Aalto University
School of Science

Geometrical Acoustics

CS-E5530 Virtual Acoustics, 15.1.2019

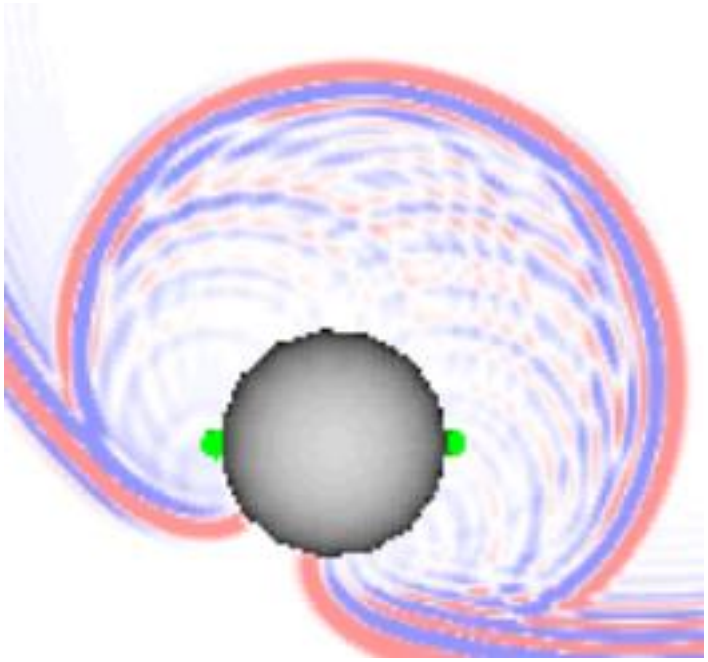
Lauri Savioja, Aalto University

Interactiveacoustics.info

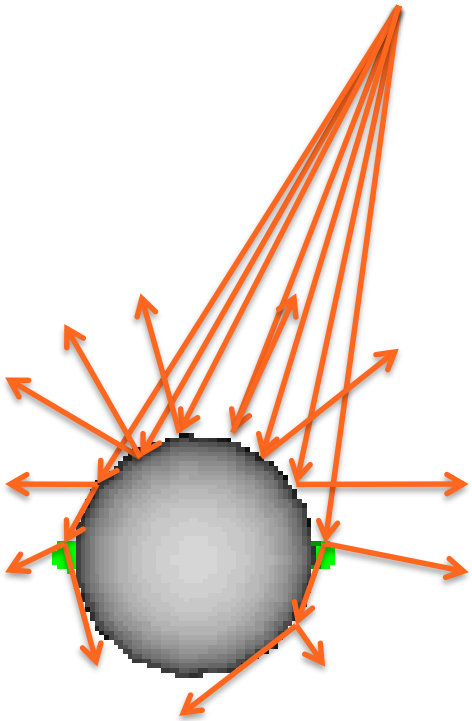
Aalto University
School of Science

Physics

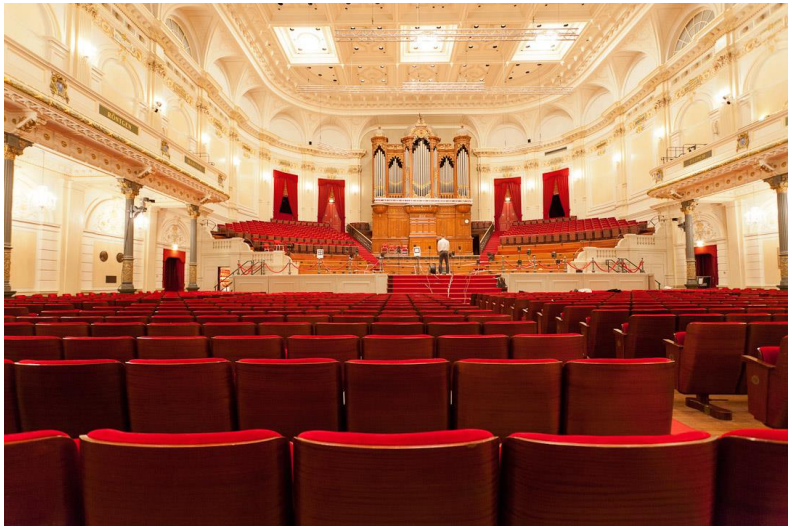
Validity

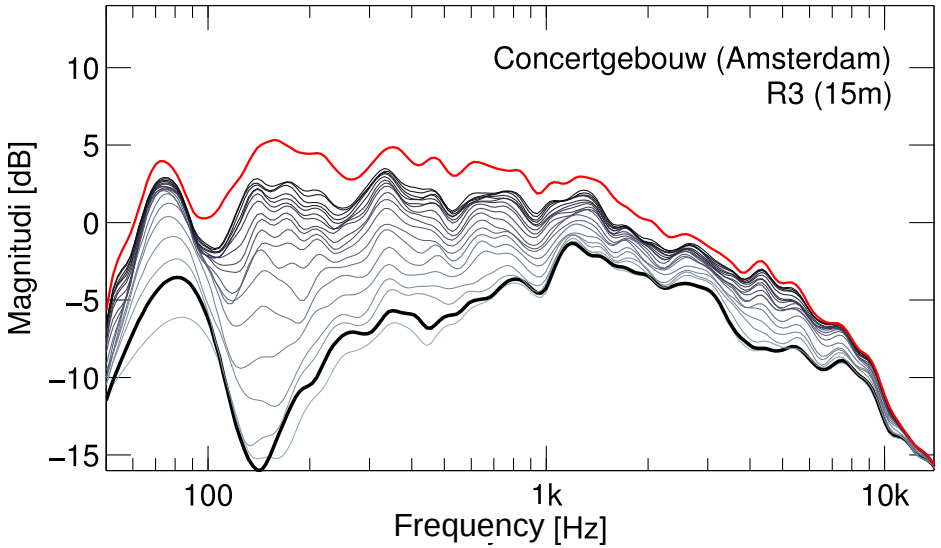


vs



Validity




Concertgebouw (Amsterdam)
R3 (15m)
Magnitudi [dB]
10
5
0
−5
−10
−15
100
1k
10k
Frequency [Hz]

Aalto University
School of Science

Computation

Modern ray-casting performance

Simulation performance	
Rays per second (NVIDIA Optix)	**300M**
Reverberation time	2s
Average path length	686m
Mean-free path	15m
Average number of reflections per ray	45,7
Maximum rays per second	6,56M

Is that enough for specular reflections?

- **Beam-tracing is the solution, not plain ray-tracing.**
- **Current beam/frustum tracers are very good and efficient.**

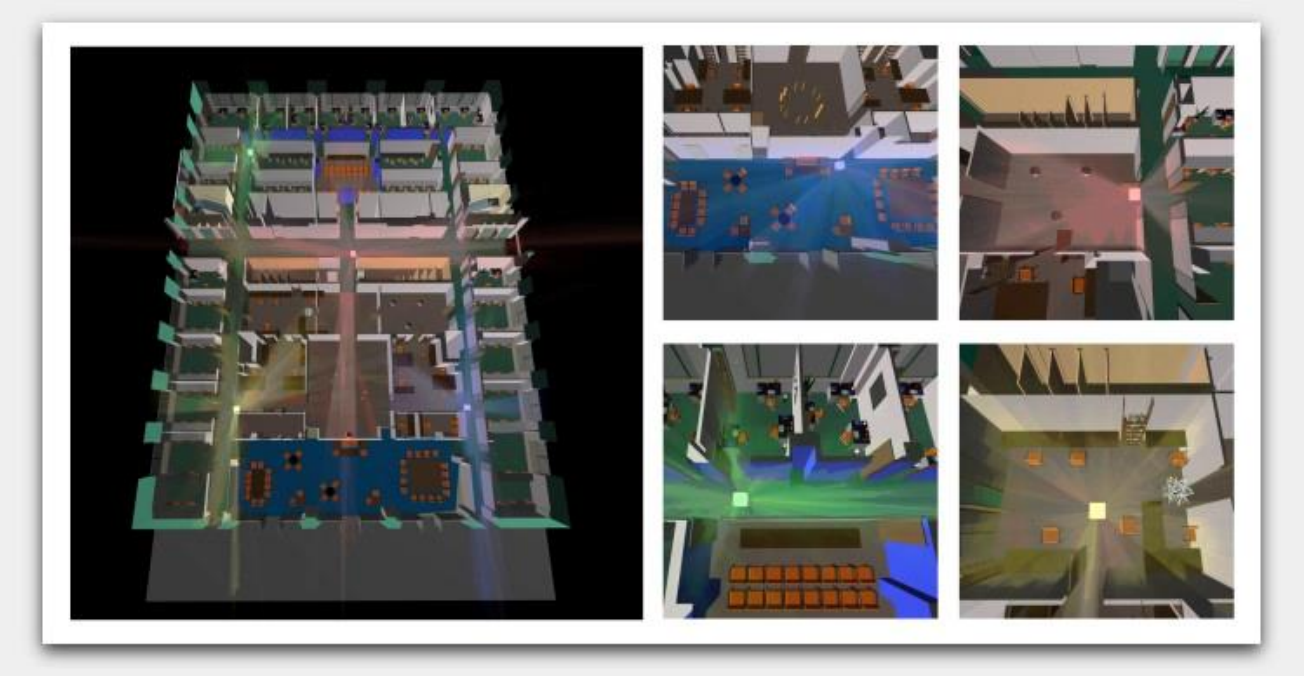


Image from http://gamma.cs.unc.edu/SOUND/

Is that enough for diffuse reflections?

- **Acoustic Radiance Transfer and Radiosity techniques**
  - Fast ray-casting helps, but has high memory cost

- **Fast ray-tracing**
  - No need for pre-computation
  - Suitable for moving source and listener, and even for dynamic geometry at some degree

Is that enough for edge diffraction?

- **It depends on application!**

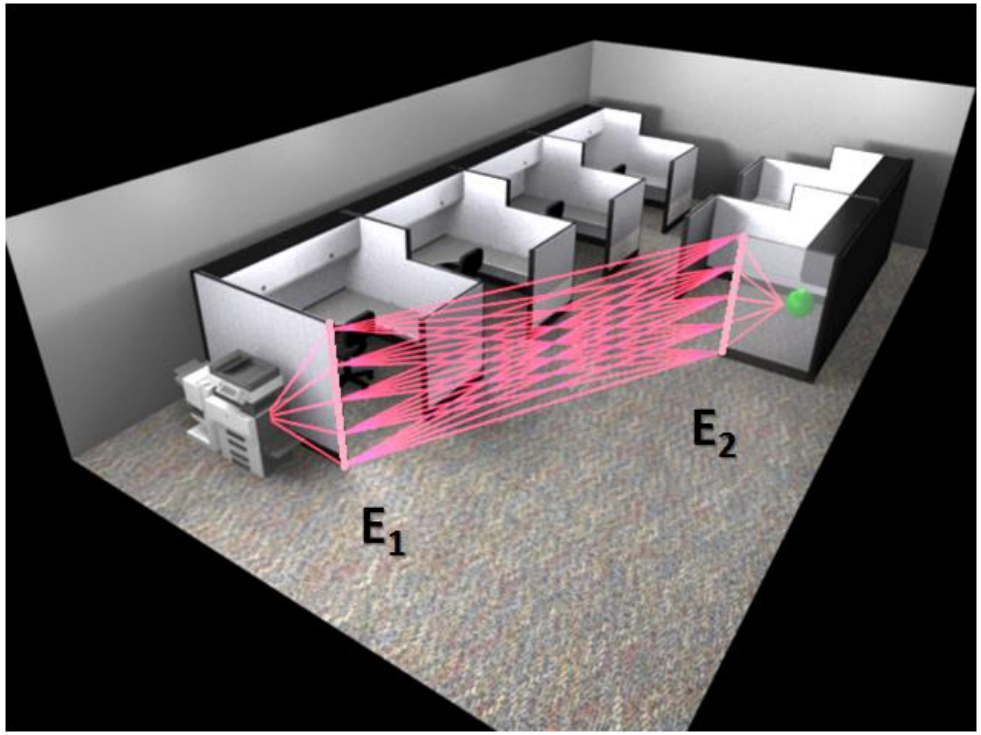


Image from http://gamma.cs.unc.edu/BTM/

Hybrid model

Starting point

1. **At the low-end the Geometrical Acoustics fails, and modeling edge diffraction won't fully solve the problem**

1. **At the high-end the Wave-based techniques come too expensive**

- **Why not combine those two?**

The best of both worlds

- **No need to compute everything with wave-based techniques**
  - Only in the region where wave phenomena are important

- **Use geometrical acoustics only at higher frequencies when it is valid**
  - No need for separate diffraction modeling
  - Easy to incorporate air absorption
  - Modeling with energies is sufficient

Cross-over frequency

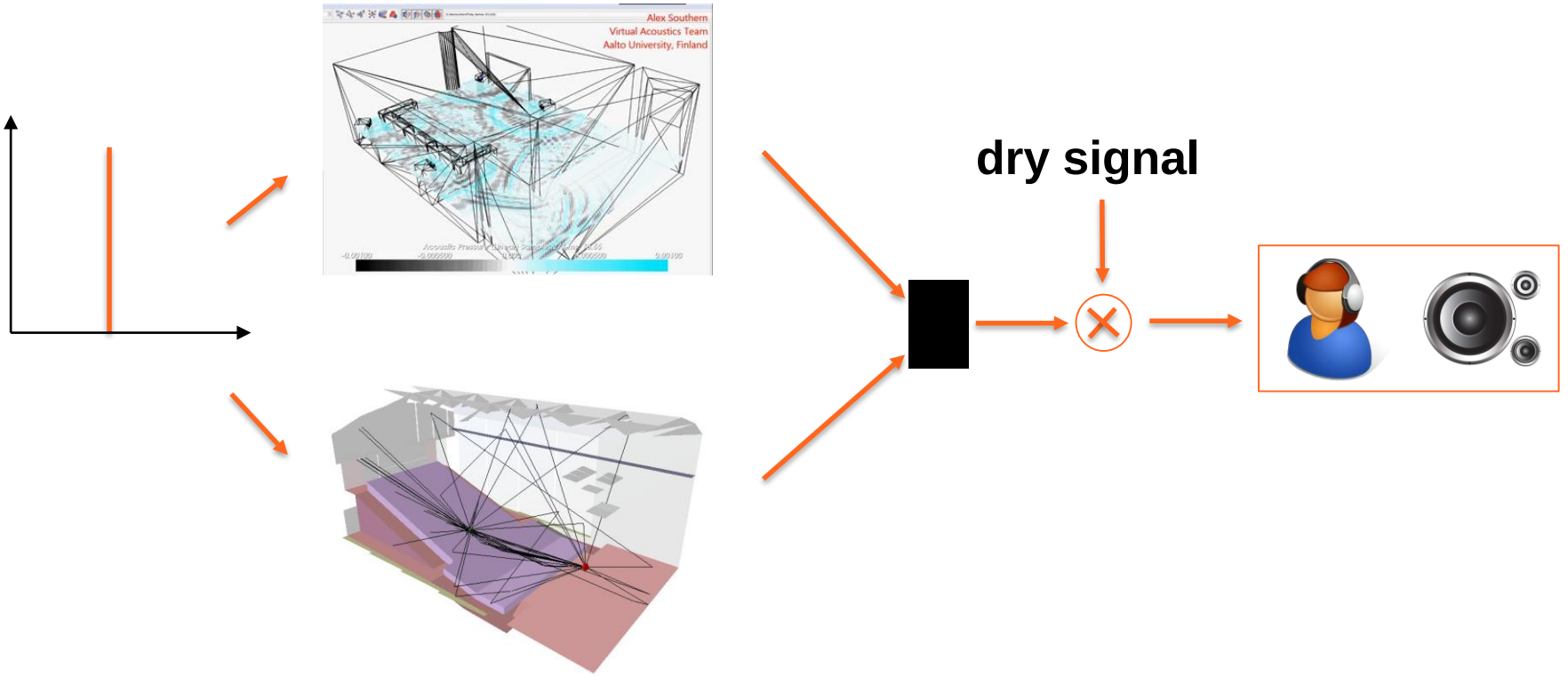
- **There is a region in which both the diffraction and air absorption are important. Which one is easier?**
  - Air absorption in wave-based, or
  - ~~Diffraction in geometrical acoustics~~

- **Go as high as possible with the wave-based techniques**

Interactive auralization

Aalto University
School of Science

Auralization



Learn more of the black box:

A. Southern, S. Siltanen, D. T. Murphy, L. Savioja, "Room Impulse Response Synthesis and Validation Using A Hybrid Acoustic Model", *In IEEE Trans. Audio Speech Lang. Process.*, vol. 21, no. 9, pp. 1940 - 1952, 2013.

Interactivity

more complicated

Learn more of the basics:

L. Savioja, J. Huopaniemi, T. Lokki, R. Väänänen, "Creating interactive virtual acoustic environments", *In Journal of the Audio Engineering Society*, vol. 47, no. 9, pp. 675-705, 1999.

Conclusions

Conclusions

- **Hybrid model**
- **Physics**
  - More accurate boundary and source models are needed
- **Computation**
  - Numerical issues need to be solved
  - Take the advantage offered by modern parallel processors (GPUs)

Tomorrow:

The assignments