking
Sound Physics
Properties of Sound Waves

• Speed: \( v = f \lambda \)
• Speed in air is (approx) 344 m/s.
• Speed in aluminum (longitudinal (sound) waves) is (approx) 5000 m/s (~3 miles/s).
• Longitudinal waves usually travel faster than transverse
• In general, speed is a function of frequency; important for solid materials.
Modal Vibration Sound Models

• Simple but effective sound model for many hard objects
• Modal vibration model accounts for
  – Shape of the object (related to frequency spectrum)
  – Location of the impact (related to tone quality of sound)
  – Material of the struck object (via internal friction)
  – Force of the impact (related to amplitude of emitted sound)
• Some related work...

- Introduced modal *sound maps*
- Details on whiteboard
- (1996 preprint online)

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First 9 eigenfunc’s of square plate

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Figure 1: Sound Pipeline.
An interesting aside...

“Can one hear the shape of a drum?”

- Example of a planar isospectral domain:

![Diagram](http://hilbert.dartmouth.edu/~doyle/docs/drum/drum/drum.html)

**Figure 1:** Homophonic domains. These drums sound the same when struck at the interior points where six triangles meet.
Modal sound maps can be scanned from real objects

\[ y_k(t) = \sum_{n=1}^{N} a_{nk} e^{-d_n t} \sin(2\pi f_n t) \]

Figure 9: Contact sound measurement

Figure 10: The power spectrum of two recorded impulse responses, their average, and the power spectrum of the background noise. The 20 most important peaks are indicated on the graph. The “best” peaks are those considered to stand out from their surrounding most clearly by “local height”

- Automatic way to generate ambient sound effects for games/movies
- Some examples: http://recherche.ircam.fr/equipes/analyse-synthese/lagrange/demos/rolling/foley.html

- Brute force computation of sound emission for deformable objects
- FEM with explicit time-stepping
  - $dt = 10^{-6} - 10^{-7}$
- Captures effects of larger deformations
- Acoustic pressure: $p = z \mathbf{v} \cdot \hat{n}$
- Sound emission: $s = \frac{\tilde{p} a \delta_{\bar{x} \rightarrow r}}{||\bar{x} - r||} \cos(\theta)$
- Delay based on distance: $d = \frac{||\bar{x} - r||}{c}$

Figure 4: One-dimensional accumulation buffer used to account for travel time delay.

<table>
<thead>
<tr>
<th>Example</th>
<th>Figure</th>
<th>Simulation $\Delta t$</th>
<th>Nodes</th>
<th>Elements</th>
<th>Surface Elements</th>
<th>Total Time</th>
<th>Audio Time</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowl</td>
<td>1</td>
<td>$1 \times 10^{-6}$ s</td>
<td>387</td>
<td>1081</td>
<td>742</td>
<td>91.3 min</td>
<td>4.01 min</td>
<td>4.4%</td>
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<tr>
<td>Clamped Bar</td>
<td>5</td>
<td>$1 \times 10^{-7}$ s</td>
<td>125</td>
<td>265</td>
<td>246</td>
<td>240.4 min</td>
<td>1.26 min</td>
<td>0.5%</td>
</tr>
<tr>
<td>Square Plate (on center)</td>
<td>6.a</td>
<td>$1 \times 10^{-6}$ s</td>
<td>688</td>
<td>1864</td>
<td>1372</td>
<td>245.0 min</td>
<td>8.14 min</td>
<td>3.3%</td>
</tr>
<tr>
<td>Square Plate (off center)</td>
<td>6.b</td>
<td>$1 \times 10^{-6}$ s</td>
<td>688</td>
<td>1864</td>
<td>1372</td>
<td>195.7 min</td>
<td>7.23 min</td>
<td>3.7%</td>
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<tr>
<td>Vibraphone Bar</td>
<td>8</td>
<td>$1 \times 10^{-7}$ s</td>
<td>539</td>
<td>1484</td>
<td>994</td>
<td>1309.7 min</td>
<td>5.31 min</td>
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<tr>
<td>Swinging Bar</td>
<td>9</td>
<td>$3 \times 10^{-7}$ s</td>
<td>130</td>
<td>281</td>
<td>254</td>
<td>88.4 min</td>
<td>1.42 min</td>
<td>1.6%</td>
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<tr>
<td>Rigid Sheet</td>
<td>10.a</td>
<td>$6 \times 10^{-7}$ s</td>
<td>727</td>
<td>1954</td>
<td>1438</td>
<td>1041.8 min</td>
<td>7.80 min</td>
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<tr>
<td>Compliant Sheet</td>
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<td>313.1 min</td>
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<tr>
<td>Bent Sheet</td>
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<td>$1 \times 10^{-7}$ s</td>
<td>678</td>
<td>1838</td>
<td>1350</td>
<td>1574.2 min</td>
<td>6.45 min</td>
<td>0.4%</td>
</tr>
</tbody>
</table>

Table 1: The total times indicate the total number of minutes required to compute one second of simulated data, including graphics and file I/O. The audio times listed indicate the amount of the total time that was spent generating audio, including related file I/O. The percentages listed indicate the time spent generating audio as a percentage of the total simulation time. Timing data were measured on an SGI Origin using one 350 MHz MIPS R12K processor while unrelated processes were running on the machine’s other processors.
Rigid Body Sound Synthesis

• Brute-force simulation is expensive. How to solve this problem?

• Pre-computation!
  – We can form a sound database
  – We use those sounds to synthesize novel sounds.

• Some examples
  – [https://www.youtube.com/watch?v=nHH8N_INZzI#t=39](https://www.youtube.com/watch?v=nHH8N_INZzI#t=39)
  – [https://www.youtube.com/watch?v=qcqGaYRYfFA](https://www.youtube.com/watch?v=qcqGaYRYfFA)
  – Still under research
Other Sound Generation Examples

• Textured object
  – https://www.youtube.com/watch?v=JOwTrmgVK4k

• Liquids
  – https://www.youtube.com/watch?v=MHBViinfmKo
Sound Propagation

- Various approximations of sound wave propagation
- Specular reflection and diffraction phenomena important
- For a good summary, see

Figure 4: Sound waves impinging upon a surface usually reflect specularly and/or diffract at edges.

Figure 5: Interference can occur when two sound waves meet.
Wave Propagation Methods

- Solve wave equation explicitly
- FEM, BEM, or ...
- Expensive
- Ineffective for real-time acoustics

Figure 6: Boundary element mesh.
Geometric Sound Propagation

- Ray-tracing (& beam-tracing)
- High-frequency approximation (without diffraction)

![Impulse response](image)

**Figure 7:** Impulse response (left) representing 353 propagation paths (right) for up to ten orders of specular reflections between a point source and a point receiver (omnidirectional) in a coupled-rooms environment (two rooms connected by an open door).
Pre-computed Sound Propagation

• Efficient, useful for games

• Interactive Sound Rendering, SIGGRAPH COURSE, 2009

• Some examples
  – https://www.youtube.com/watch?v=lRRmi5YfwuM
  – https://www.youtube.com/watch?v=MQt1jtDBNK4