Sound Technology in Games

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Graphics Lunch Series

Spring 2007

Outline

- Audio Pipeline, Hardware and APIs
- Audio Games
- Sound in Virtual/Augmented Reality Environments Console Gaming
- Will not cover:
  - HRTF
  - Audio Synthesis
    - Analog to Texture synthesis

Motivation: User Immersion

- "Game audio is judged against all audio played on that system. We must not just meet those standards but exceed them." [Marty O'Donell 2002 about Halo]
- Sound "serves the story, creates a mood, … and can be the key to bringing the visuals to life." [LoBrutto,1994]
- 20% of perception is acoustic [Dobbler et. Al. 2002]
- Screen space limited
  - Can hear what is going on around you and what is approaching you from off screen

Aural Rendering Pipeline: Goals

- 3D localization
  - Head related impulse response
- Room Simulation
  - Room related impulse response
- Speed and efficiency
  - Balance number of sources against real time constraints
- Output
  - Stereo, Surround Sound (e.g. Dolby 5.1, 7.1)

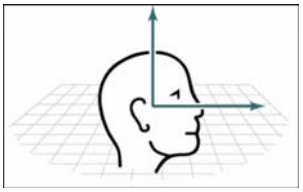
Aural Pipline

Basic Elements

- Buffers
  - Primary
  - Secondary
- Sound Sources
- Listener
  - Position
  - Orientation
  - Velocity

Enhanced Elements

- Directionality
- Doppler Shift
- Effects

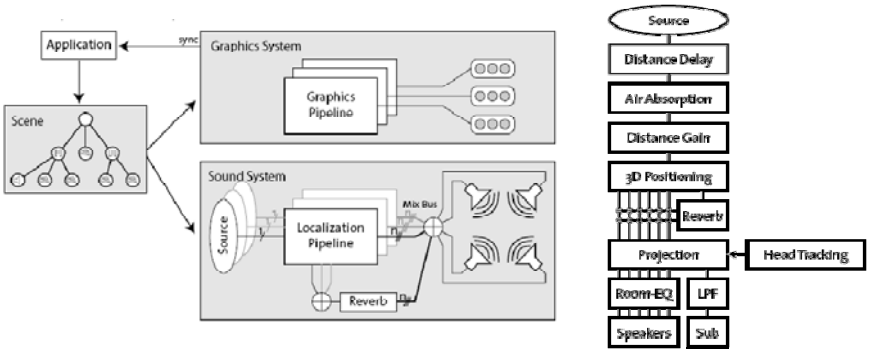


Adapted from [Dobler 2004]

Aural Pipeline: Functionality

- Playback
  - Play
  - Pause
  - Stop
  - Rewind
  - Loop
- Notifications
  - Important for synchronization
- Volume/Gain
  - Adjustable
    - Smooth fades
    - Panning / Positioning
  - Relative vs. absolute
    - Relative more practical
- Frequency
  - Resampling
  - Pitch shifting

Aural Pipeline



Images from: [Naef, 2002]

Aural Pipeline: Distance

- Volume doubles when distance is halved
  - Inverse square law
  - Measured in Decibels
- Problem
  - Limited Dynamic Range
- Minimum distance
  - Sound does not get louder when source is closer
- Maximum distance
  - Volume does not decrease when source is farther
    (Like Near and Far Planes)

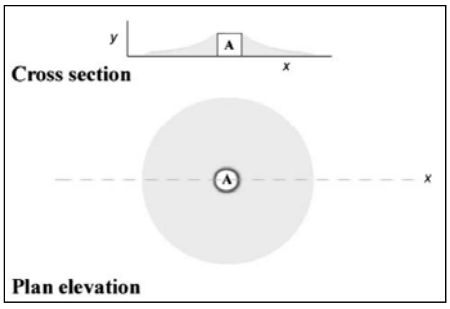


Image from [Schutze, 2003]

Distance and Scale

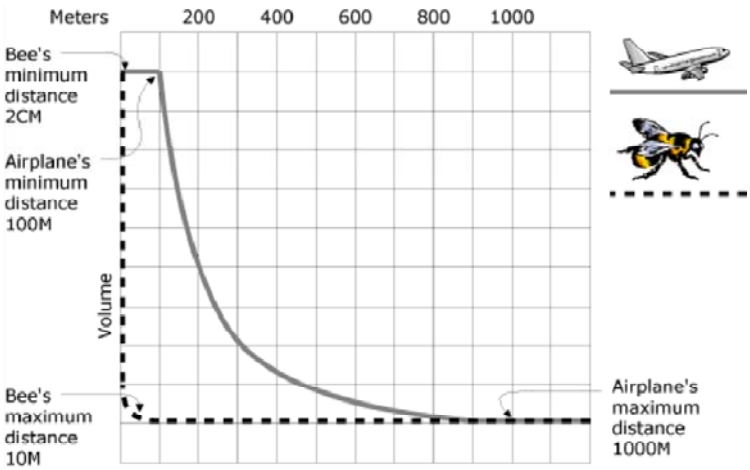


Image from DirectX documentation

Audio Engines

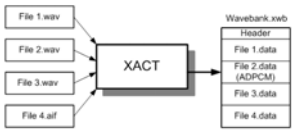
- Microsoft DirectX
- OpenAL
- fMod
- Miles
- Java 3D

Direct Sound

- Part of DirectX
- Platform for Windows and Xbox
- Features
  - HRTF integration
  - Audio effects
    - Filters
    - One primary buffer
    - Secondary buffers limited by sound card
- DirectX 10 and XNA
  - Deprecates audio hardware requirements in favor of software rendering

XACT

- Microsoft Cross-Platform Audio Creation Tool
  - Windows and Xbox
- Replaces Direct Sound
- Wave Banks
  - Collections of wave files logically combined into a single file
- Sound Banks
  - Collections of sounds and cues
    - Sounds: One or more waves along with how to play waves
      - e.g. volume, pitch, play, pause etc…
    - Cues: Triggers to play a sound
      - synchronized with game events



I3DL2

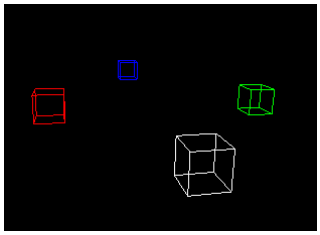
- Interactive 3D Audio Rendering, Level 2 (1999)
- Standard for Simulating
  - 3D position
  - Environmental reverb
  - Occlusion materials

from [Selfon GDC05]

- Challenges
  - Multiple players, one set of speakers
  - Complex geometry
    - Rivers, non-cube rooms
  - AI Response to sound propogation

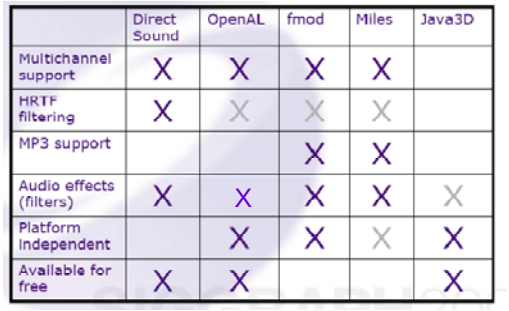
OpenAL

- Founded by Terry Sikes and Bernd Kreimeier @ Loki
  - Ported Windows games to Linux
- Subsequently taken over by Creative (~ 2000)
  - With support from Apple
- Goal: Platform independent Audio API
  - Styled after OpenGL
  - ALUT similar to GLUT
    - Deprecated
- Used in VRJuggler via SONIX
- Under active development
- Demo…



Other Audio Engines

- Commercial Engines
  - Miles
    - RAD Game Tools
    - Various Render Engines
  - fmod
    - Free for Non-Commercial use
- Java3D sound API
  - Intelligent class structure
  - Limited to Stereo output
  - Not very popular



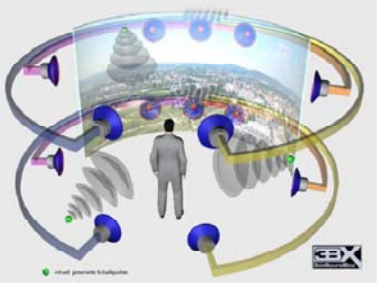
	Direct Sound	OpenAL	fmod	Miles	Java3D
Multichannel support	X	X	X	X	
HRTF filtering	X	X	X	X	
MP3 support			X	X	
Audio effects (filters)	X	X	X	X	X
Platform independent		X	X	X	X
Available for free	X	X			X

TRIPS [Neumann, 2003]

- Spatial Audio System for more complicated scenes
- Built on top of OpenSG
  - Scene Graph system for Virtual Reality
  - Multi-threaded
  - Handles OpenGL primitives, and transformations
  - Flexible geometry
  - Multiple inputs and outputs
- Adds two audio nodes
- Uses fMod spatial audio engine

3deSoundBox [Stampfl, 2003]

- Platform independent
- Scalable
  - Can drive any number of speakers
  - Master/Slave system similar to routers
- No CPU cost
  - External device computes spatial audio



Curved screen with 2 sound boxes
driving 14 speakers
Image courtesy of: [Stampfl. 2003]

Retained Mode [Gehring 2000]

- Render 3D audio in advance
  - Like retained mode in graphics
- Can use lots of filters: HRTF and room
- Process during initialization
- Very small hit to CPU during runtime

- *Seems to be used in Java3D*

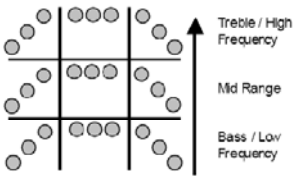
Audio Games

- "Games for the hearing"
  - Similar to video games, but only feedback is audible
  - Originally started for visually impaired
- Growing gap between visual and audio games
- 'Earcon' – auditory icon
- New markets
  - Cell phones
  - Ipods
  - Audio artists
- Voice Recognition

Rendering from: GoForce 5500 Handheld GPU

Domain

- Spoken descriptions of visual situations
  - e.g.Sleuth (similar to Clue) [Drewes, 2000]
- Non-verbal clues
  - Tic-tac-toe
  - Mastermind
- Often levels begin with a monologue



- Head tracking devices can help users disambiguate complex sounds

Examples

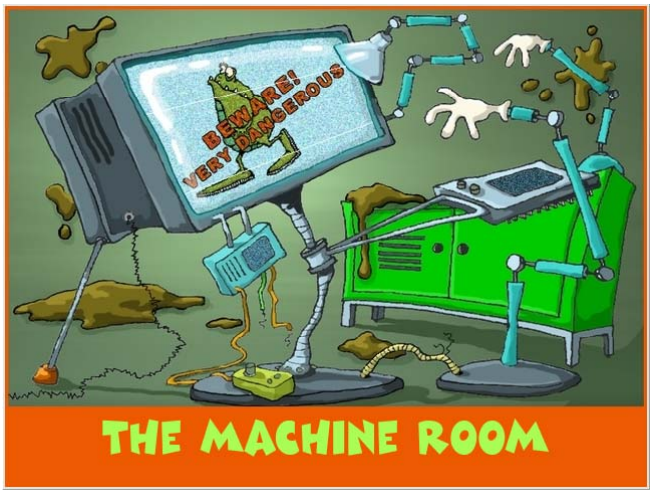
- Terraformers [http://www.terraformers.nu]
  - People use robots to make habitable planets
  - Something goes wrong….
- SuperDeekout [http://www.danzgames.com/superdeekout.htm]
  - High school science project gone wrong
  - Robot you created is too intelligent and decides that you are his enemy

Examples(2)

- Demor [http://student-kmt.hku.nl/~g7/site/index_.html]
  - Location based 3D audio shooter
  - Failed human clones have taken over the apocolyptic world of 2066
  - Goal: Unite the colonies of humans
  - Soundscape changes upon task completion
- More…

AudioGames.net

Mud Splat

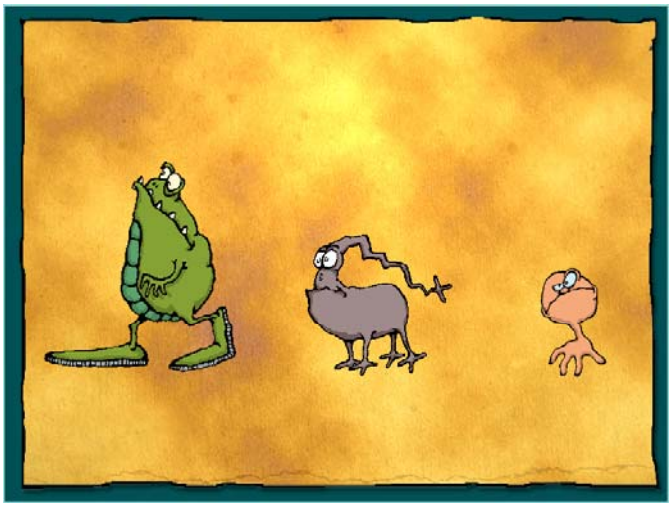


Mudsplat images courtesy: http://timgames.org/

Mud Splat

- Developed by TiM Games for Visually Impaired Children ages 6-12
- Premise
  - Mud throwing monsters have invaded the city….
  - and stolen the six sonixes which play a beautiful song when all are together
  - You go in to retrieve the sonixes armed with water to splash the monsters
- Good Luck!

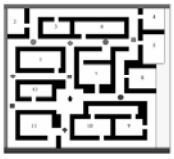
Demo



Virtual/Augmented Reality Systems

- Goal: Star Trek's Holodeck
- Virtual Environment (VE) [Larsson, 2001][Whitton, 2003]
  - Emphasizes modalities other than sight
  - Enhance visuals
  - Add information beyond the visual field
  - Feedback on user's action
  - Need consistency between all sensory stimuli
- Presence
  - Degree to which users react to VE as if it were the real world

3D Sound Aids Navigation [Gunther, 2004]



- Audio provides a sense of spatial context
- People can attend to multiple audio streams
  - "Cocktail party" phenomenon
- Spatial knowledge
  - Landmark knowledge - important visual details
  - Procedural knowledge - critical points along a route
  - Survey knowledge
    - estimate distances between landmarks along a global coordinate system and find new paths
- Results:
  - Spatial sound decreases the time to navigate in complex environments
  - But does not increase survey knowledge
- Advice:
  →Designers should be careful in implementing spatial VE

Audio Communication in MMOG

[Nguyen 2004]

- Massively Multi-Player Online Games are becoming increasingly popular
  - E.g. World of Warcraft (over 8 million subscribers),
- Improvement needed in audio communication in MMOG
  - Local Interactive Zone
  - Background Zone
- Paper focuses on server architectures to support spatial avatars
  - Minimize latency and delays
  - Dynamic centralized server most cost effective in terms of scalability and resource efficiency

Classic Game Soundtracks

- Old School
- ….Guess that tune….

Interactive Audio Design [Schmidt 1999]

- Holy Grail: “Creation and delivery of interactive entertainment that gives the illusion of being created post-production but are generated in real-time.”
  - Tightly integrate soundtrack with action
  - Maximize audio in context of game
    - Bearing in mind space and processor time
  - Foreshadowing
  - Non-linear compositions that still have form
  - Sound effects designed to be listened to repeatedly
    - Without predictability or monotony

Audio Jobs/Roles

- Composer
  - Writes/orchestrates music
- Interactive arranger
  - Formats composed pieces
- Sound Effects Designer
  - Identifies and creates required sound effects
- Audio Integration Engineer
  - Integrate (programs) audio components into game
  - Helps designer utilize technology to the fullest
- Audio Architect (Director)
  - Provides blueprint for audio implementation to rest of team
  - Defines audio strategies with “big picture” in mind
  - Identifies resource issues and estimates performance implications
  - Maximizes audio without negatively impacting game

Audio Director [Boyd 2004 GDC]

- Common Problems
  - Audio work begins too late in the process and never has enough time
  - Budgets not large enough
  - Programming team doesn’t understand audio
- Solution: In-house audio director
  - Lets composers compose
  - Focuses on larger issues

Game Audio Mixing and Automation

[Selfon, 2005]

- Challenges:
  - Post-production
    - Movies: All visuals and audio completely locked
    - Games: Visual still change day before shipping
  - Little definition of which elements are most important
  - Many different environments – Multiplayer, voice
  - Calling attention: Perception vs. Realism
  - Avoid Listener Fatigue

LOD Based on Sonic Importance

- Live mixing during the game
  - Evaluate the cost on each platform
- Prioritization – Optimize for what will actually be heard
  - By function
    - Goal-relevant
    - Sounds that impact user
    - Ambient sounds
  - Dynamic
    - Distance
    - Attenuation
    - Game-Specific
  - Ducking
    - Compresses other signals when a higher priority one comes along
    - Used when radio announcer talks over a song
  - Filter (e.g. blur) low priority sounds
- Recovery
  - Going back to original sound when high priority sound finishes

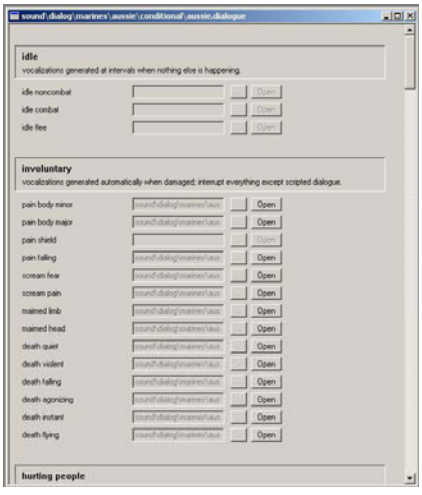
Producing Audio for Halo [O'Donell, 2002]

Less is more…silence is golden

- First game to use Surround Sound 5.1
- Goals
  - Music sets the mood
  - Give player information
  - Make the world seem alive
- Dynamic sounds
  - Responds to environment
  - Permutations and randomization
- Content
  - 80 Minutes need to last 20 hours
- Sound Tags
  - Ambient
    - In
    - Loop (also has alt_loop)
    - Out (w/ corresponding alt_out)
  - Impulse
    - Interruptible
    - "Cascading"

Producing Audio for Halo (2)

- Dialog
  - Casting
  - SAG actors
  - Linear dialog
  - Improvised dialog
    - AI matrix
- Final tally
  - 4311 Soundtags
  - 2.5 GB uncompressed



Sidebar: Machinima

- Rendering of CGI using low end 3D engines
  - Exploit Glitches in software
  - Roots in demoscene of ’70s and ’80s
  - Blue vs. Red
    - Story of two opposing teams in a civil war
    - Act out pre-written scripts in Halo
  - This Spartan Life
    - Talk show
    - “Body Count”
      - Debate as participants kill each other
    - Most interviews end with a kill

Spatial Audio Experiences [Rowland,2005]

In-car view: Spatialised audio can immerse the player in appropriate wheel/engine/exhaust sounds.

Chase view: If the listener is placed behind the car, all that will be heard is the exhaust.

In chase view (3rd person), the listener can be placed in-car to maintain the immersive audio. To create a different audio effect to that experience in-car, the listener can be moved back slightly to make the sound more “exhausty”.

6th Generation Consoles

Sony PlayStation 2	Nintendo GameCube	Microsoft Xbox
•Processor 128-bit "Emotion Engine" 300 MHz •3.2 GB per second bus •"Graphics Synthesizer" –150 MHz, 4 MB VRAM –75 million polys per second •Audio: SPU2 (+CPU), 48 channels, 2 MB memory •RAM: 32 MB RDRAM •Proprietary 4.7-GB DVD and original PlayStation CDs •Drive bay (for hard disk or network inteface) •Controller: Two controller ports, "Dual Shock 2" analog controller •Other features: •Two 8MB memory card slots •Optical digital output •Two USB ports, 1 Firewire •Support for audio CDs and DVD-Video	•Processor: "Gekko" IBM Power PC 485 MHz •2.6 GB per second bus •"Flipper" ATI graphics chip –162 MHz, 1 MB embedded texture cache 3 MB SRAM –12 million polys per second •Audio: Special 16-bit digital signal processor, 64 channels •RAM: 40 MB •Proprietary 1.5-GB optical disc •Controller: Four controller ports, Wavebird wireless controller •Handle for carrying •Two slots for 4-MB Digicard Flash memory cards or a 64-MB SD-Digicard adapter •High-speed parallel port •Two high-speed serial ports •Analog and digital audio-video outputs	•Processor: Modified Intel Pentium III 733 MHz •6.4 GB per second bus •Custom nVidia 3-D graphics –250 MHz –125 million polys per sec •Audio: 64 channels, 5.1 Surround Sound (7.1 Dolby TrueHD for HD movies) •Custom 3-D audio processor •RAM: 64 MB UMA •Proprietary 4.7-GB DVD •10/100-Mbps Ethernet, 56K modem (optional) •Controller: Four game controller ports •8-GB built-in hard drive •5X DVD drive with movie playback •8-MB removable memory card •Expansion port

Source [Diefenbach 2006]

7th Generation Consoles

Sony PlayStation 3	Nintendo Wii	Microsoft Xbox 360
•**Processor:** 3.2 GHz PPC w/ 7 SPEs codenamed "Cell" 218 GFLOPS, 18 billion dot products per second •**Memory:** 256MB XDR @ 3.2GHz, 256MB GDDR3 @ 650MHz •**GPU:** RSX 550 MHz NVIDIA (based on G70 architecture), 1.8 TFLOPS (theoretical), 74.8 billion shader operations per second, 33 billion dot products per second, 255GFLOPs 32bit programmable shaders, Distinct Pixel & Vertex Shaders, SM3.0 •**Audio:** 7.1 Digital, Dolby TrueHD •**Controllers:** Seven wireless devices over Bluetooth 2.0, Six USB 2.0 ports, Three Ethernet ports •**Media:** At least 2x (9 MB/s or 72 Mbit/s) Blu-ray Disc DVD, CD-ROM Detachable HDD, Memory Stick standard/Duo, SD standard/mini CompactFlash (Type I, II) •**Storage:** Detachable 2.5" {20,60} GB hard drive with Linux •**Online Service:** PlayStation Network Platform	•**Processor:** Codenamed "Broadway" (IBM) @ 729 MhZ •**Memory:** 1T-SRAM by MoSys •**GPU:** Codenamed "Hollywood" (ATI) •**Audio:** Dolby Pro Logic II Controller has built-in speaker •**Controllers:** Four wireless, devices over Bluetooth, Two USB 2.0 ports, Four GameCube Controller ports, Two GameCube Memory card ports •**Media:** Propreitary CAV 12 cm Revolution optical disk, 8 cm GameCube optical disk, DVD, CD-ROM, SD/MMC card •**Storage:** 512MB built in Flash Memory •**Online Service:** Nintendo Wi-Fi Connection, includes Virtual Console	•**Processor:** 3.2 GHz PPC Tri-Core codenamed "Xenon" 115 GFLOPS 9.6 billion dot products per second •**Memory:** 512MB GDDR3 @ 700MHz shared between CPU & GPU, 10MB Embedded eDRAM •**GPU:** 500 MHz ATI, 1.0, 48 billion shader operations per second, 24 billion dot products per second, 240GFLOPs 32bit programmable shaders, Unified Shaders, SM3.0+ 10MB eDRAM (internal bandwidth of 256GB/s) •**Audio:** 5.1 Digital and Pro Logic II •**Controllers:** Four Wireless devices over 2.4 GHz RF, 3 USB 2.0 Ports, 1 Ethernet Port •**Media:** 12x (8.2–16.5 MB/s or 65.6–132 Mbit/s) DVD CD-ROM •**Storage:** Optional Detachable HDD, USB Mass Storage Devices •**Online Service:** Xbox Live

Source [Diefenbach 2006]

Case Study
Jurassic Park: Operation Genesis [Schutze 2003]

- Nonlinear, interactive and dynamically mixed sounds place game audio far from traditional film and television audio
- Hard limitations on soundscape implementations
- User terraforms a simulated dinosaur world
- T-Rex is the star
  - Can always hear him regardless of location
- 2D sound: Stereo output
  - Always output at same volume
- 3D sound: Spatialized
  - Input must be monophonic

Case Study
Jurassic Park: Operation Genesis

Audio Components

- World Positioned Ambiance
  - Same sound everywhere
  - Changes based on terrain
- World Weather Ambiance
  - Varies temporally to match 'season'
- Creature/Object Sounds
  - Localized with object
  - Temporally static
- Voice Layer
  - 2D audio – outside of game
- Music Layer
  - 2D audio, static in position, linear
- User Input Layer
  - Acknowledge user input
  - Breaks immersion, but necessary

Case Study
Jurassic Park: Operation Genesis

- Memory Limitations on Environmental Sounds
  - 5-10 seconds
  - Loop seamlessly and unobtrusively
  - No highlight sounds that would emphasize actual length
- Changing min and max distance gives the effect of seasons
  - i.e. decreasing min value and increasing max makes it seem like there are a lot more animals

XBOX 360

- First 7th Generation to hit the market
- Audio
  - All games must support at least six channel (5.1)
  - Support for 48 kHz 16-bit audio
  - 320 independent decompression channels
  - 32 bit processing
  - 256+ audio channels
  - No voice echo to game players on the same Xbox console; voice goes only to remote consoles
  - Voice communication is handled by the console, not by the game code. This allows players to communicate online even if they are playing different games.
  - Uses XMA codec (based on WMA Pro) (6:1 – 12:1 compression)
- **Space and resources no longer an issue!**

Burnout Revenge [Laviers, 2006]

- Xbox 360 : More memory and channels
- Every element of a crash has its own sound
  - Each piece of debris is spatialized in 5.1
- Mix and match cars to produce super sounds
- Only given four months for project
- Main point: High Dynamic Range allows crashes to have even more impact
- Explosions are 3 dB louder than anything else

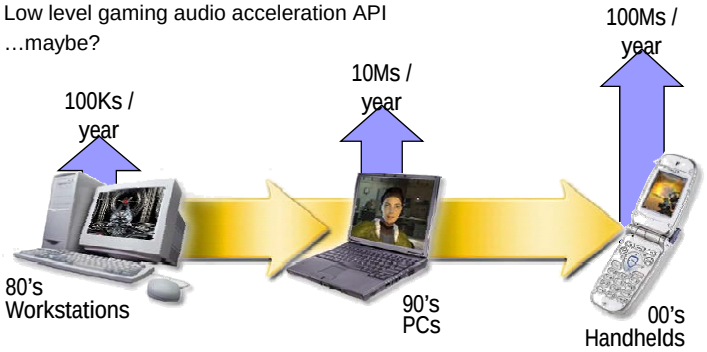
Burnout Revenge: Demo Video

Guitar Hero I and II

- Playstation 2 only (Probs with guitar controller on PS3)
- XBox360 version just released, Wii coming
- Users play along as lead guitarist (using an included mini Gibson SG) in rock and roll and heavy metal songs
- Roughly 2:1 ratio of mainstream to indie music
- New version:
  - Two guitars at once (Lead and {Bass, Rhythm})
- Won numerous awards

Mobile Platforms: Audio [Khronos, 2006]

- Handsets are becoming the predominant personal computing platform
  - Sophisticated media processing will be central to this revolution
- 50% of phones will have multimedia hardware acceleration by 2008
  - Source - Jon Peddie & Associates
- Significant opportunity for games developers
  - Handhelds are the largest market for a manufactured device – ever – period
- OpenSL | ES
  - Low level gaming audio acceleration API
  - …maybe?



GDC 2006
Choice Awards: Audio

- **Guitar Hero** (Harmonix Music Systems / RedOctane)
  - Eric Brosius, Kasson Crooker
  - Also won for innovation
- **Call of Duty 2** (Infinity Ward / Activision)
  - Mark Ganus
- **Electroplankton** (Nintendo)
  - Toshio Iwai, Koichi Kyuma, Yuichi Ozaki
- **God of War** (Sony Computer Entertainment America)
  - Brad Aldredge, Clint Bajakian, Chuck Doud, Dave Murrant
- **Project Gotham Racing 3** (Bizarre Creations / Microsoft Game Studios)
  - Nick Bygrave, Guy Whitmore, Nick Wiswell

GDC 2007
Choice Awards: Audio

- **Guitar Hero II** (Harmonix Music Systems / RedOctane)
  - Jeff Allen, Eric Brosius, Izzy Maxwell
- **Company of Heroes** (Relic Entertainment / THQ)
  - Crispin Hands, John Johnson, Jennifer Lewis, John Tennant
- **DEFCON: Everybody Dies** (Introversion Software)
  - Alistair Lindsay, Michael Maidment
- **Lara Croft Tomb Raider: Legend** (Crystal Dynamics / Eidos Interactive)
  - Troels Folmann, Karl Gallagher, Mike Peaslee, Gregg Stephens
- **LocoRoco** (Sony Computer Entertainment)
  - Kemmei Adachi, Tomonobu Kikuchi, Kouji Niikura, Nobuyuki Shimizu

Less is more

- High Dynamic Range
  - Staying away from full volume most of the time make loud noises that much more memorable
- Repetition and predictability get boring quickly

Image from: New Yorker © 2003

Links

- Ramani's Course on 3D Spatial Audio
  - http://www.umiacs.umd.edu/~ramani/cmsc828d_audio/
- Scott Selfon USC course
  - http://interactive.usc.edu/members/scottsel/
- Art of Foley
  - http://www.marblehead.net/foley/index.html
- Tonedeaf Test
  - http://jakemandell.com/tonedeaf/
  - Also rhythmdeaf and pitch perception test
- Audacity (freeware)
  - http://audacity.sourceforge.net/

Bib

- Lo Brutto (as referenced by Larsson)
- Goldin 1982 (ref'd by Gunther 2004)
- http://www.audiogames.net/
- http://www.terraformers.nu/
- http://www.openal.org/
- Tutorials: http://www.devmaster.net/articles.php?catID=6
- http://www.fmod.org/
- http://www.radgametools.com/miles.htm
- http://www.gamasutra.com/features/gdcarchive/
- Slides – Boyd 2004
- Ohagen 2005 = isg.urv.es/cttt/minho_2005/courses/ohagan/Session3.ppt
- [Diefenbach, 2006] http://www.pages.drexel.edu/~pjd37/Gaming_Overview/

Extra Slides

Localization [Ohagen 2005]

- Must translate all audio (and textual) assets.
- Country-specific censorship
- Translation Issues:
  - Lip synch
  - Songs: translated, re-produced & subtitled

"1000 Words" from Final Fantasy X-2 lyrics (translated from Japanese)

(English version by Kumi Koda who sang in the original Japanese release)	(English version by Jade for the North American and the International releases)
I know that you lied to me *Using just your words to shelter me* *Your words are like a dream* *But dreams could never fool me* *It's not right to me*	*I know that you're hiding things* *Using gentle words to shelter me* *Your words were like a dream* *But dreams could never fool me* *Not that easily*
I'm acting so distant now *Turned my back as you walked away* *But I was listening* *That you fight your battles far from me* *It's not right to me*	*I acted so distant then* *Didn't say goodbye before you left* *But I was listening* *You'll fight your battles far from me* *Far too easily*

Audio Layers [Lions, 2000]

- Ambient Sounds
  - Helps create the fantasy and places user in the desired environments
  - i.e. water dripping in a cave, wind blowing past the user's head
- Sound Effects
  - Indicates what is going on in the game
  - i.e. Speech and interactions between characters, footsteps
- Narrator
  - Reinforces action
  - Explains non-obvious events and story

Downloadable Games [Sweet 2005]

- Different demographics
  - Middle Aged Women
- Less time to play games
- Budget and file size constraints
- Variety and mix of music styles
- Need to hook gamers quicker

Sound Technology in Games : Bibliography
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1 Aural Pipeline

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