Sound in VR

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RESEARCH SCIENTIST

OCULUS RESEARCH

oculus

VR and sound

Sense of presence and immersion

Situational awareness

Additional information about environment

Better audio-visual correlation

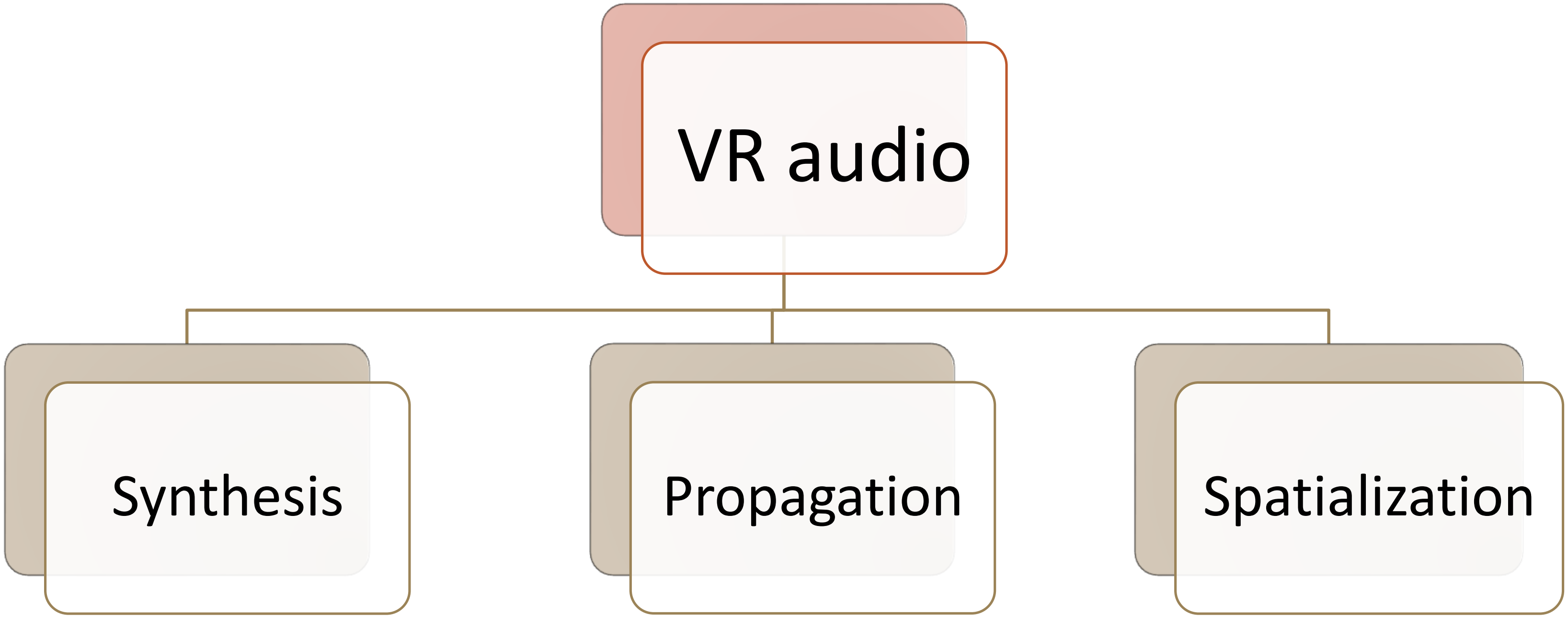
What about VR makes sound different?

You are part of 3D virtual world rather than watching on 2D screen

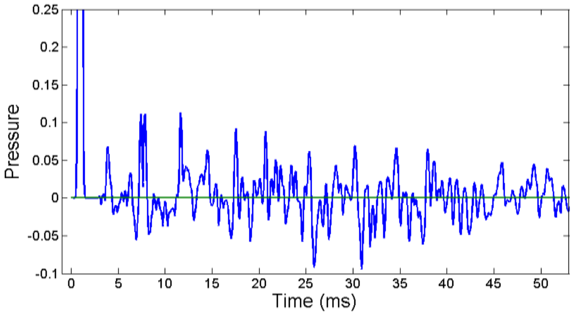
Fidelity and accuracy requirement significantly higher

Interact with the virtual environment

Physically-based Sound Simulation

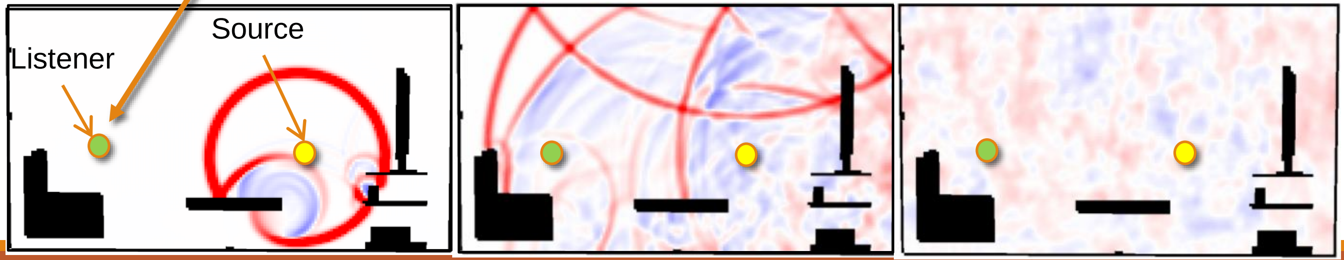


Sound propagation



Propagation filter

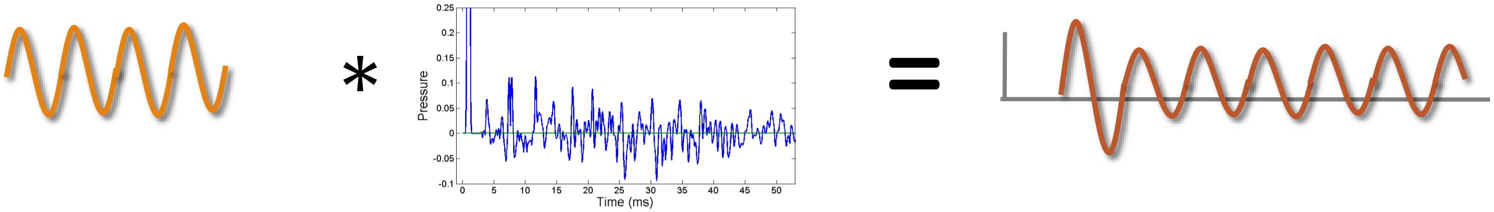
High pressure   Low pressure

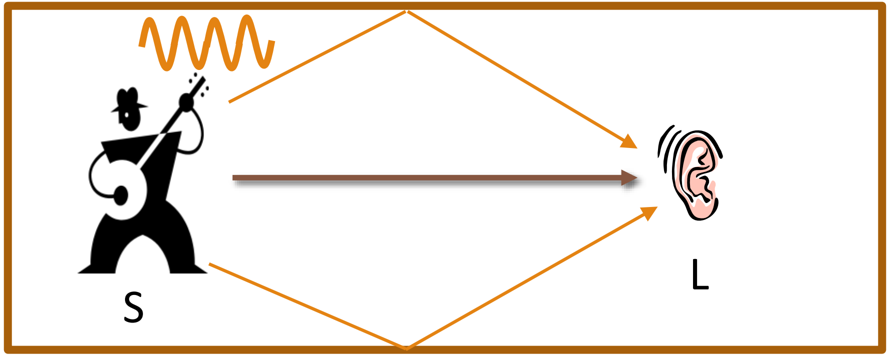


t = 2 ms   t = 8 ms   t = 50 ms

Sound propagation filter

dry audio * propagation filter = propagated audio





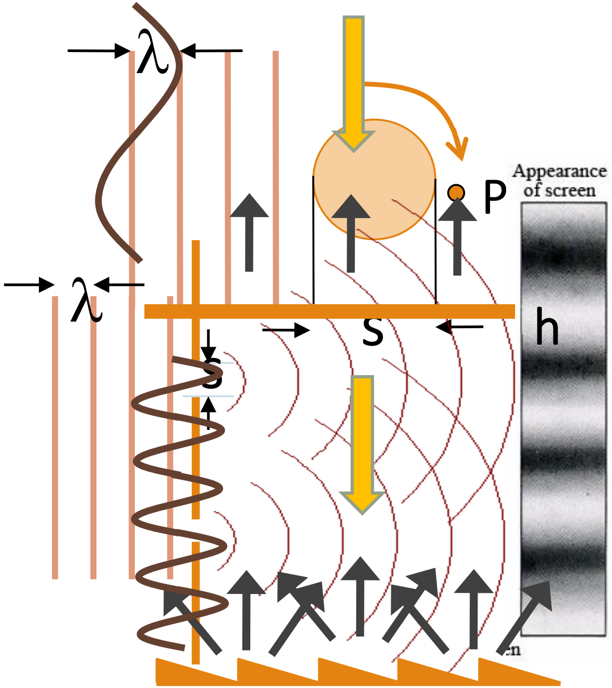
Sound propagation effects

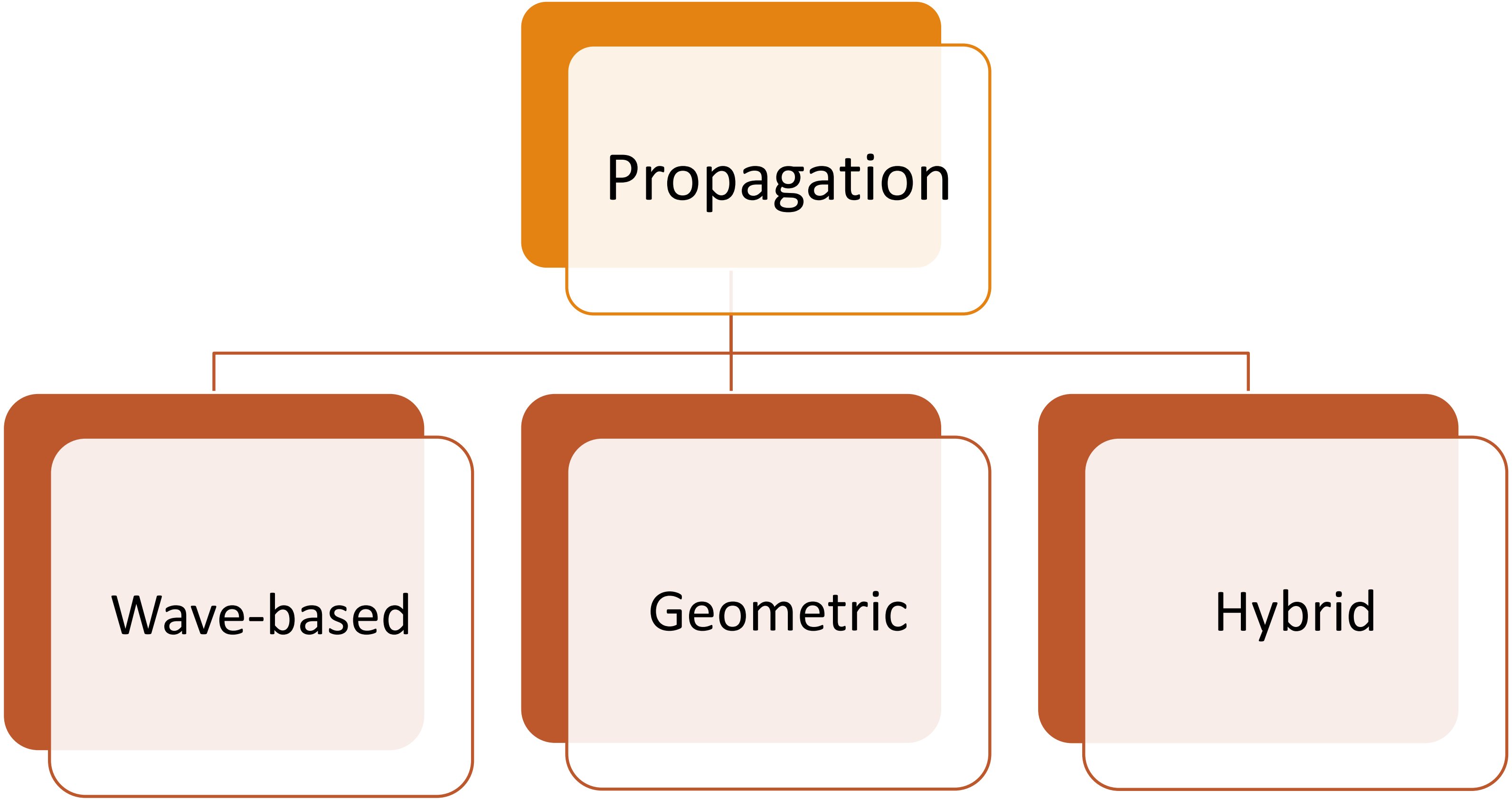
wavelength ~ object size

- diffraction
- interference

wavelength << object size

- specular reflection
- scattering

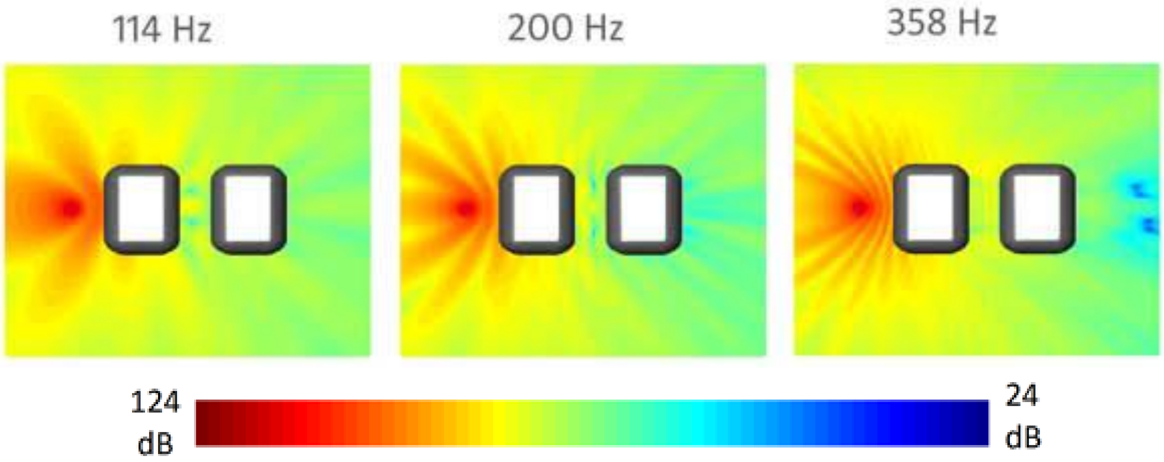



Propagation
Wave-based
Geometric
Hybrid

Wave-based techniques

Solves underlying physics of sound propagation

$$\nabla^2 P + \frac{\omega^2}{c^2} P = 0$$



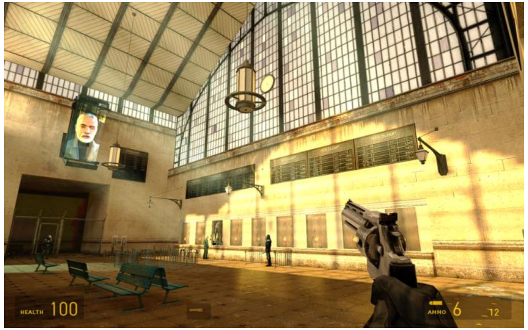
Wave-based techniques

Sound radiation

- precomputed acoustic transfer [James 2006]

Sound Propagation

- medium scenes, dynamic sources [Raghuvanshi 2009]
- large scenes, directivity [Mehra 2014]
- + dynamic sources [Mehra 2015]



Wave-based techniques

Accurate at all frequencies

- reflection, diffraction, interference

Precomputation $\propto \mathrm{freq}^4$

- hours on CPU cluster (low freq.), days to months (high freq.)

Interactive runtime

- 10s of MBs, < 50 ms update rate

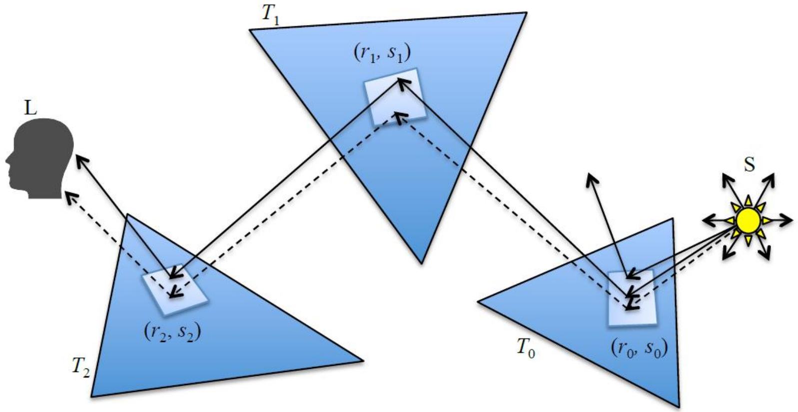
Sound Diffraction

Sound gets low passed behind the doorway

Geometric techniques

Ray-like behavior of sound waves

- valid for high-frequencies
- similar to global illumination
- ray-tracing, visibility graph, etc.



Geometric techniques

Typical techniques

- ray-tracing [Krokstad 1968], image sources [Allen 1979]
- beam tracing [Funkhouser 1998], phonon tracing[Bertram 2005]

Approximate diffraction

- uniform theory of diffraction (UTD)

Combined techniques

- ray-tracing, UTD

Geometric techniques

Approximate at low, accurate for high frequencies

- reflection, diffuse reflection

Negligible precomputation

- mins on single desktop

Interactive runtime

- 10s of MB, < 100 ms update rate

Office Benchmark

154,020 triangles

6 static sources:
- 2 copy machines
- 2 human voices
- elevator
- telephone

Moving listener

~34 ms per audio frame

Hybrid techniques

Wave-based techniques

- efficient at low freqs., expensive at high freqs.

Geometric

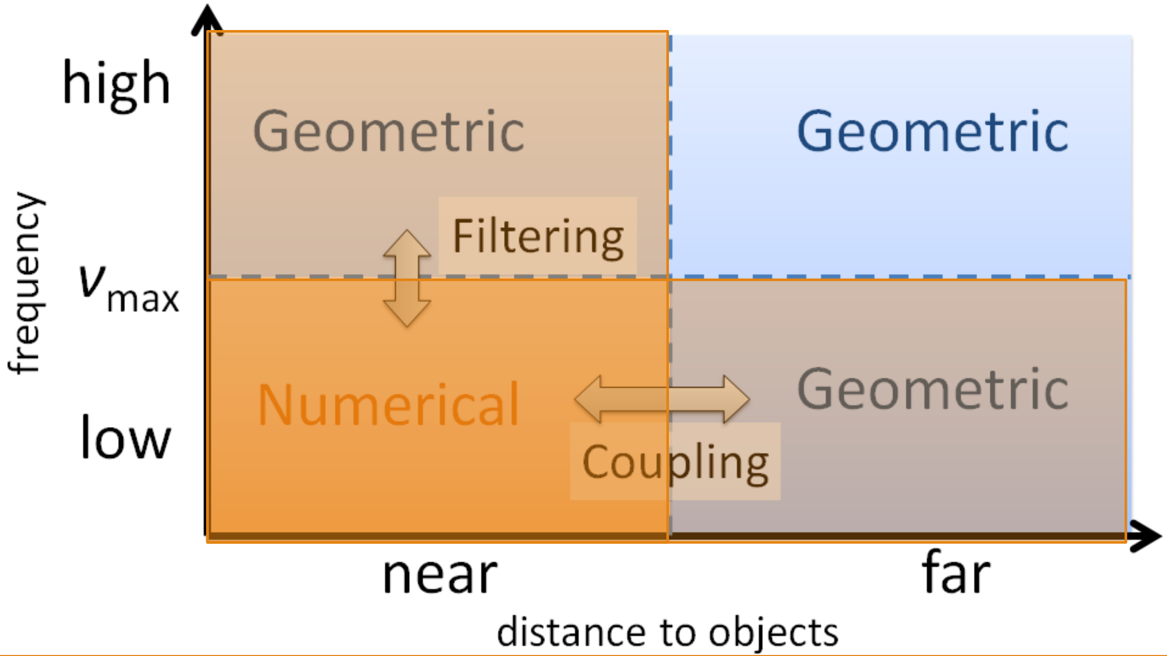
- inaccurate at low freqs., accurate at high freqs.

Hybrid = wave + geometric

- accurate, efficient for all freqs.

Hybrid techniques

[Hyeh 2013]



Hybrid techniques

Accurate at all frequencies

- reflection, diffraction, interference

Reasonable precomputation

- hours on CPU cluster

Interactive runtime

- 10s of MBs, < 50 ms update rate


Numerical
HEALTH
100
AMMO
6
0

Challenges

Dynamic scene geometry

VR game audio

- source, listener position, scene geometry
- compute propagation filter dynamically

Access to dynamic scene geometry

Precomputation budget

Sound propagation is computationally expensive

- multiple freqs., wave-effects

Analogous to light propagation

- CPU cluster for light maps
- tens of hours of cluster time

Runtime resources

Audio processing

- < 10% of single CPU, < MBs of memory

Graphics processing

- dedicated graphics processor
- GBs of memory

Runtime budget

- at least 1 core, tens to hundreds of MBs

Comparison


Source
100
6

XAudio 2

Sound Propagation

Conclusion

Accurate sound simulation is important for VR

Physically-based propagation techniques

- Wave-based, geometric and hybrid

Unsolved problems

- dynamic geometry, pre-computation cost, real-time runtime