Interaktive Auralisation für die Hörforschung

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Communication in complex acoustic space

Target source with directivity

Interfering sources
- Speech, noise, music
- Reverberation

Head turns ("binaural unmasking")

Dynamic reconfiguration
- Interferers or receiver move
- Reflection pattern changes
- Interactivity

Interactive conversation

Interactive 3D visual space

With / without hearing devices

Christmas wish list

Auralization for hearing research

I “Research-grade” sound reproduction in the free-field:
- Measurement tool
- Control over level, spectrum, binaural cues

II rtSOFE: Real-time room acoustics auralization:
- We know behaviour of algorithm
- Reproducibility: common approaches, open source
- Computational resources vs shortcuts critical

III Verified, reproducible audio-visual scenes:
- defined test environments & situations

IV Bringing the real life into the lab: Interactive behaviour to improve dynamic speech intelligibility in rooms

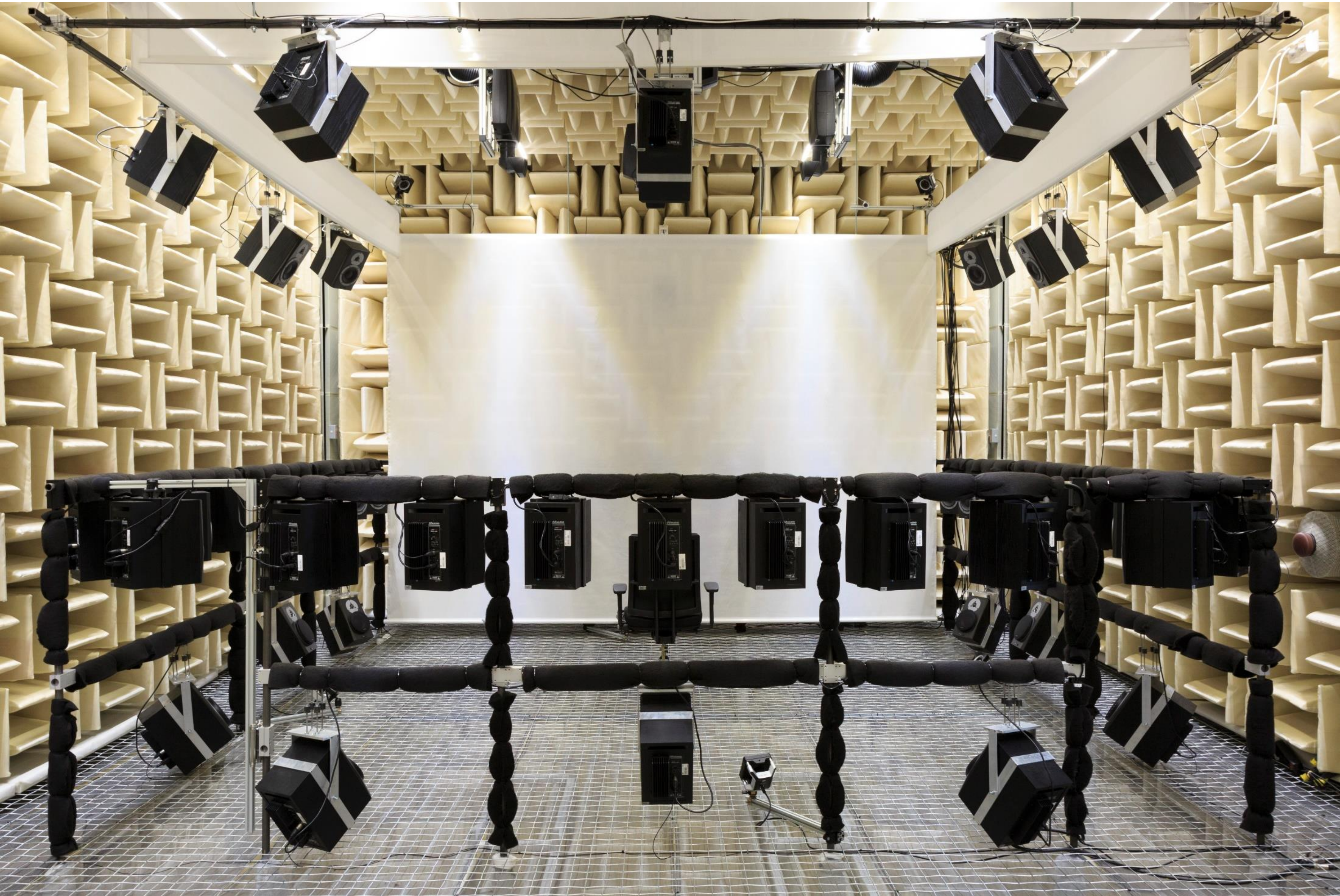
I "Research-grade" sound reproduction in the free-field or Which ear signals can we expect in situ?

Kuntz M., Kolotzek N., Seeber B.: Gemessener Schalldruckpegel im Lautsprecherarray für verschiedene Schallfeldsyntheseverfahren. *Fortschritte der Akustik – DAGA '21:* 1437-1440, 2021.

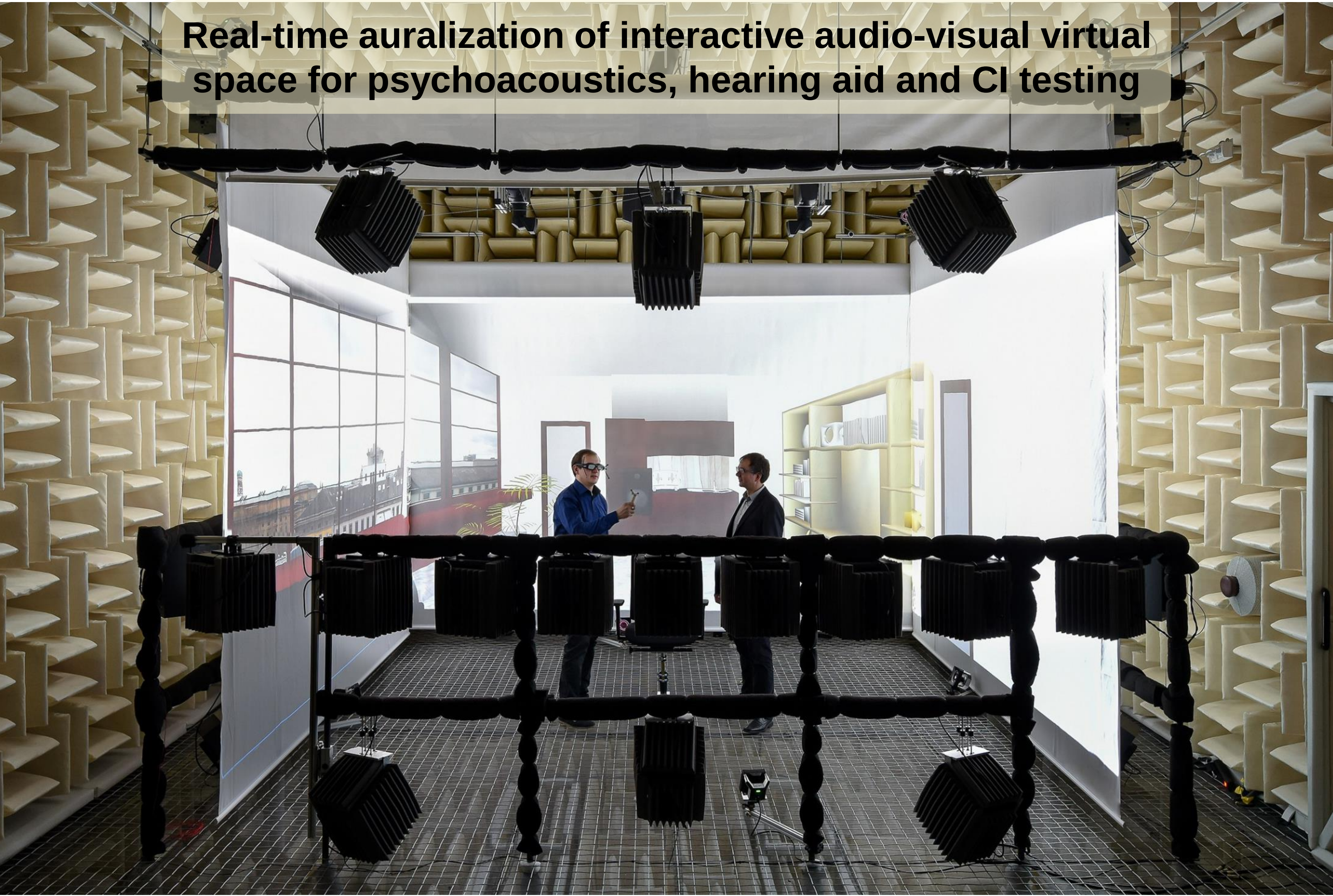
Kuntz M., Seeber B.: Sound field synthesis: Simulation and evaluation of auralized interaural cues over an extended area. Euronoise 2021, in print.

Matthieu Kuntz
Norbert Kolotzek

Simulated Open Field Environment (SOFE)



real-time Simulated Open Field Environment



In-situ evaluation of sound field reproduction

Aim: Audiological and psychoacoustical measurements in free field

- ISO-spec anechoic chamber
- But equipment: loudspeakers, frames, video projectors, cameras

Sound field synthesis/reproduction techniques have been numerically evaluated, but what is their accuracy in situ? Off center?

1. Measurement according to ISO 8253-2: Sound field audiometry

2. Measurement of reproduced sound field inside loudspeaker array

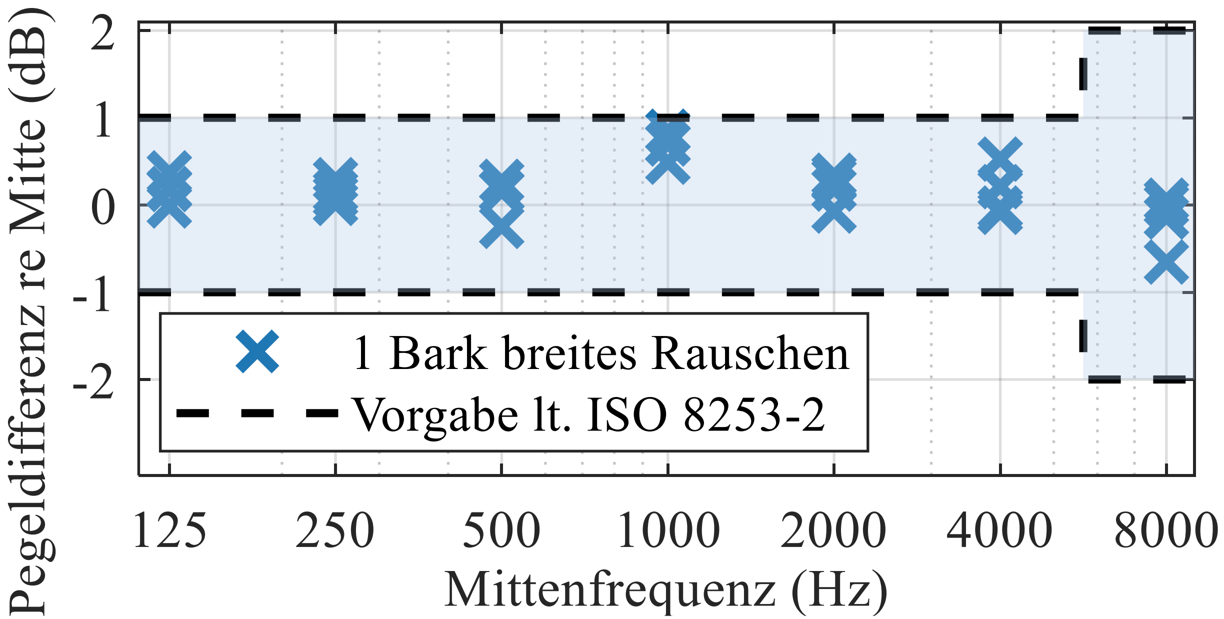
3. Evaluation of simulated binaural cues

1. Verify audiological standard ISO 8253-2

Permissible level deviations in the free field, frontal loudspeaker:

- ±15 cm in 4 directions: < 1 dB
- Difference left-right: < 3 dB
- Deviation from 1/r law: < 1 dB

Suitable for narrow-band measurements



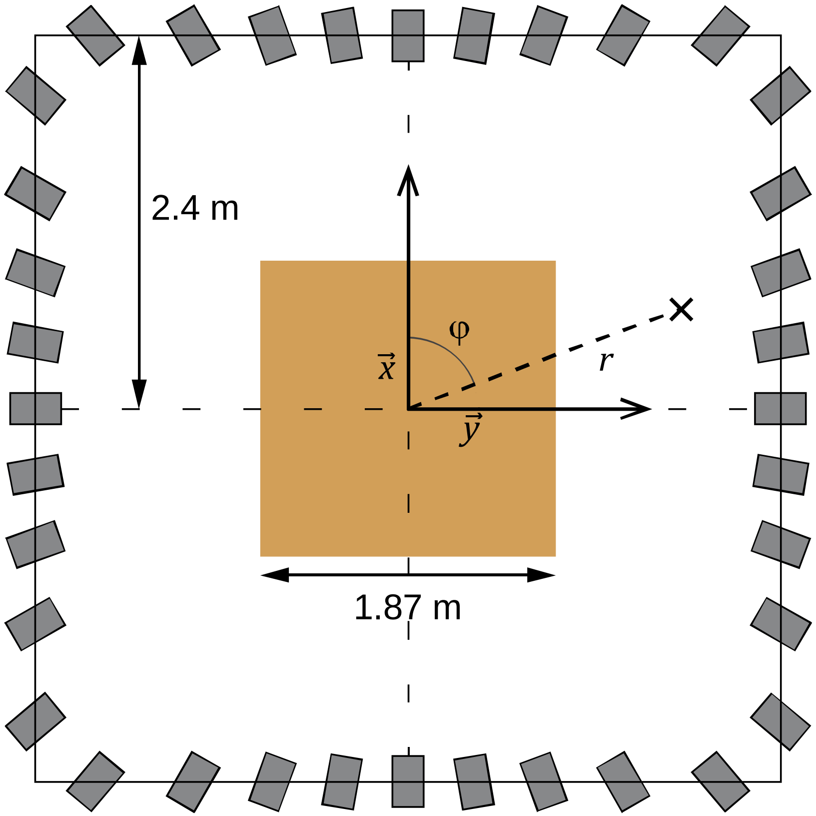
1 Bark wide Uniform Exciting Noise (UEN) at audiological frequencies

2. in-situ sound field reproduction measure

SOFE loudspeaker array
- 36 horizontal loudspeakers
- 1024-taps FIR filter equalization
- 2D HOA 17^{th} order
- Virtual source at 13°
- Stimuli as ISO measurement

Sound field synthesis techniques
- HOA *basic*
- HOA *max rE*
- VBAP
- Nearest loudspeaker (NLS)

Measure 529 points ±0.9 m from center



2. in-situ sound field reproduction measure

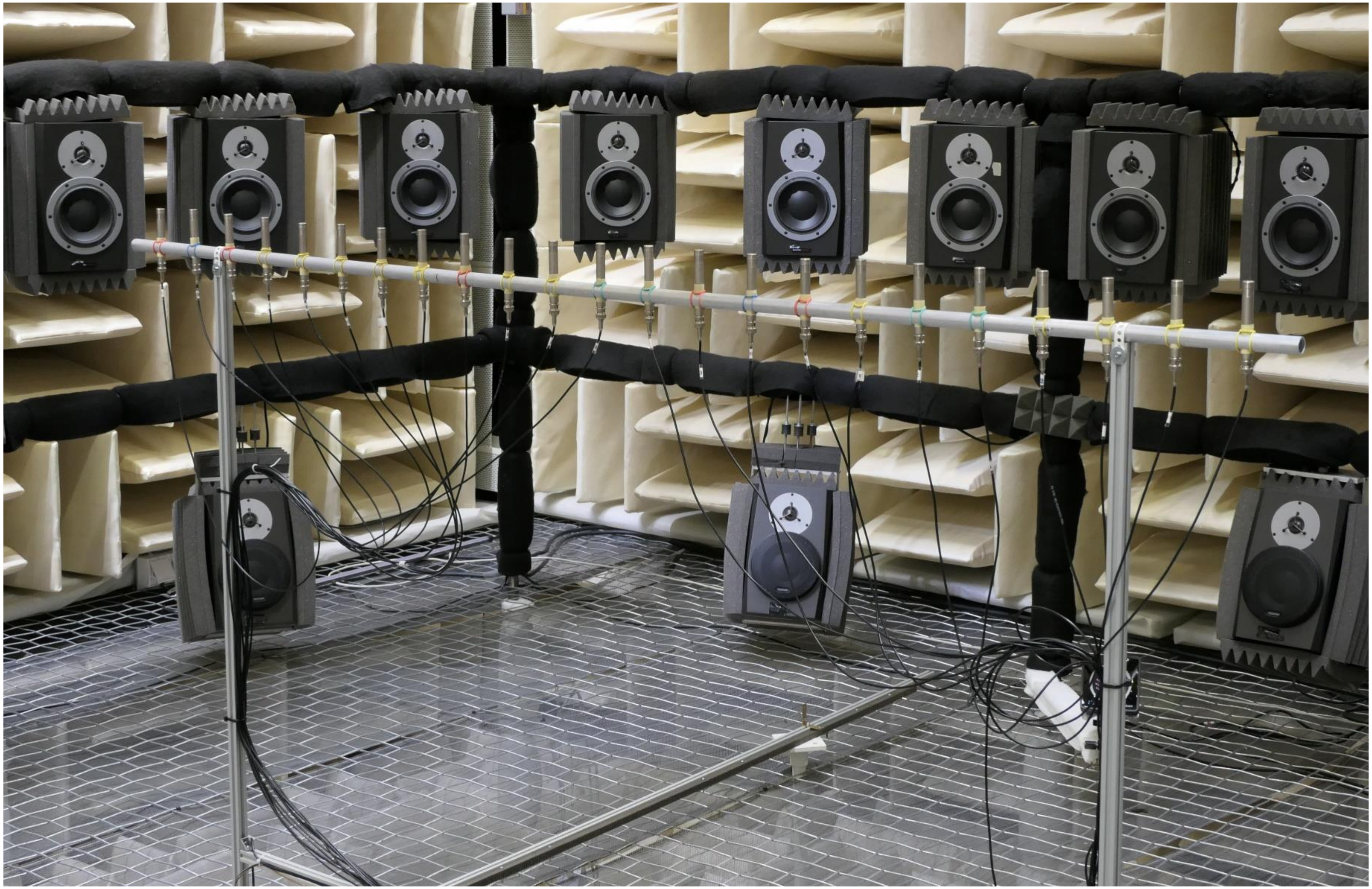
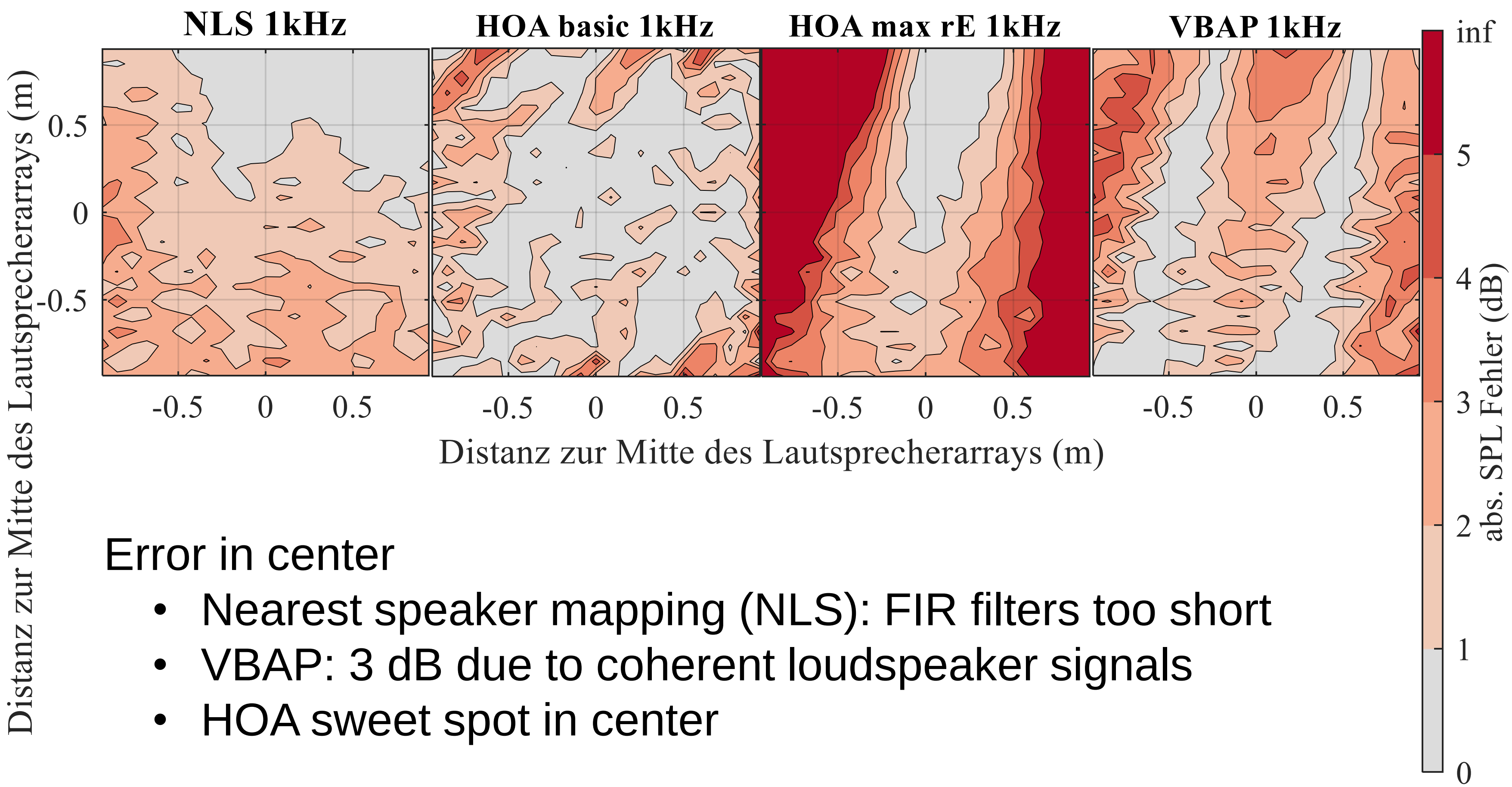


Image: Kolotzek, TUM

2. in-situ sound field reproduction measure



Error in center

- Nearest speaker mapping (NLS): FIR filters too short
- VBAP: 3 dB due to coherent loudspeaker signals
- HOA sweet spot in center

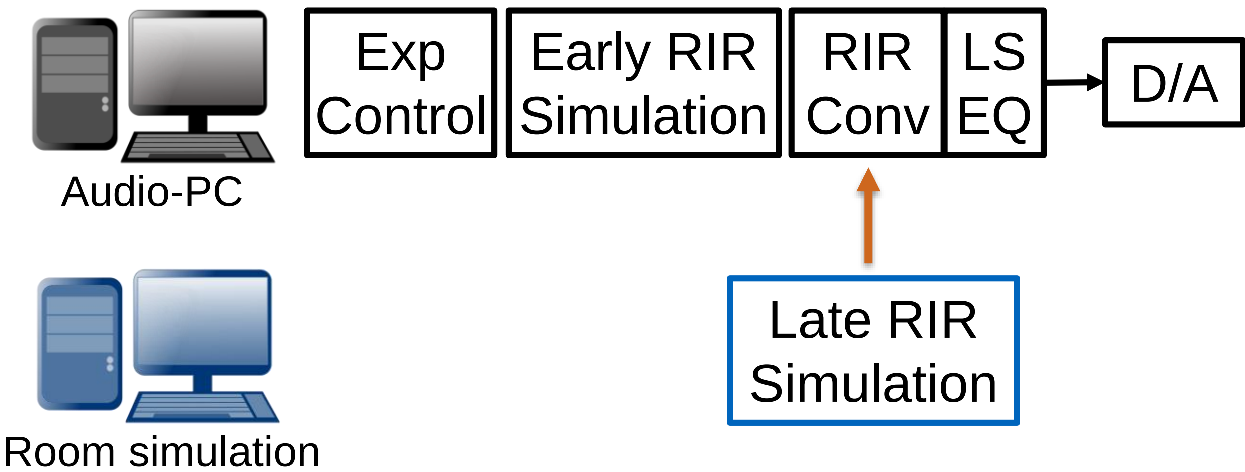
II rtSOFE: Real-time room acoustics auralization

Key student contributors:
Manuel Hornung
Niklas Löcherer
Hendrik Nöller
Maximilian Kirchmeier

Bernhard Seeber since 1999…

Tong Wang 

real-time Simulated Open Field Environment



Modular concept, OSC control

Mirror-image source method to high orders

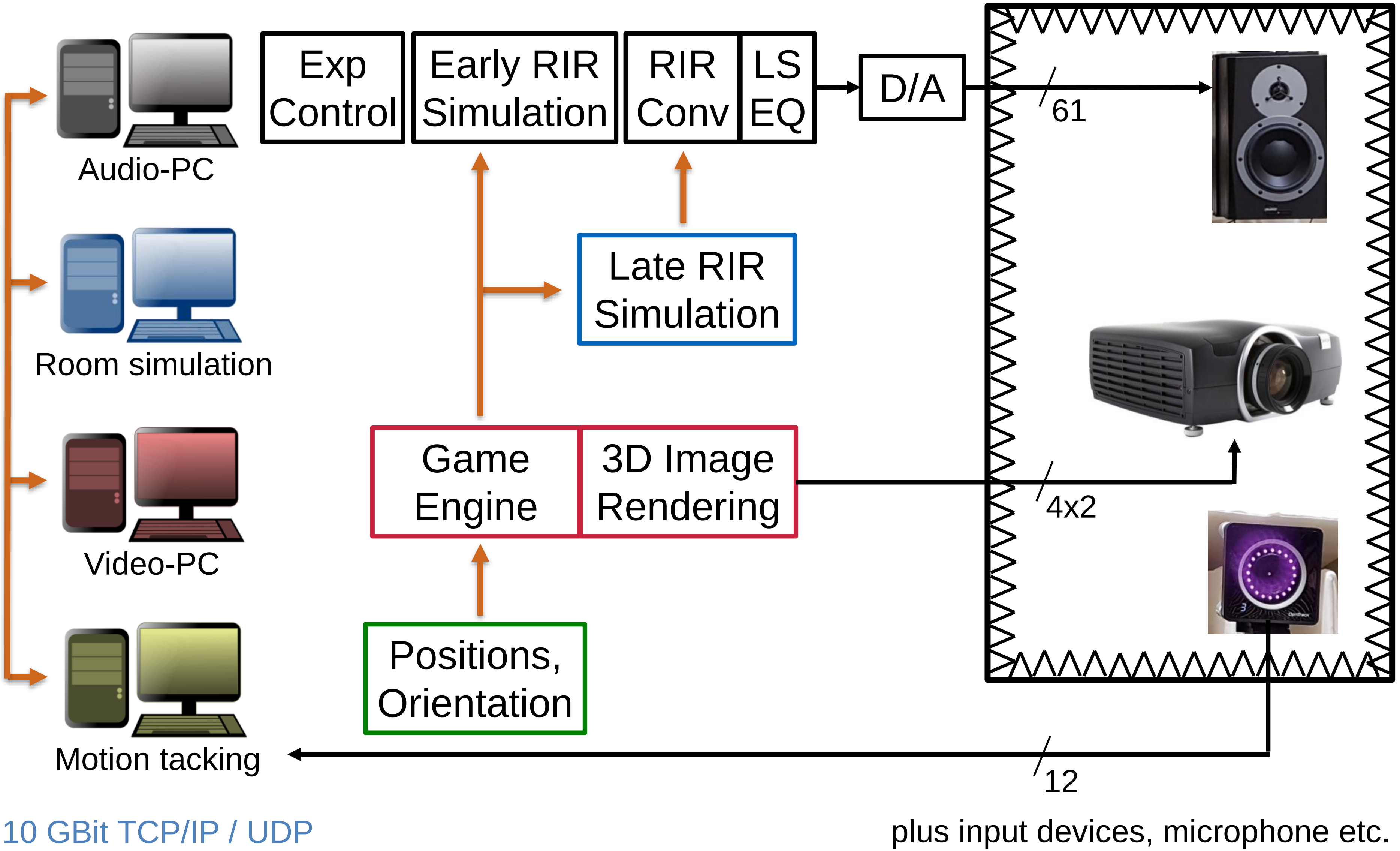
Real-time computation and convolution >3s RIRs @360 Hz update rate (motion tracker)

Latest:

- **New rendering schemes including HOA and binaural rendering**
- **New multi-source convolver incl. loudspeaker equalization**
- **“Professionalized” code development with testing pipeline**

rtSOFE available at: zenodo.org/communities/aip-tum

real-time Simulated Open Field Environment



rtSOFE available at: zenodo.org/communities/aip-tum

III Verified audio-visual scenes

How to bring a realistic representation of audiologically relevant listening situations into the lab – controlled, verified and repeatable?

Enghofer, Hladek, Seeber: An 'Unreal' Framework for Creating and Controlling Audio-Visual Scenes for the real-time Simulated Open Field Environment. Fortschritte der Akustik – DAGA '21: 1217-1220.

Hladek, Ewert, Seeber: Communication conditions in virtual acoustic scenes in an underground station. I3DA 2021

Pulella, Hladek, Seeber: Auralization of acoustic design in primary school classrooms. EEEIC 2021

Hladek, Lubos, van de Par, Steven, Ewert, Stephan D., & Seeber, Bernhard U. (2021). Audio-visual scenes repository: How to contribute (1.0). Zenodo. https://doi.org/10.5281/zenodo.5532673

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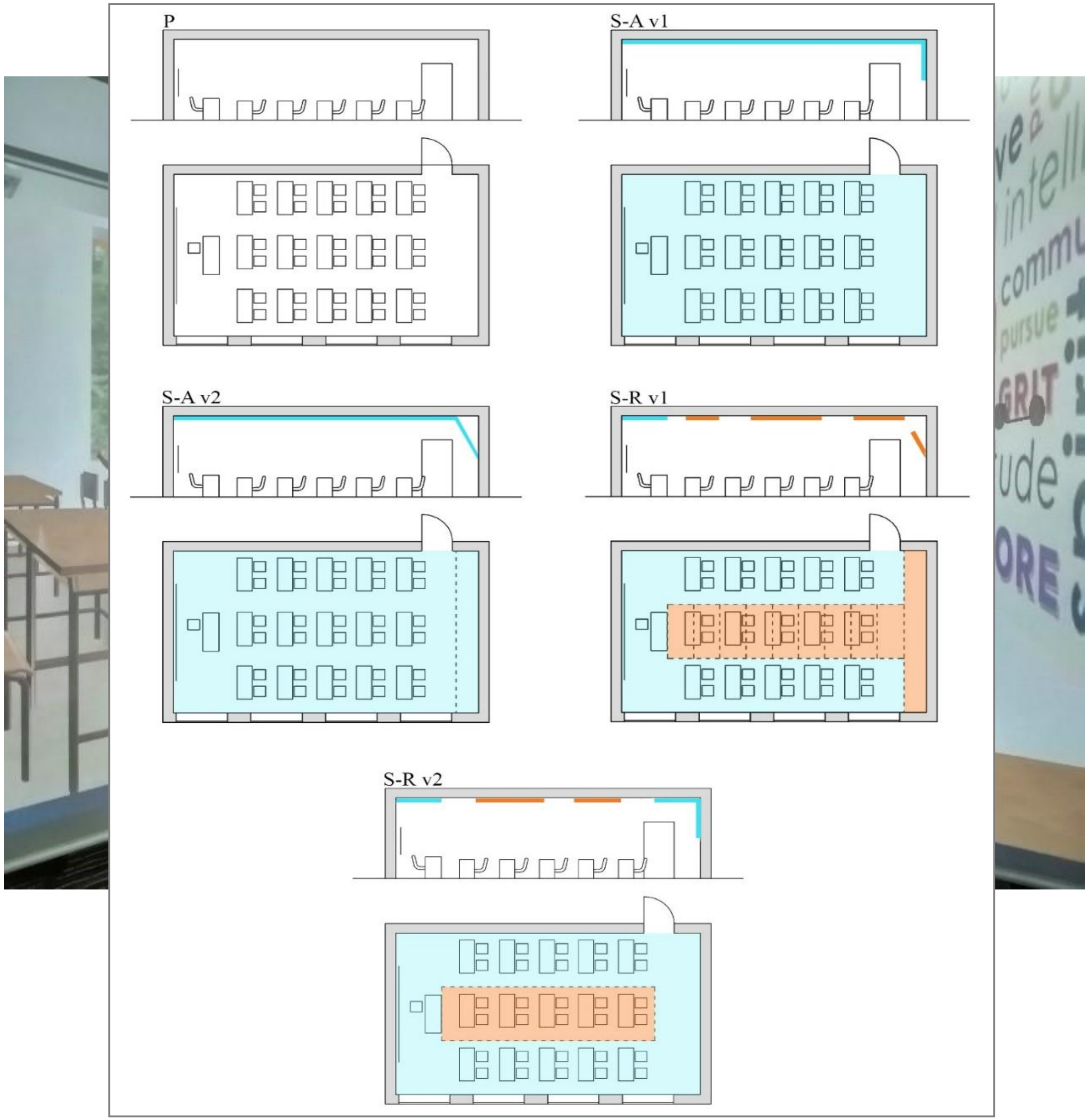
Environments for hearing research

Classroom

Visual model

Acoustic model



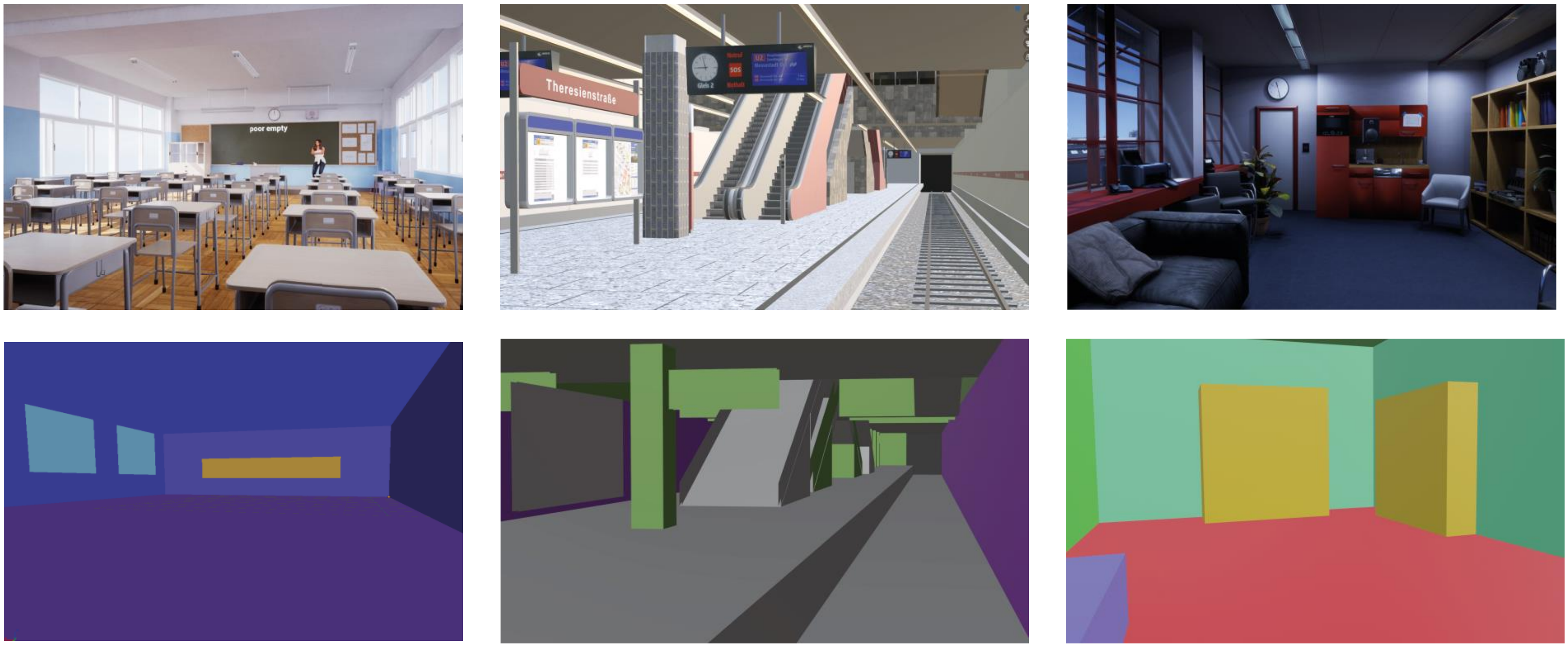
Pulella, Hladek, Seeber: Auralization of acoustic design in primary school classrooms. EEEIC 2021

Environments for hearing research

Classroom | Underground | Seminar room

Visual model

Acoustic model



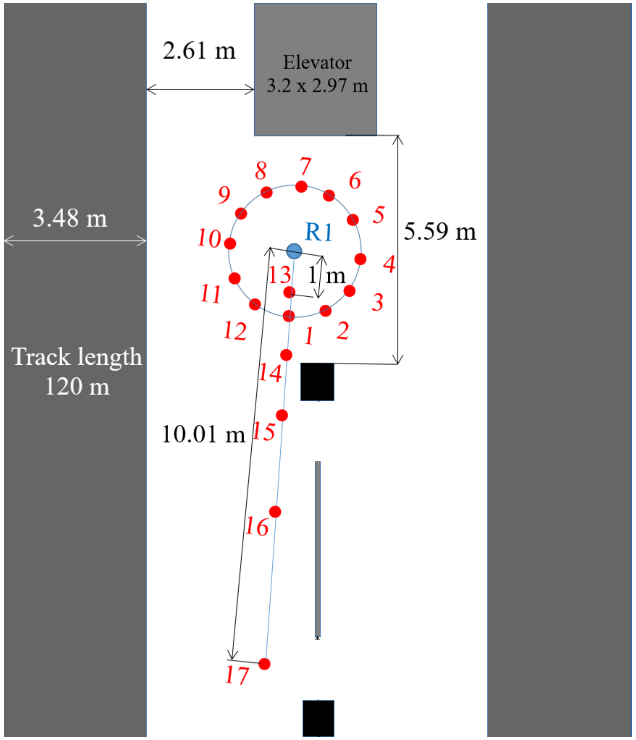
Underground scene and other scenes available open-source:
zenodo.org/communities/audiovisual_scenes
incl. contribution guidelines

Enghofer, Hladek, Seeber: An ’Unreal’ Framework for Creating and Controlling Audio-Visual Scenes for the real-time Simulated Open Field Environment. Fortschritte der Akustik – DAGA '21: 1217-1220, 2021.

Underground scenes for hearing research

Scene A:
Circle

Scene B:
Approach



R1 Listener

Source

Photo: Hladek

Physical verification:

- Room acoustical parameters (T30…)
- Binaural parameters (ILD, ITD, IC)

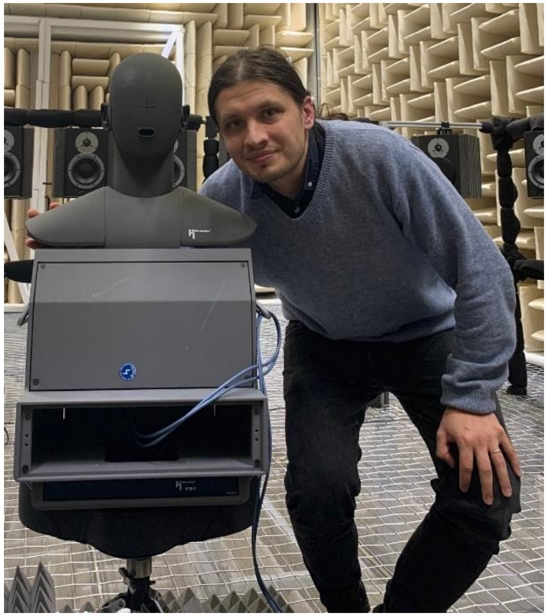
Hladek, Ewert, Seeber: Communication conditions in virtual acoustic scenes in an underground station. I3DA 2021

IV Bringing the real life into the lab: Interactive behaviour to improve dynamic speech intelligibility in rooms

Hládek and Seeber: The effect of self-motion cues on speech perception in an acoustically complex scene. Proc. Forum Acusticum 2020, DOI: 10.48465/fa.2020.0364

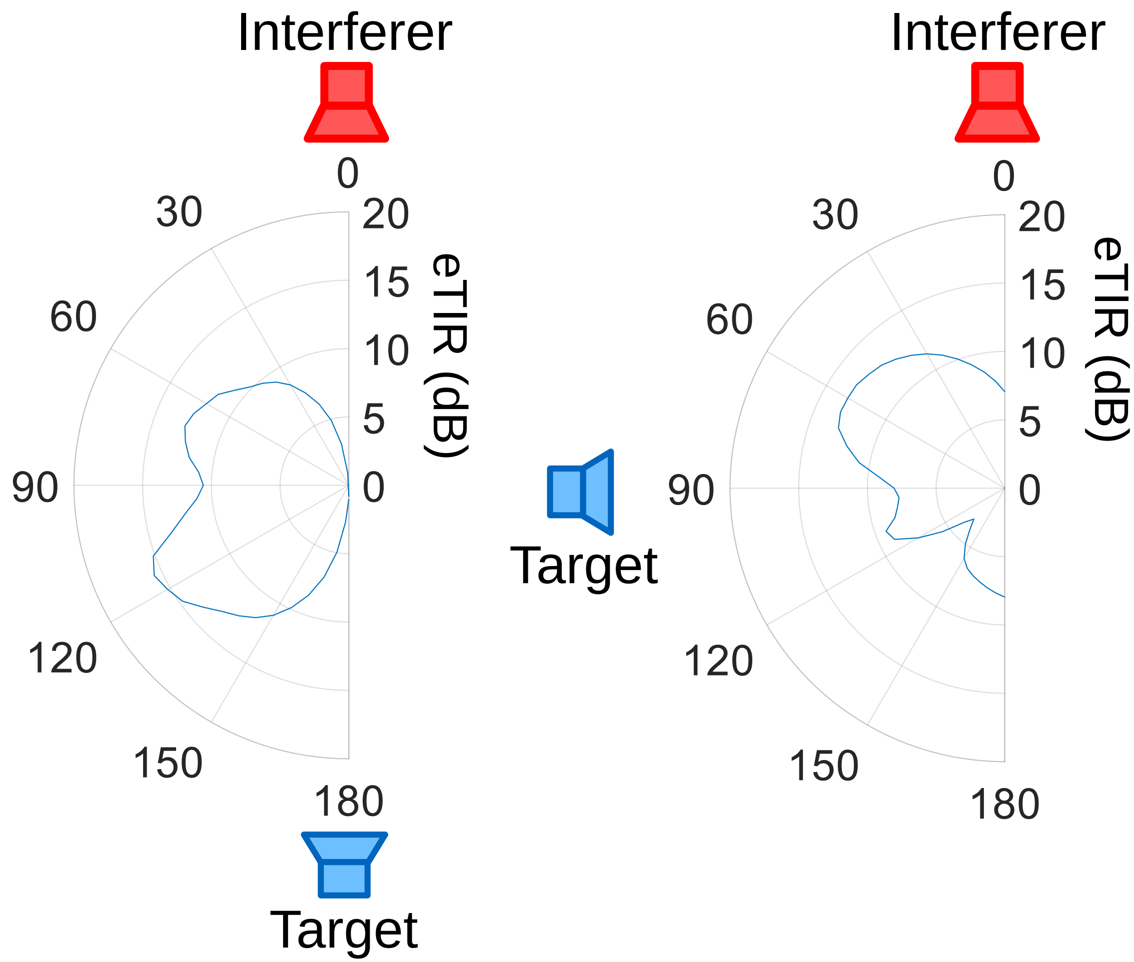
Hladek, L.; Seeber, B.U.: Behavior and Speech Intelligibility in a Changing Multi-talker Environment. Proc. 23rd International Congress on Acoustics, ICA 2019: 7640-7645, 2019.

Ľuboš Hládek & Aloisius Akustikus



Dynamic listening in cocktail parties

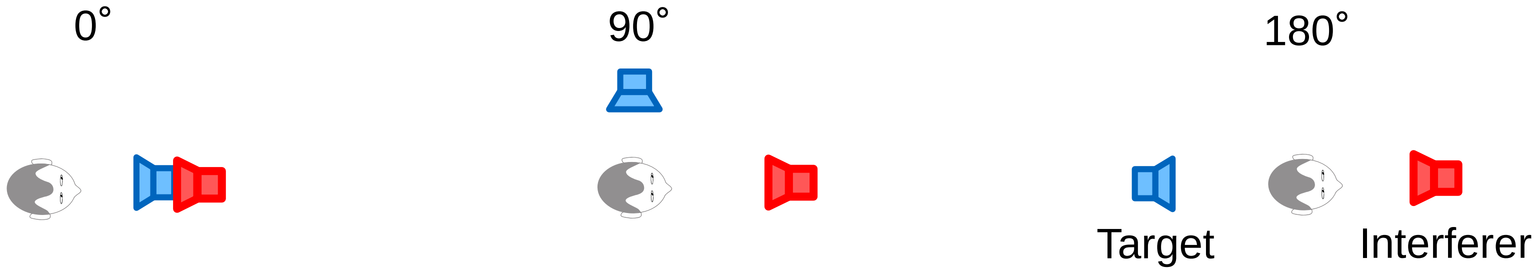
Spatial release from masking –
benefit for speech intelligibility



eTIR: Jelfs et al., 2011

Dynamic listening in cocktail parties: Methods

Target-Interferer Configurations – in virtual room



Presentation Type

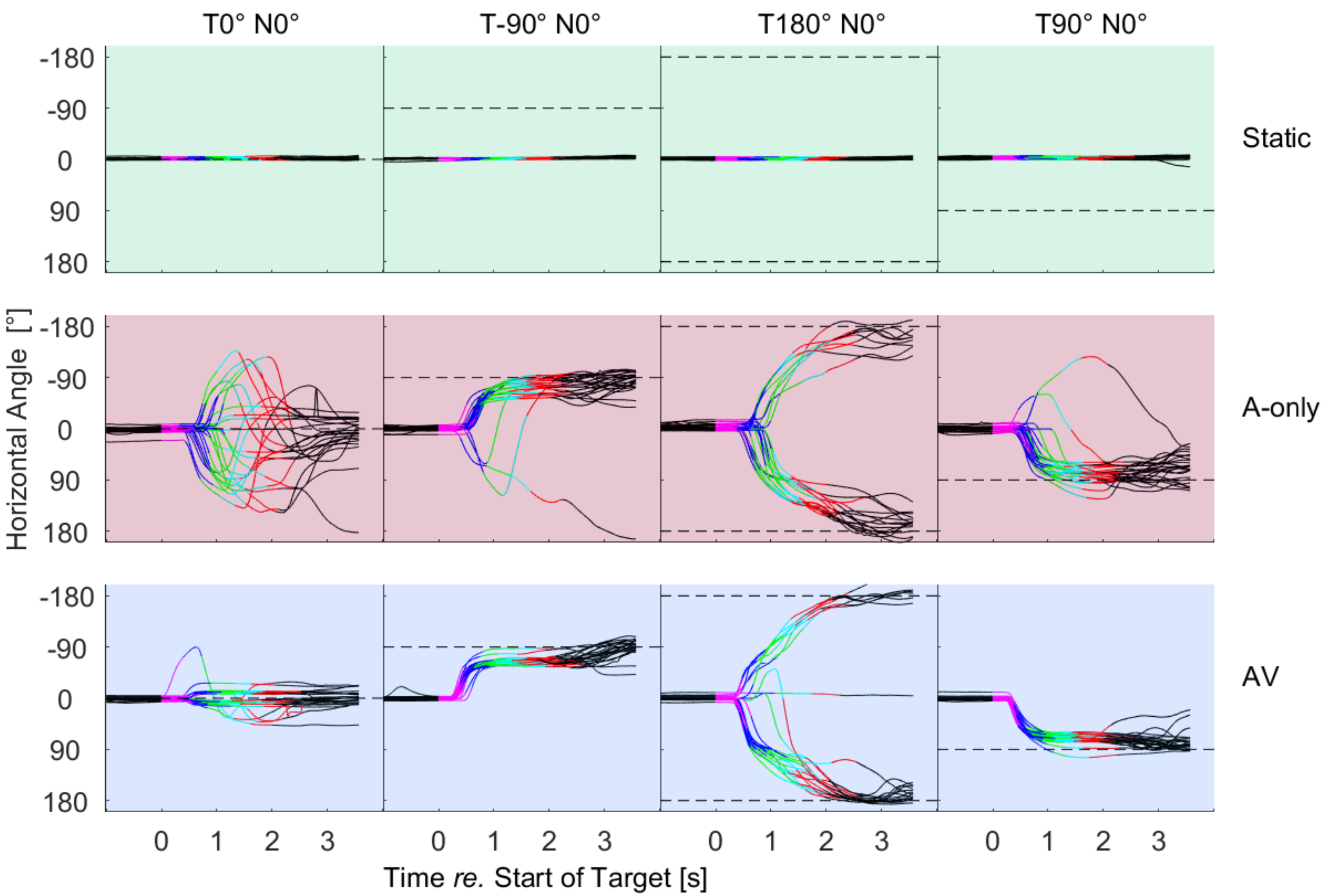
- Audio-visual
- Audio-only
- Static Baseline (Interferer always at the front)

Speech understanding measured with 5-word Oldenburger sentence test:

"Karin hat fünf rote Schuhe"

Dynamic listening: Head movement patterns

Oldenburger sentence test: “Karin hat fünf rote Schuhe”



Summary

Free-field sound reproduction verified against audiological standard and for wide-area reproduction:

HOA basic at low f and nearest speaker at high f

“real-time Simulated Open Field Environment” for research in psychoacoustics, audiology, sound quality:

HOA + binaural rendering, Unreal control, testing pipeline

Verified underground scenes for reproducible research

Speech intelligibility in rooms reduced during head turns

Head orientation occurs to optimal position

Thank you!

Bernstein Center for Computational Neuroscience Munich

DFG SFB 1330 “HAPPAA”, project C5

Anechoic chamber: TUM, AIP, DFG