Sound and Animation

Paper Summaries

• Any takers?

• This week is the last week for paper summaries.

Announcements

• AniFest 04
  – Western Connecticut State University
  – [http://149.152.225.94/festival04.html](http://149.152.225.94/festival04.html)
  – Deadline for submission: Feb 28th
  – See me for more details

Announcements

• Want to learn Maya?
  – 2001-753
  – 3D Modeling in Maya
  – Designed for gamers and non-design majors
  – Contact: Marla Schwappe
    • mkspph@rit.edu

Grad Report

• Presentations:
  – February 11th – Next Wednesday.
• Written reports
  – Due by Feb 18th – last class.

Projects

• Final Reports
  – Note that final reports / code are SEPARATE grading components
  – Final reports/code are due on the last day of class (Feb 18th)
Projects

- Final Report
  - Textual description of your system
  - Sections
    - Problem/Project Description
    - Approach
    - Implementation
      - Overall System Architecture
      - Overall Program Architecture
      - Description of major data structures / objects
  - Results / User Documentation
  - Future Enhancements
  - Appendix – All Code listings

Assignments

- Assignment #1
  - Submitted and graded
- Assignment #2
  - Grace period ends today
- Assignment #3
  - Due Feb 11th (next Wednesday)

Plan for today

- Sound and Animation

About Monday’s class….

- Today: Sound and Animation
- Monday:
  - Project day
    - No lecture
    - Will be in office
- Wednesday: Grad Reports
- Following Week:
  - Project Presentations

Motivation Films

- Animations by Wayne Lytle
  - Visualization Guru at Cornell Theory Center
  - Quit to start Animusic in 1995

Motivational Film

- More Bells and Whistles (1990)
  - Lytle wrote the code for each band member
  - Motion is MIDI controlled
  - First of several Animusic pieces to be shown at SIGGRAPH
Motivational Film

• Pipe Dream (2001)
  – Animusic
  – Can’t See too much Animusic
  – Sound drives motion

Motivational Film

• Train Wreck (2003)
• Martin Burolla
• From last year’s animation class

Sound and Animation

• Issues in Sound and Animation
  – Sound Generation
    • What do we play?
  – Sound Synchronization
    • When do we play?
  – Spatial Sound
    • Where do we play

Sound

• What is sound?
  – From webster.com
    • mechanical radiant energy that is transmitted by longitudinal pressure waves in a material medium (as air) and is the objective cause of hearing

Sound

• What is sound?
  – Sound can be described as a 1 dimensional signal in time
    \[ \text{sound} = f(t) \]

Remember this?

• Spatial vs frequency domains
  – Most well behaved functions can be described as a sum of sin waves (possibly offset) at various frequencies
  – Describing a function by the contribution (and offset) at each frequency is describing the function in the frequency domain
Sound

• A mathematical description of an audio signal:

\[ f(t) = \sum_{i=0}^{\infty} A_i \sin(2\pi f_i t + \phi) \]

Contribution/amplitude frequency phase

Sound: Loudness

• Looking at sound in the temporal domain
  – Sound can be described as a 1 dimensional signal in time
  – Signal values represent amplitude.
  – We perceive the effect of amplitude as loudness.

Sound: Pitch

• Looking at sound in the frequency domain.
  – Humans “hear” sounds because of periodicities in the audio signal.
  – Humans perceive frequency as the sensation of pitch.
  – Humans can perceive pitches due to periodicities ranging from 20 – 20000 vibrations / sec (Hz).

Sound: Pitch

• Remember our discussion of CD audio
  – sampling rate of 44,100 samples/sec
  – \( \Delta = 1 \) sample every 2.26x10^-5 seconds
  – CDs can accurately reproduce sounds with frequencies as high as 22,050 Hz.

Sound: Timbre

• Tone quality of a sound
• Formally defined as
  – Characteristic of sound not due to amplitude and pitch.
• Also defined
  – Quality of tone that distinguishes between musical instruments
  – Sound shape
Sound: Timbre

- Timbre is the perception of the “spectral makeup” of a signal.
  - Adding non-fundamental frequency to the signal.
  - Another annoying audio applet – Timbre

Sound: Summary

<table>
<thead>
<tr>
<th>Physical Characteristic</th>
<th>Perceptual Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>Loudness</td>
</tr>
<tr>
<td>Frequency</td>
<td>Pitch</td>
</tr>
<tr>
<td>Spectral “shape”</td>
<td>Timbre</td>
</tr>
</tbody>
</table>

Sound Generation

- So how does one generate sound for animation?
  - Easiest means
    - Recording / Sampling -- Still the primary means for sound generation in the film industry
    - Using sampled sound – Still the primary means for sound use in games.

- When talking about digital (sampled sound)
  - The process of digitizing is called pulse code modulation (PCM).
  - PCM == sampled sound
    - WAV
    - AIFF
    - MP3 (compressed PCM)

Sound Generation

- Additive Synthesis
  \[ f(t) = \sum_{i=0}^{\infty} A_i \sin(2\pi \omega_i t + \phi_i) \]
  - Define values for \( A_i \), \( \omega_i \), and \( \phi_i \)
  - Calculate sin and add
  - Alternately, do in the addition in frequency space.

- Subtractive Synthesis
  \[ f(t) = \sum_{i=0}^{\infty} A_i \sin(2\pi \omega_i t + \phi_i) \]
  - Start with noise (equal energies at all frequencies)
  - Subtract contribution of frequencies from noise.
Sound Generation

- Granular Synthesis
  - Like particle system
    - Combine a multitude of sound “grains” into a sound events
    - Questions

Sound Synchronization

- Sound must be synchronized to the motion
  - Methods:
    - Motion driving sound
      - Defining Sound events
      - Deriving timbre from motion
    - Sound driving motion

Sound Synchronization

- Generating sound from physical simulation
  - Video examples

Sound Synchronization

- Sound driving motion
  - MIDI
    - Designed as a communication mode between sythesizers, samplers, instruments, computers
    - Sound events
      - Pitch
      - Devices
    - Used by Animusic in creating their videos

Spatial Sound

- Sounds (and listeners) have spatial positions
  - 3D sound
    - Making sounds appear as if they are emitted from a given position accounting for listener position
  - Reverberation
    - Filtering of sound based on reflection off of environment
  - Doppler Effect
    - Change in pitch due to moving objects

3D Sound

- Making sounds appear as if they are emitted from a given position accounting for listener position
  - Head related transfer functions (HRTF)
  - Audio cubes / surround sound
    - Strategic placing of speakers
3D Sound: HRTF

- a description of all the physical cues of sound localisation.
  - Implemented as filters
  - function of four variables: ie three space coordinates and frequency.
  - Determined by measurement

3D Sound: reverberation

- Like light, sound can be seen as traveling in 3D environment in rays.
- Unlike light, sound travels much slower
  - Speed of sound:
  - Speed of light

3D Sound: reverberation

- Reverberant sound is the collection of all the reflected sounds in an enclosed space
- Acoustics
- Reverb Time = time required for sound to decay one millionth of the original power

3D Sound: reverberation

- Examples
  - From BKL Consultants Ltd. (http://www.bkla.com/reverb.htm)
  - No reverb
  - 0.8 sec reverb time
  - 1.5 sec reverb time
  - 5.0 sec reverb time
3D Sound: Doppler effect

• Non-annoying applet

Sound: Putting It all Together

• Sound Rendering Video Examples

Sound: Putting It all Together

• Questions?

• Break!

Remember CGII: Procedural Shading

• Shade Trees [Cook84]
  – Shading calculated by combining basic functional operations.
  – Operations are organized in a tree.
    • Nodes - Operations
    • Children - operands
  – Result of shade tree evaluation is a color
  – Equiv to parse tree (compiler design)
  – Basis of Renderman shading language.
Remember CGII: Procedural Shading

- Shade Trees - example…copper

Remember CGII: Procedural Shading

- Basic ideas behind shade trees:
  - Describe textures / shading functionally
  - Using Parameters from 3D world

- Can we use a similar model for sound?

Timbre Trees

- Functional sound synthesis
  - Sound related functions
    - Periodic functions
    - Convolution
    - Noise
    - Filtering
  - Nodes for animation, 3d parameters

Timbre trees

- Nodes could also be used to simulate:
  - Reverberation
  - Delay
  - Spatial Sound
Timbre Trees

- What we failed to realize
  - Functional sound, unlike functional textures, was far from novel...
  - Quite popular in the Computer Music circles
    - Nyquist -- CMU
    - csound – MIT (basis of MPEG-4 Structured Audio)
  - However…

Genetic Texture

\[
\sin \left( \sqrt{-\left( \text{grad-direction} \left( \text{blur} \left( \text{if} \left( \text{hsv-to-rgb} \left( \text{warped-color-noise} \left(0.57, 0.73, 0.92\right) \cdot \left(1.85 \left(\text{warped-color-noise} x, y \cdot 0.02 \cdot 3.08\right) / (0.54 \left(0.73, 0.59\right) \cdot \left(1.06, 0.82, 0.06\right) / 3.1\right) \cdot 1.46 \cdot 5.9\right) \cdot \text{hsv-to-rgb} \left(\text{warped-color-noise} y \left(4.5 \left(\text{warped-color-noise} y \left( x, y \right) \cdot 2.4 \cdot 2.4\right) \cdot 0.02 \cdot 2.4\right)) x\right) \right) \right) \right) \right) \right) + 1.465.9)
\]

[Sim91]

Genetic Sound

- Since Timbre trees were nothing more than functional description of sound (using LISP expressions)
  - Experimentation with genetic manipulation was natural

Timbre Tree

- Video examples

Good news about this research

- Sound now integrated as part of rendering pipeline
  - DirectSound
  - VRML2.0
  - openAL

Bad news about this research

- Sound effects for motion pictures is still done using foley artists
Questions

• Next time
  – No lecture