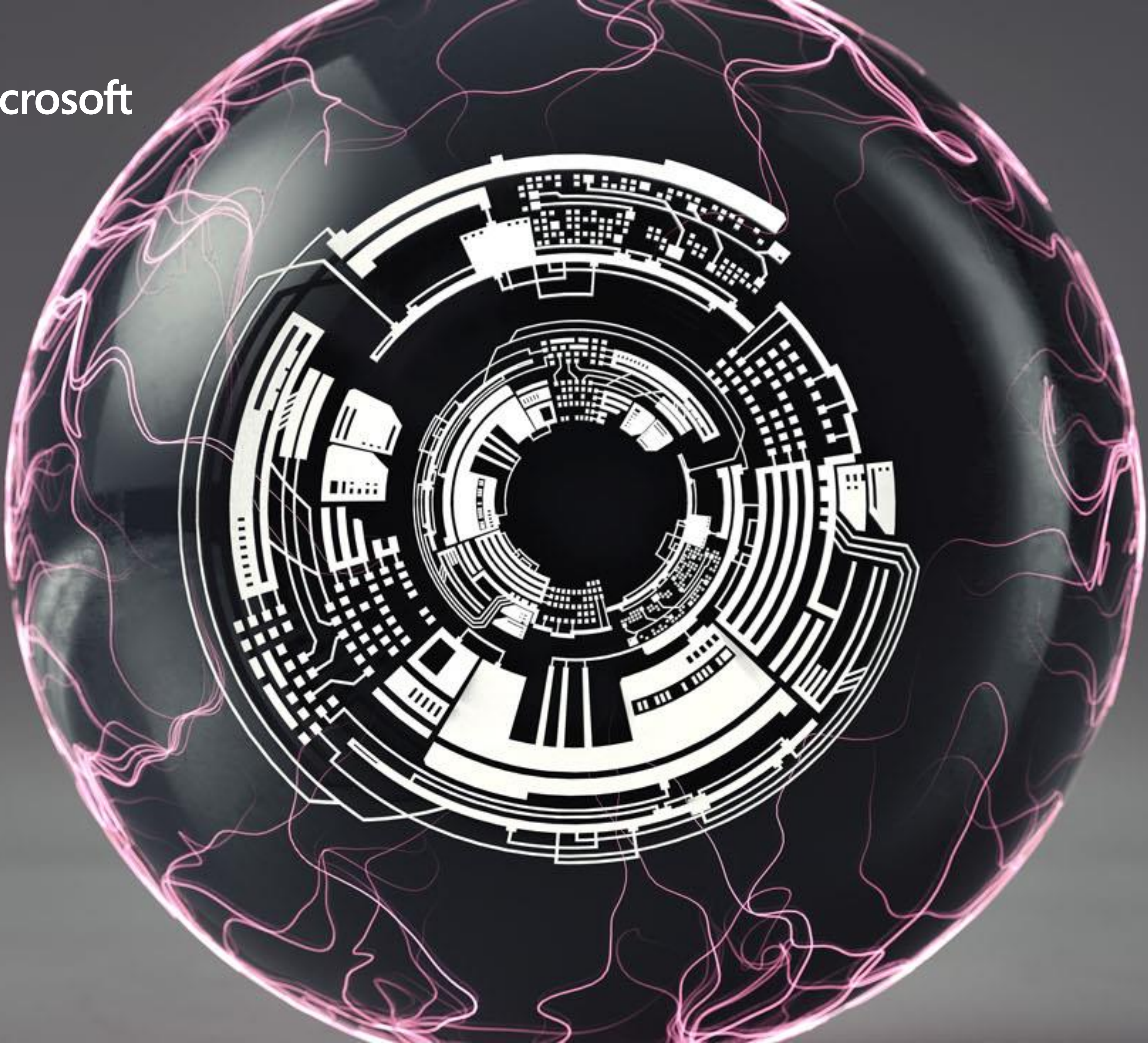
Microsoft

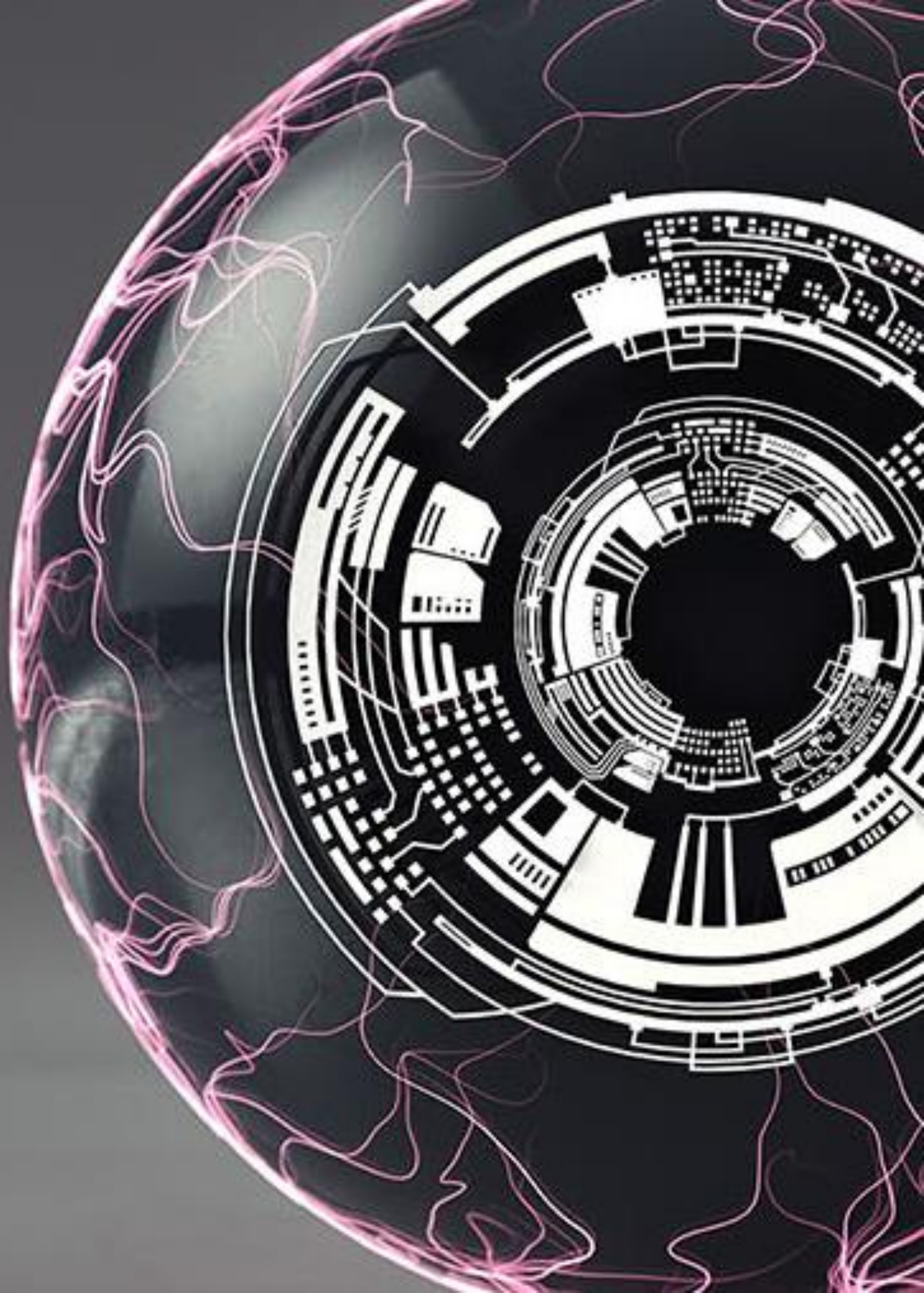


Microsoft Research Faculty Summit 2016

Microsoft

Spatial Audio research at Microsoft

Hannes Gamper
MSR Labs



Collaborators and contributors

Audio and Acoustics Research Group in MSR Labs

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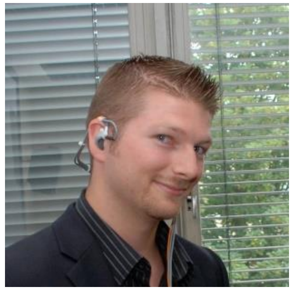
Microsoft Research

David Johnston
Microsoft Research

Ivan Tashev
Microsoft Research



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Dolby Laboratories

Jens Ahrens
Chalmers University, Sweden

Interns: Piotr Bilinski, Archontis Politis, Keith Godin

The exceptional engineering teams in HoloLens, Kinect, and Windows we had the honour to work with

Introduction

VR & AR devices

Oculus Rift

Samsung Gear VR

Microsoft Hololens

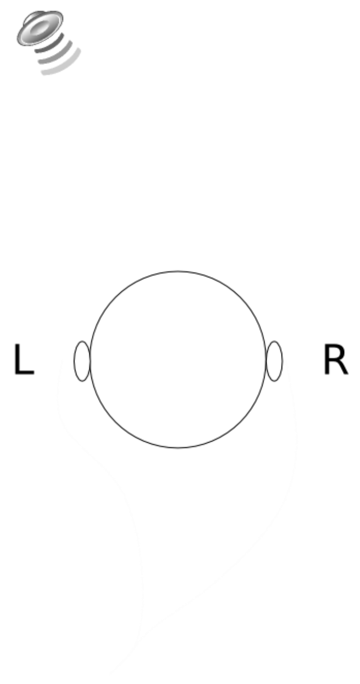
Definition: Spatial audio

- Within audible frequency and dynamic range
- Delivered to one or both ears
- Contains auditory localisation cues:
  - Interaural time and level differences
  - Spectral cues
  - Reverberation
  - Dynamic and multimodal cues
  - (expectation and experience)

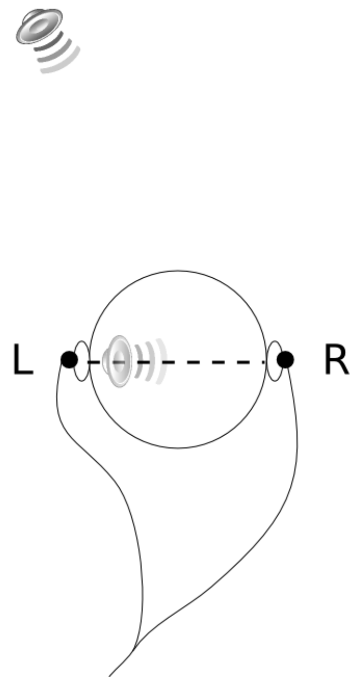
(Interaural time and level differences, Spectral cues) } Head-related transfer function (HRTF)

Spatial audio rendering

Spatial audio rendering

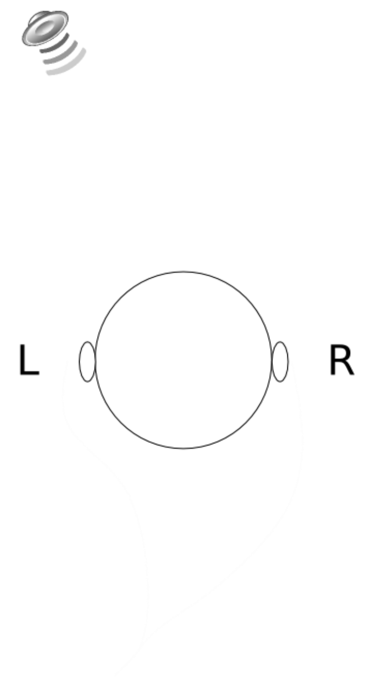


Real sound source

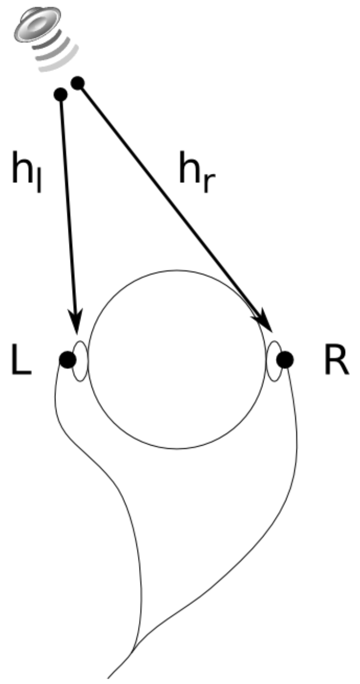


Virtual sound source

Spatial audio rendering

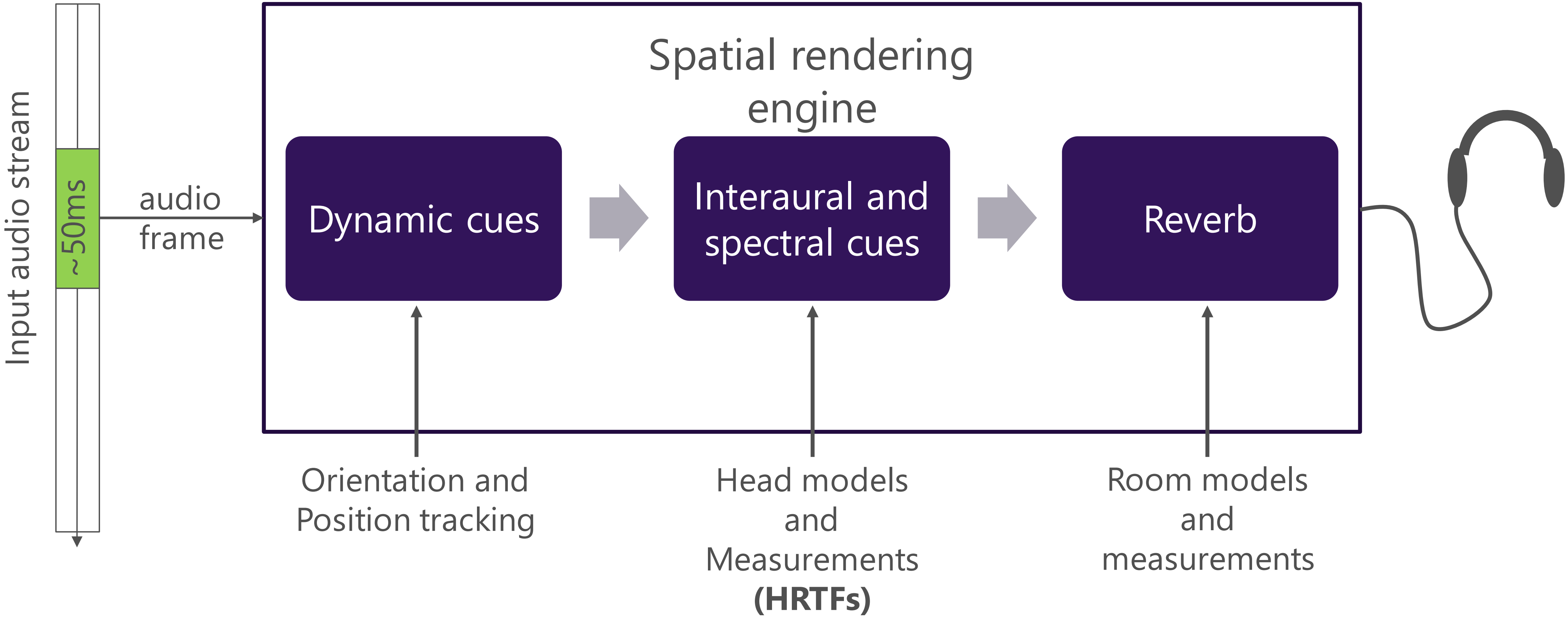


Real sound source

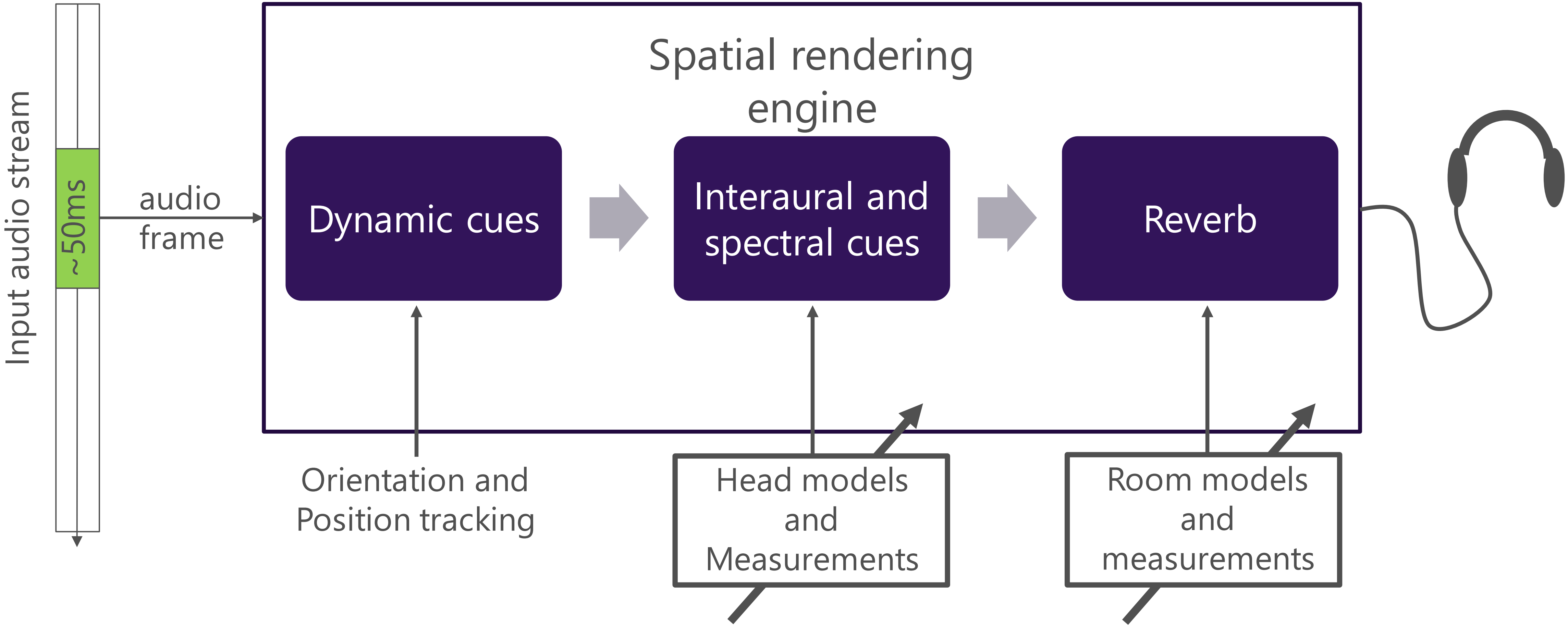


Spatial audio rendering via head-related transfer functions (HRTFs)

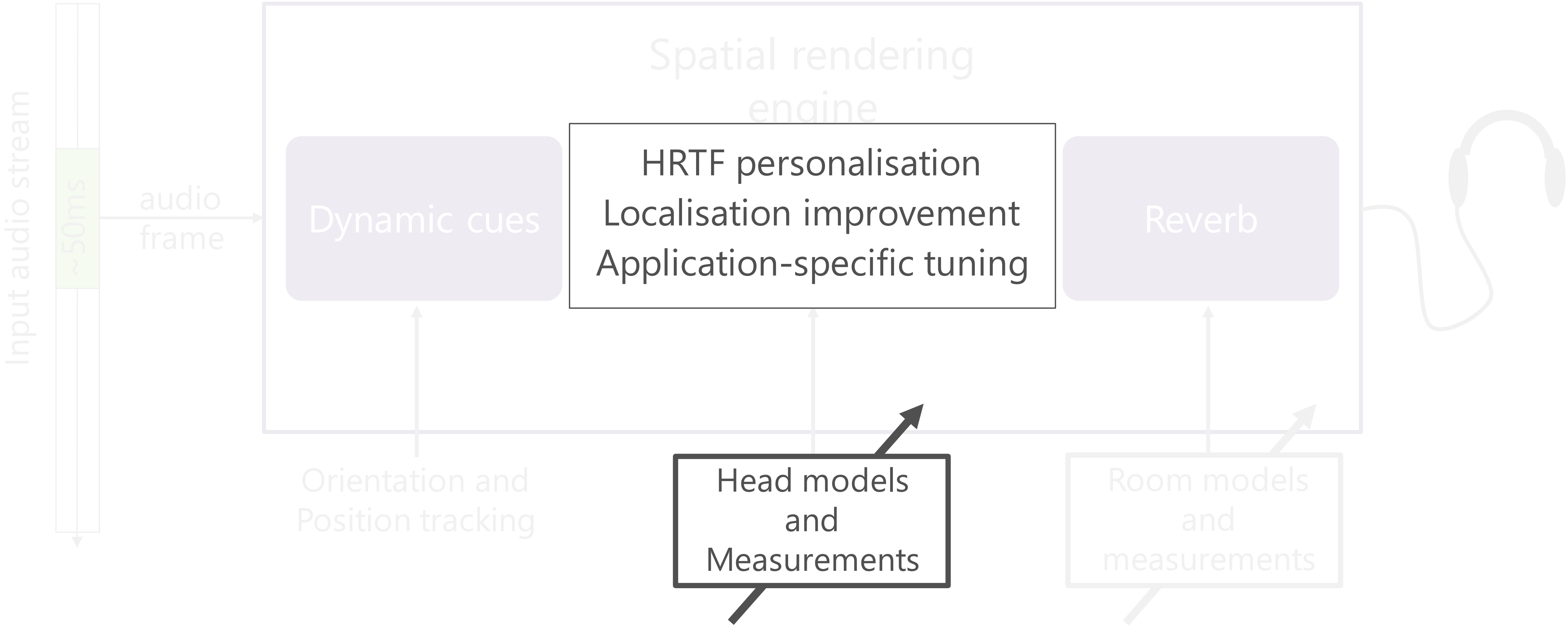
Spatial audio rendering



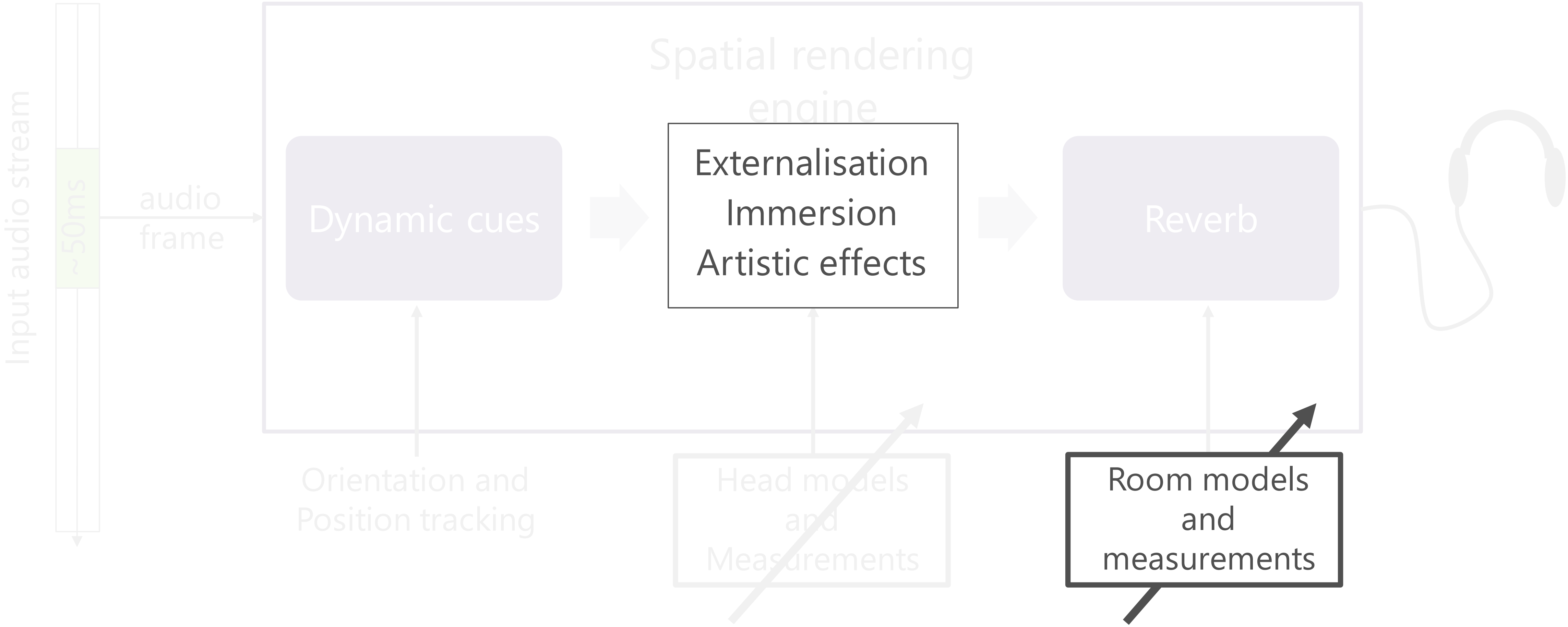
Spatial audio rendering



Spatial audio rendering



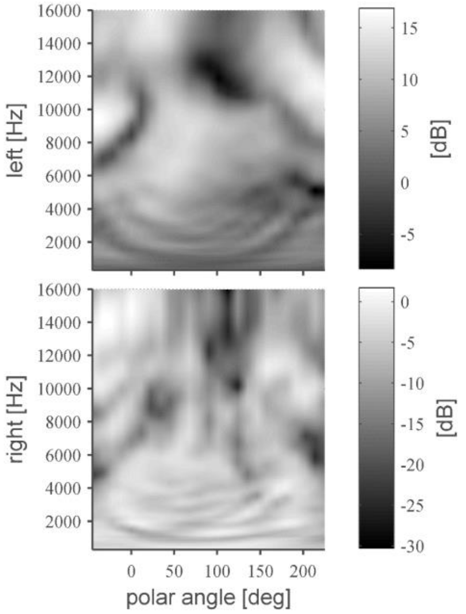
Spatial audio rendering



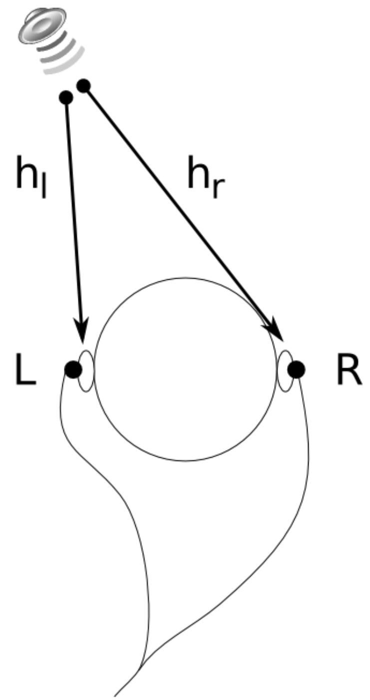
HRTF measurement and personalisation

Rendering framework

Personalisation



Rendering



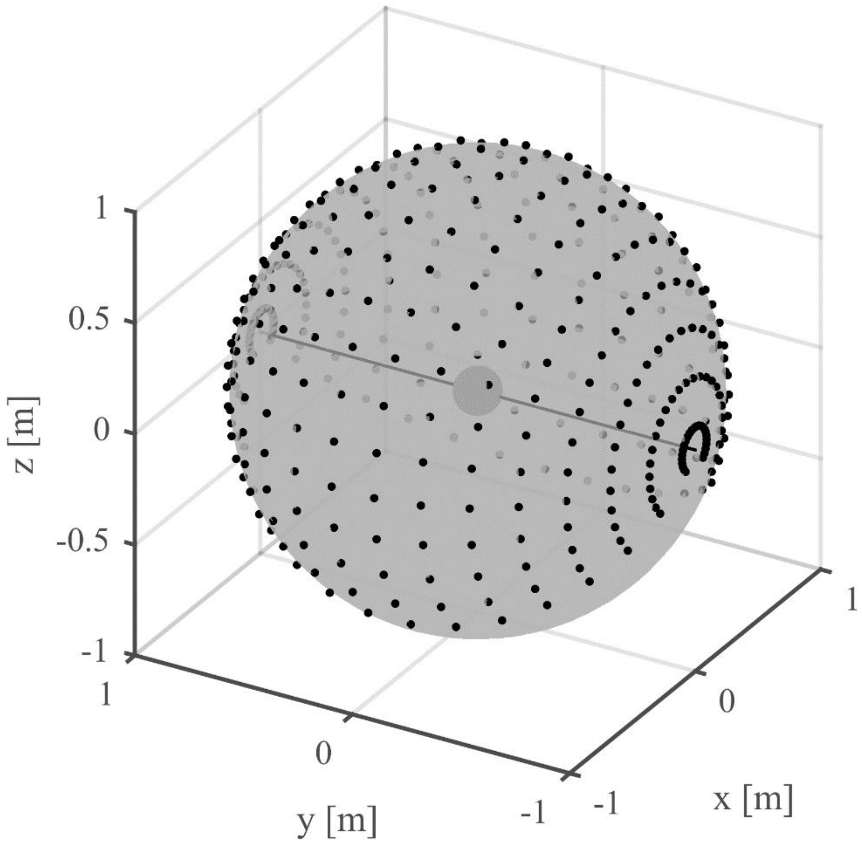
Anthropometry
3-D scan, photo, questionnaire, measurements

HRTFs
Measured, modelled

Spatial sound
Hololens, Windows 10, Cities Unlocked

HRTF measurement

HRTF measurement rig



Measurement locations

MSR HRTF database

- ~200 subjects
- HRTFs measured at 400 locations
- High resolution 3D head scans
- Direct anthropometrics measurements
  - Head width, depth, height, etc.
- Questionnaire
  - Hat size, shirt size, jeans size, etc.

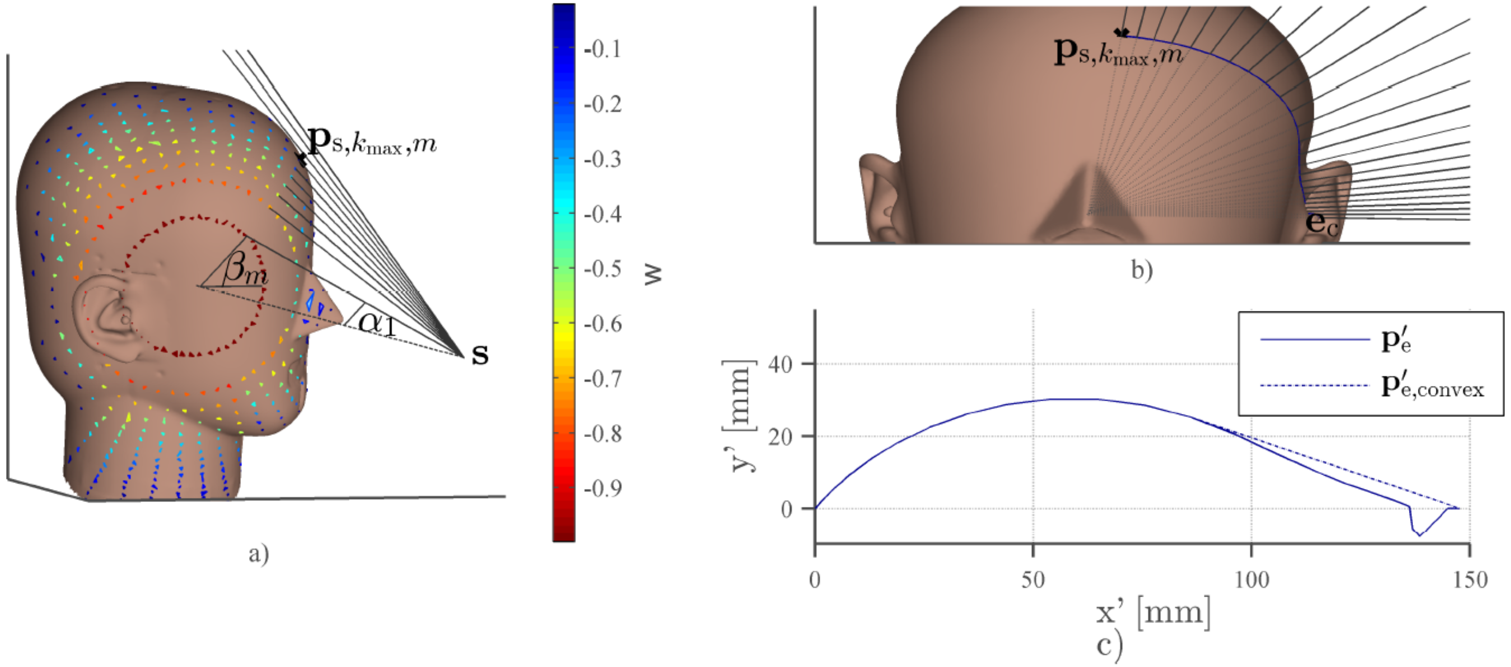
3-D head scan

Measurement tools

Direct estimation

Trace acoustic propagation from source positions to ear entrances.

Good results with high-resolution scan

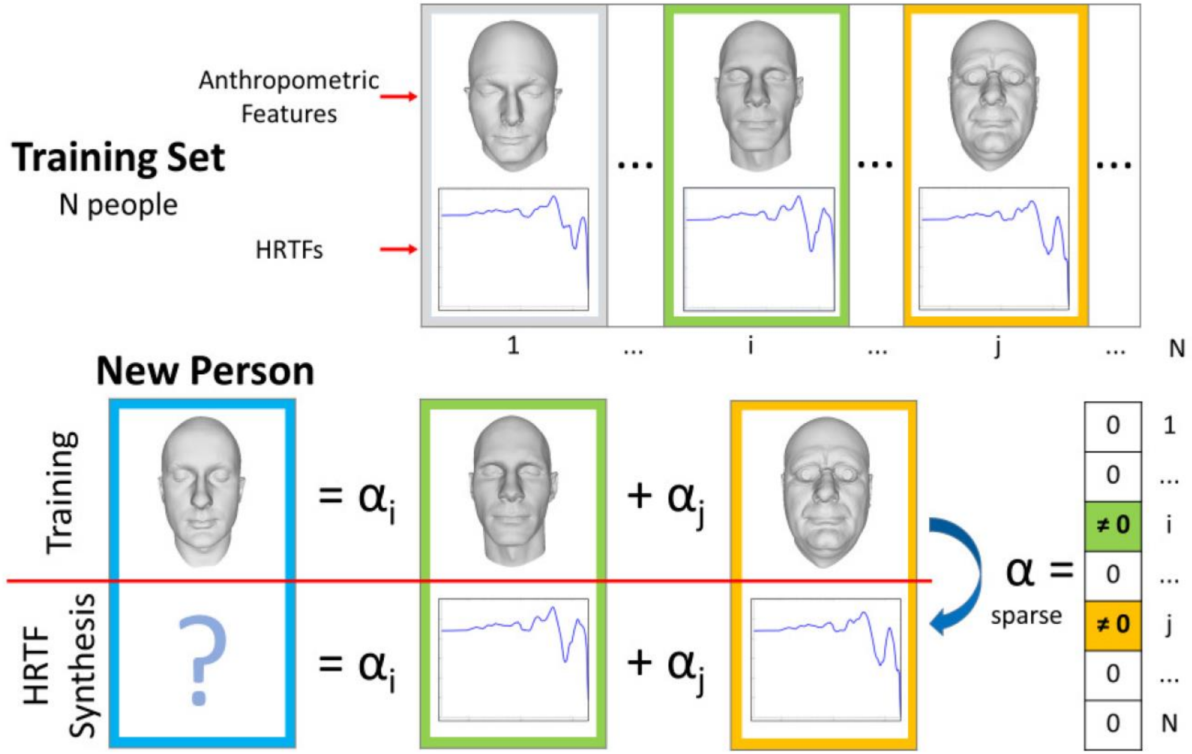


Gamper, H.; Thomas, M. & Tashev, I. (2015). "Estimation of multipath propagation delays and interaural time differences from 3-D head scans." *Proc. IEEE Int. Conf. Acoustics, Speech, and Signal Processing (ICASSP).*

Anthropometry-based personalisation

Given database of anthropometric features, represent a new candidate's features as a **sparse combination** α of people in the database.

Combine HRTF magnitude spectra with **same weights** α to synthesize personalized HRTF.

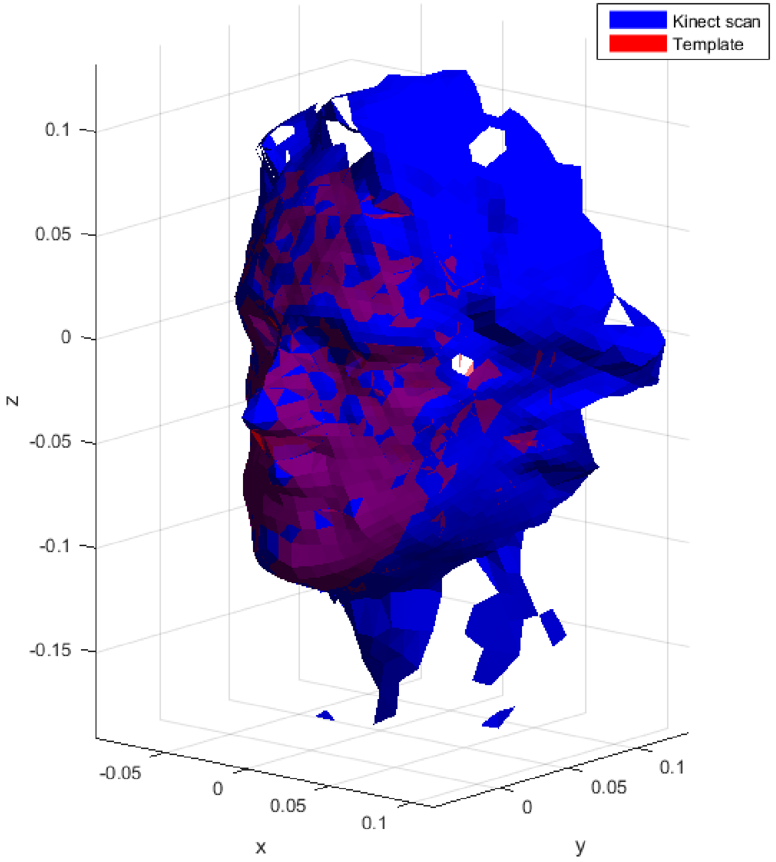


P. Bilinski, J. Ahrens, M. R. P. Thomas, I. J. Tashev, J. C. Platt, "HRTF magnitude synthesis via sparse representation of anthropometric features," *ICASSP*, 2014.

Model-based personalisation

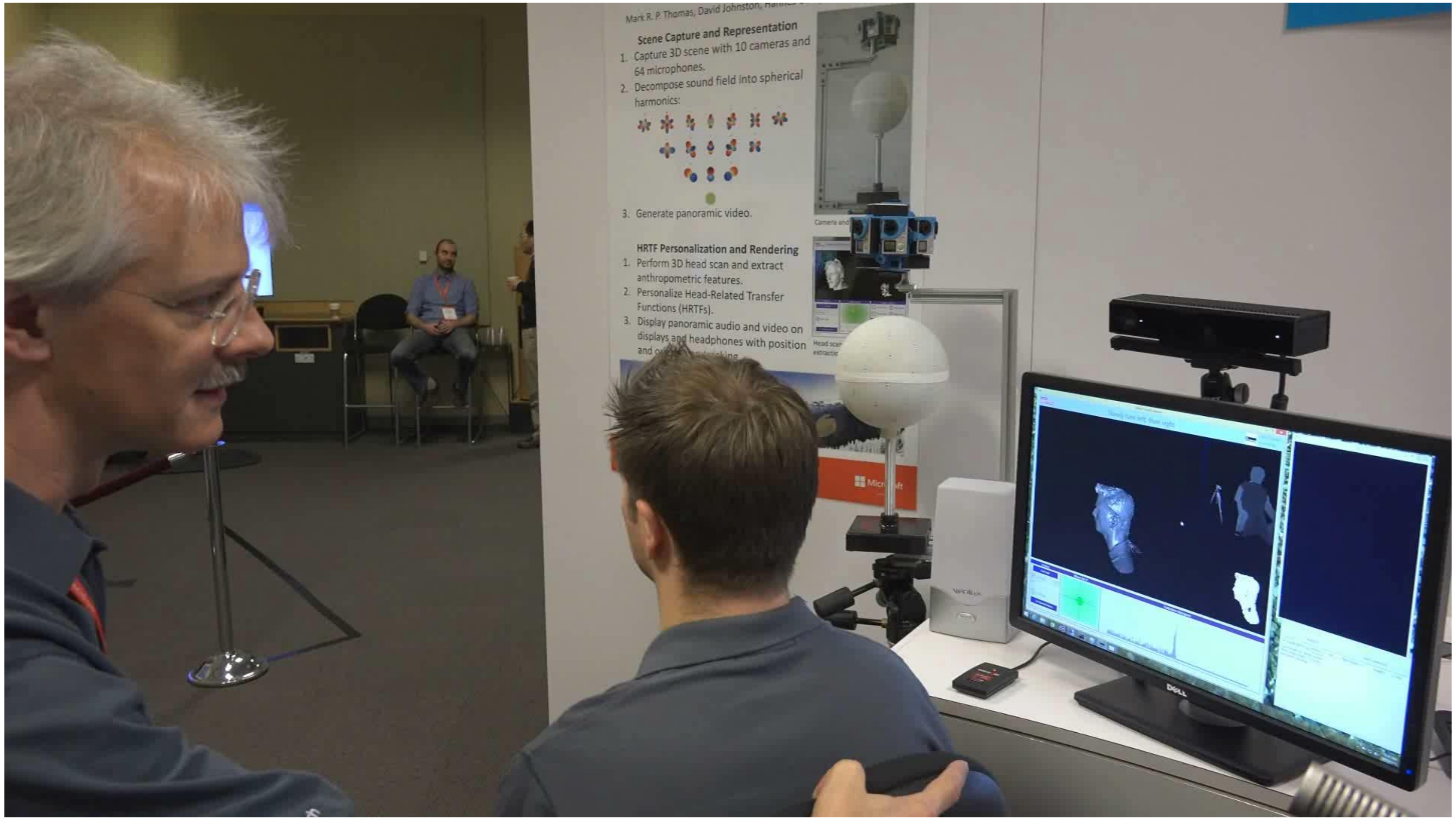
Given single (Kinect) depth image, fit average face to scan.

Map geometric deformation to acoustic features.



Average face fitted to depth image.

HRTF personalisation demonstration



Rendering approaches

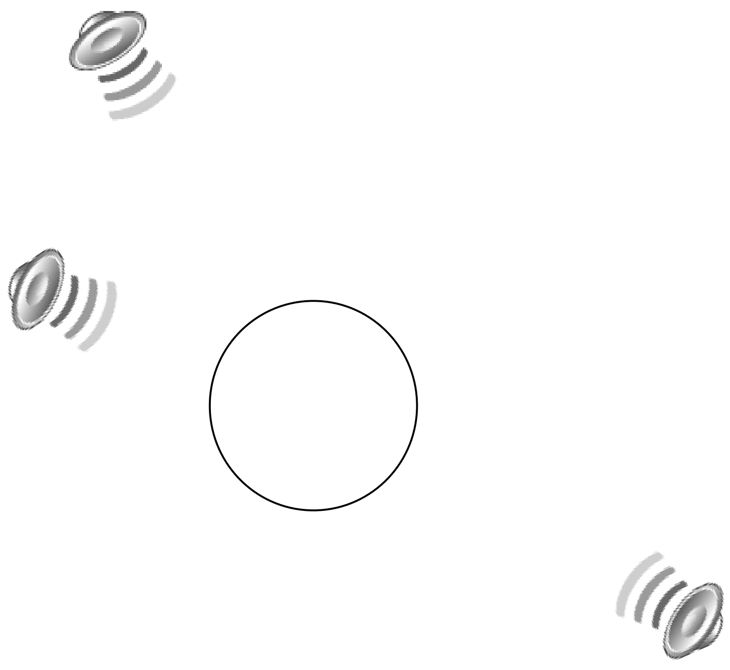
Object-based rendering

Render each source individually

Provides full 3-D control

Complexity increases ~linearly with #sources

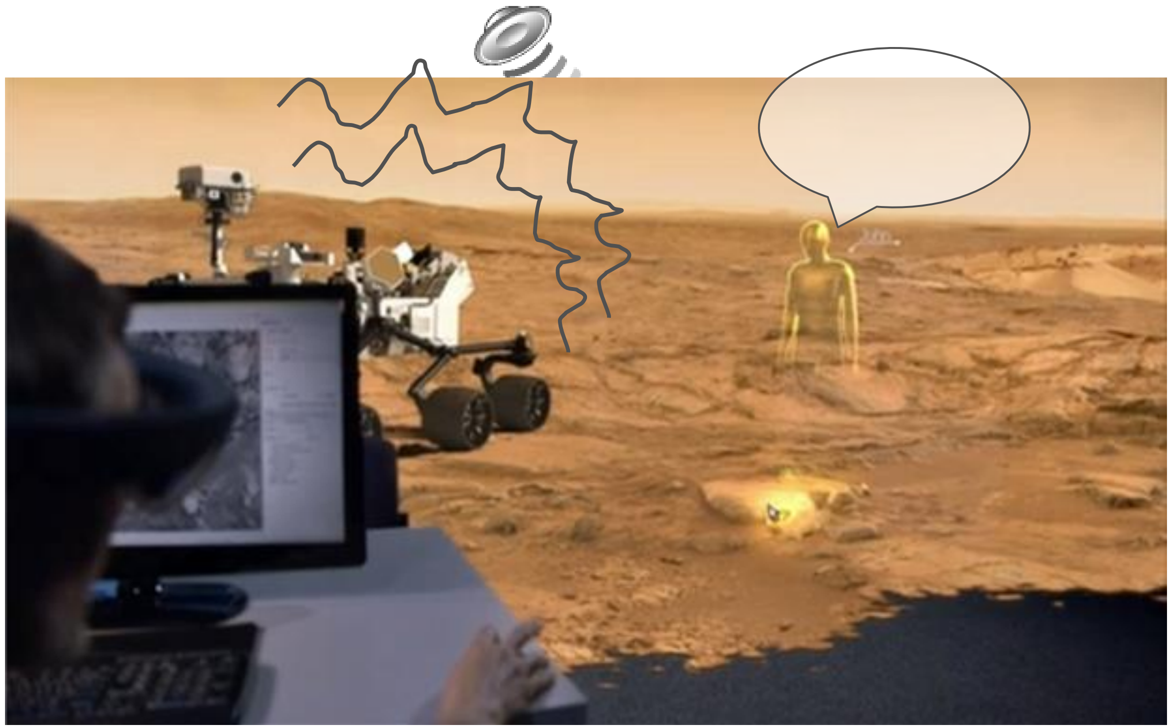
Suitable for synthetic (AR/VR) scenes
→ e.g., Hololens



Object-based rendering

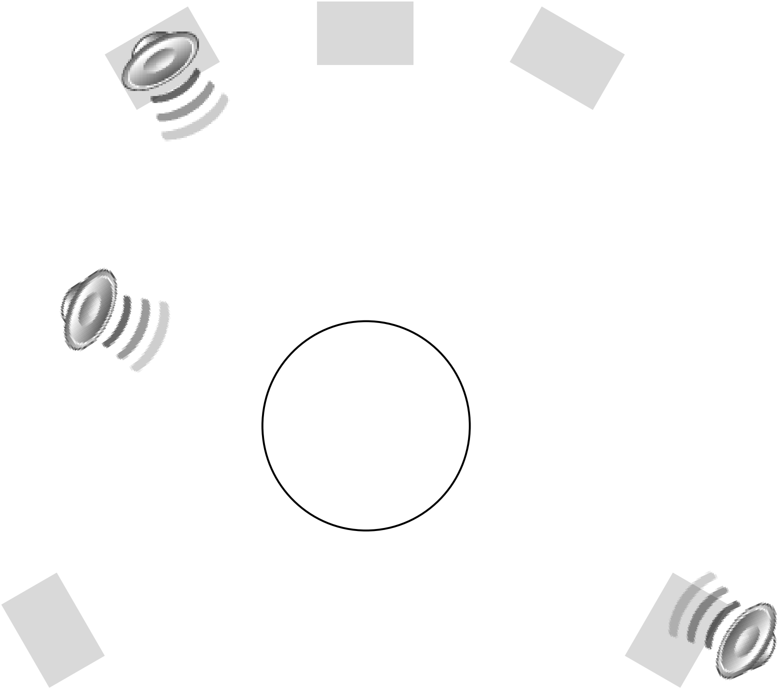
Render each source individually

sou



Channel-based rendering

d



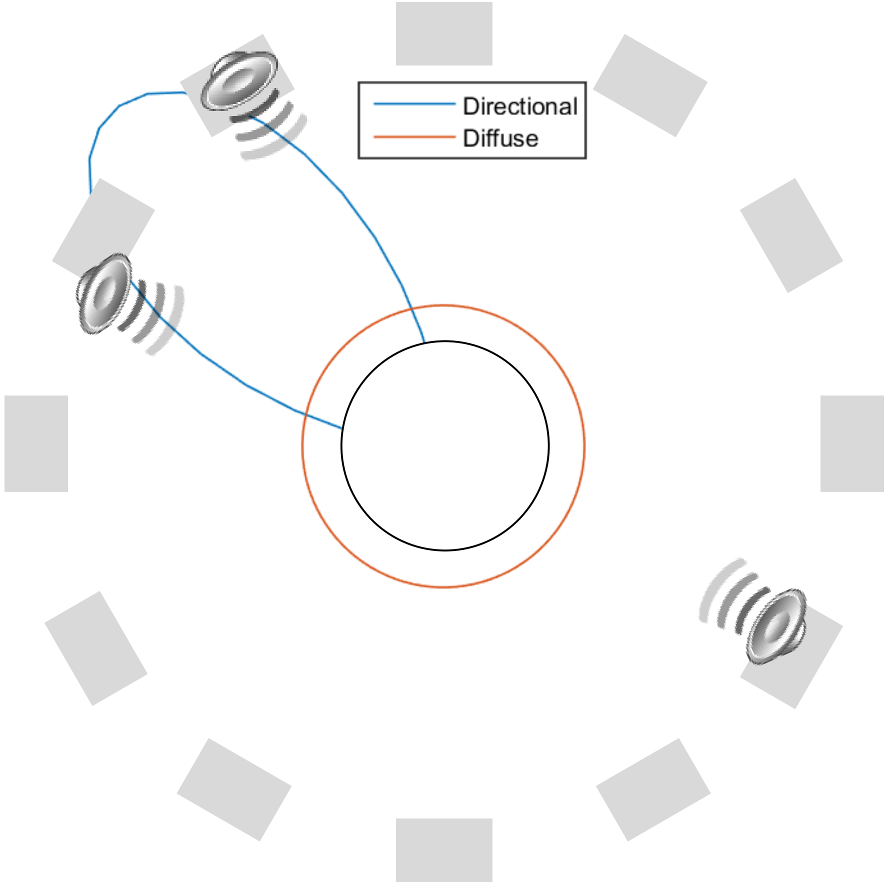
Parametric approaches

Render (fixed) number of virtual speakers

Based on psychoacoustics

Constant complexity

Suitable for spatial recordings
→ Directional Audio Coding (DirAC)*



*V. Pulkki, "Spatial sound reproduction with directional audio coding," J. Audio Eng. Soc., vol. 55, no. 6, pp. 503-516, June 2007.

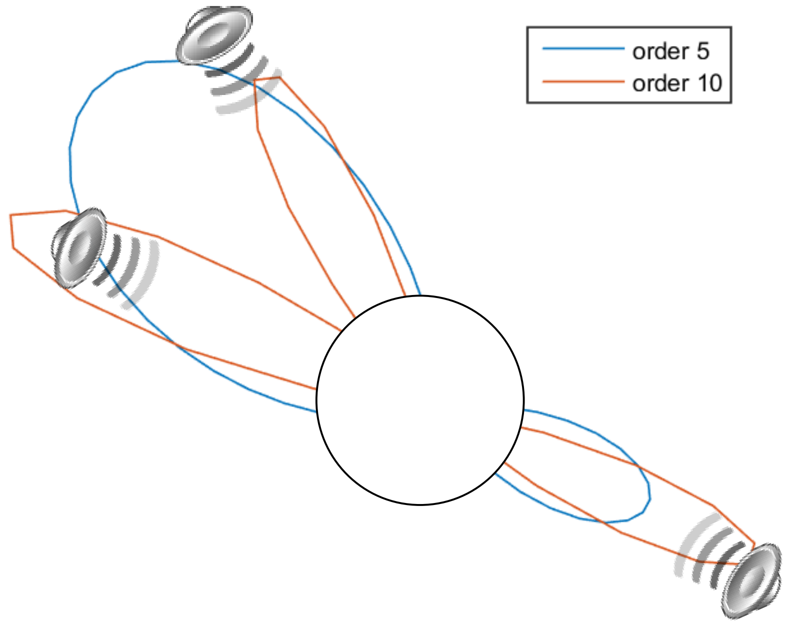
Modal rendering

Render fixed spherical order

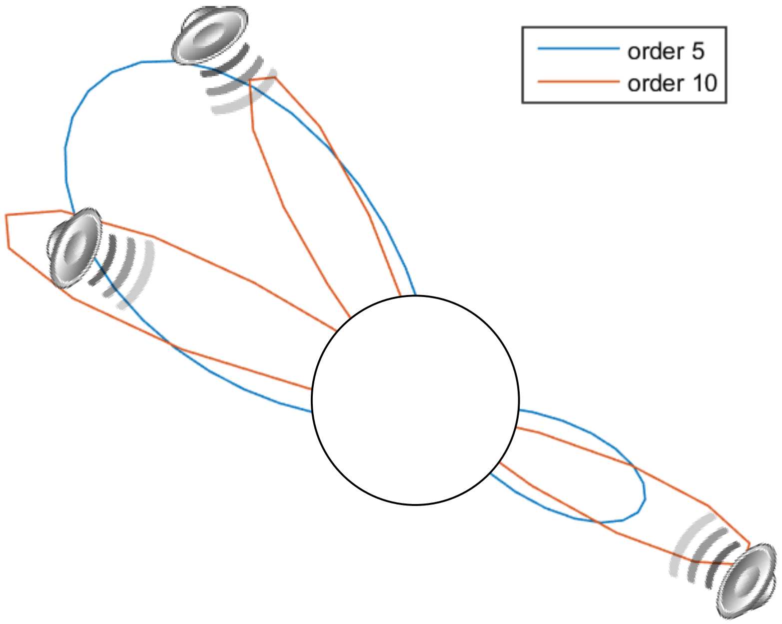
De facto media standard

Variable complexity

Suitable for spatial recordings (e.g., Ambisonics)
→ e.g., Ambisonics



Modal rendering



Sound field capture

16-ch. 4.5″
spherical mic. array

64-ch. 200mm
spherical mic. array

16-ch. 4.5″
cylindrical mic. array

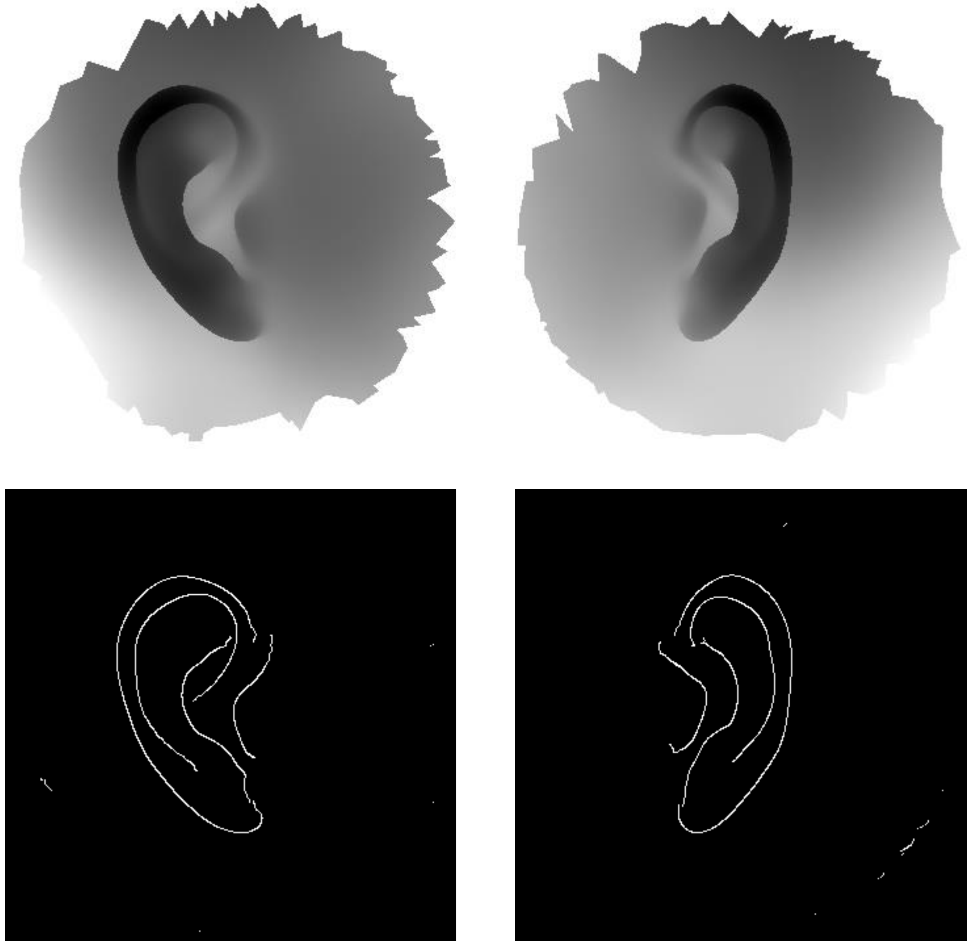
Future outlook

Improve rendering engine

Continue HRTF personalization efforts

Collect user feedback

Study elevation perception
(intern: Vani Rajendran)



Pinna scans.

HRTFs: Application-specific tuning

AR vs. VR

Object-based rendering vs. modal rendering

Dealing with constraints, expectation

Reverb and room modelling

AR vs. VR

Object-based rendering vs. modal rendering

Dealing with constraints, expectation

Conclusion

Spatial audio is key component of AR/VR experience

Growing number of devices/applications/users

Many open research questions – we have only scratched the surface!

Thank you!

Microsoft

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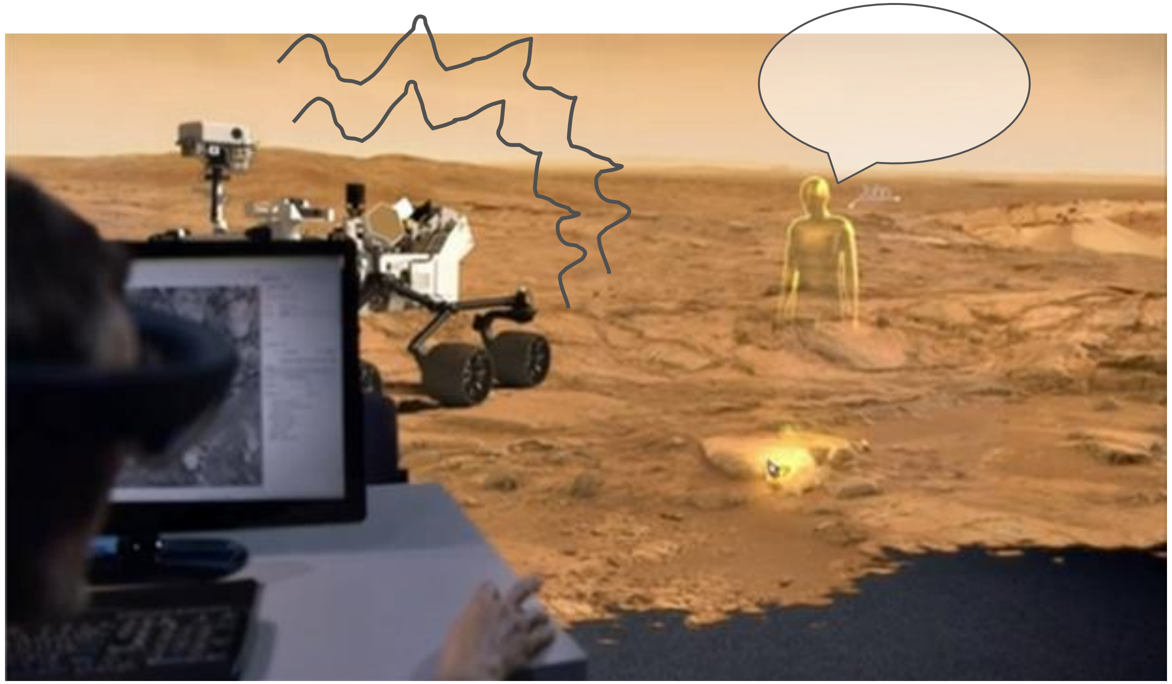
Backup slides

AR & VR scenes



Microsoft Research
Faculty Summit 2016

Microsoft

Comparison: vision vs. hearing

	Vision*	Hearing
Frequency range	430 – 770 THz (1 octave)	20 – 20000 Hz (10 octaves)
Wavelength	700-390 m^{-9}	17 - 0.017 m
Dynamic range	~140 dB	~140 dB
Spatial resolution	~1 arc minute	~5-20 degrees
Temporal resolution	~1/25 s	~10-20 µs
Field of view	130° vertical, 200° horizontal	4π steradians
Energy	Up to 1000 W/m^2 in a daylight	Pain threshold 10^{-5} W/m^2

*Source: Wikipedia

→ Sound is a low energy phenomenon with wavelengths comparable to objects surrounding us.

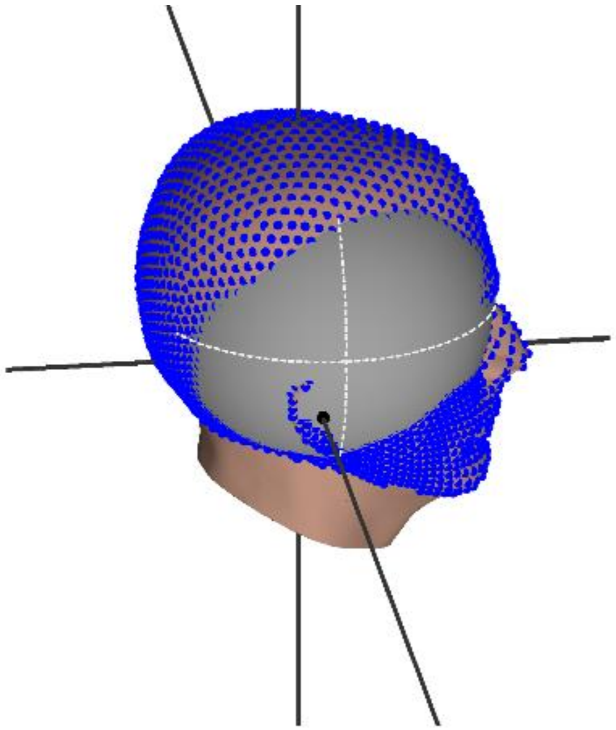
→ Human hearing has high temporal/low spatial resolution, unlimited field of view.

→ Both senses are head-locked!

Interaural time delay modelling

Fit sphere to scan to parameterise ITD models.

Should work with noisier scans (e.g., Kinect)



Sphere fitted to 3-D head scan.

Gamper, H.; Thomas, M. & Tashev, I. (2015). "Anthropometric parameterisation of a spherical scatterer ITD model with arbitrary ear angles." *Proc. IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA).*