Auralization and Geometric acoustics

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Auralization – what and why?

Auralization

From Wikipedia, the free encyclopedia

Auralization is a procedure designed to model and simulate the experience of acoustic phenomena rendered as a soundfield in a virtualized space. This is useful in configuring the soundscape of architectural structures, concert venues, public-spaces and in making coherent sound environments within virtual immersion systems.

- For a given acoustic situation (space, sound source(s), listener position...), what sound does the listener hear?
Auralization – what and why?

Virtual spaces –
Acoustic Design
Auralization – what and why?

Virtual spaces –
Entertainment
Overview

• Intro to Auralization
• Audio sources
• Something about systems
• Room models
  – Geometric acoustics
• Receiver modelling
Sound propagation – system model

Reality

Source

Room

Ears

Perception
Sound propagation – system model

Reality
- Source
- Room
- Ears
- Perception

Auralization
- Source
- RIR
- HRTF
- Perception
Sound propagation – system model

Reality

Source
Room
Ears
Perception

Auralization

Source
RIR
HRTF
Perception
Sound sources

• What they actually sound like
  – It turns out it doesn’t really matter (as we shall see later)
• Directivity $d(\phi, \theta)$
• Trumpet? Reasonably independent of theta
  – Generally nice with symmetry
Sound sources – spatial extension

- What about a wall?
Sound sources – conclusion

• Hard problem!
  – Current solutions mainly directed point sources
  – No current software accurately models transmission
Sound propagation – system model

- Source
- Room
- Ears
- Perception
- Source
- RIR
- HRTF
- Perception
Sound propagation – system model
Room Impulse Response (RIR)

- Can be measured (recall reverberation time measurements)
Room Impulse Response (RIR)

- Can be measured (recall reverberation time measurements)
- Can also be simulated:
  - $\text{RIR}(x_r, x_s, G)$
    - $x_r$ – receiver position
    - $x_s$ – source position (+directivity)
    - $G$ – geometry of the room – including acoustic data
RIR – acoustic parameters

• Some measure of absorption
• Some measure of reflection
• More?
How to create the RIR?

• Insane method: Full pressure field simulation from 20Hz to 20kHz – lots of time and/or money.
  – Sampling theorem: mesh must match frequency.
How to create the RIR?

• Insane method: Full pressure field simulation from 20Hz to 20kHz – lots of time and/or money.
• Less insane: use what we know!
  – Wave phenomena only very important below Schroeder frequency!
  – Wave models below that, simpler models above
  – Combine somehow…
Geometric acoustics

• Has been used since ~1990. (when computers became powerful enough to do it)
• Models sound as rays – no wave phenomena
Image source method

• Make a mirror image in each surface
Image source method

- Store distance, amplitude of each mirror source
- Energy rather than pressure
Image source method

- Non-convex rooms need visibility lookup
Image source method

• Exact solution for flat hard surfaces, convex rooms
Stochastic Ray tracing

- Computationally heavier than IS – but scales better
- Can handle scattering
- Not exact.
Stochastic Ray tracing

- Fire rays in a spherical distribution, and see what they hit.
Stochastic Ray tracing

• Fire rays in a spherical distribution, and see what they hit.

• (1) reflected sound
• (2) direct sound
• (3) miss – wasted computation
Stochastic Ray tracing

- Fire rays in a spherical distribution, and see what they hit.

- (1) reflected sound
- Uses BRDF as probability distribution for reflected ray
Conclusion – modelling techniques

• Full wave simulations are still computationally expensive
• Several approximate methods exist – each with strengths and drawbacks
• Current research: ray tracing, wave simulation, radiosity.
  - Goal: interactive auralizations for VR
Sound propagation – system model

Reality

Auralization

Source

Room

Ears

Perception

Source

RIR

HRTF

Perception
What a difference a head makes

Interaural Time Difference, Interaural Level Difference
What a difference an ear makes

Elevation dependent filter
Directional audio (DTU Copenhagen)
Head related impulse response - HRIR

Head related transfer function - HRTF

- HRTF = FFT(HRIR) – terminology difference
- Captures the effect of the head and torso on sound
How do we obtain the HRTF?

- Measurement in anechoic chamber
- Cumbersome and expensive
  - HRTFs are individual!
How do we obtain the HRTF?

• Simulation – 3d scan of torso + solve wave equation
• Less cumbersome, but still quite
How do we obtain the HRTF?

- HRTF individual - but is governed by body dimensions
How do we assign the HRTF?

• HRTF individual - but is governed by body dimensions

Figure 6: Scatterplots for estimation of the ITD
How do we assign the HRTF?

• Microsoft hololens – Augmented Reality headset
• Measures some head parameters, maps to interpolation of HRTF measurements.
Conclusion

• Many open problems
• Renewed interest with VR development – especially for HRTF.
Bonus Material:

- Microsoft TRITON. Full wave simulation of game levels
  - Insane indeed
Triton = baked wave simulation

• Wave simulation: Accurate & reliable results on complex scenes
• Runtime = lookup + interpolation. Light on CPU.
• Need *dynamic* source & listener: large RAM!
• Baking is restricted to static geometry
  – Feasible first step
  – Dynamic scenes (doors/destruction): could layer heuristics on top, like lighting

After slide by Erik Molin
Auto-layout adaptively-sampled player probes
Baking for moving sources & listener is costly

- 100 machines $\Rightarrow$ ~4 hours
  - ~10-20 minutes per player probe
  - ~1000-1500 player probes per Gears campaign map
- Trivially parallel: double machines, half time
- Bake tool runs on PC/Xbox (latter as “bake game”)
50 TB → 100 MB
A Shift in Thinking: How “Real” is “Too Real” for Game Acoustics?

Lesson 3:

Triton simulations can violate expectations:

- small spaces can generate very long decay times.
- large spaces can generate short decay times.

In games, we have emotional requirements for reverb to inform storytelling.

Solution: Scriptable designer-based interpretations of the Triton data. AKA The “Triton Tweak Acoustics node”.

After slide by Erik Molin
Image source method

• Scales badly with room complexity, time.