Toolbox for acoustic scene creation and rendering (TASCAR)

Render methods and research applications

Giso Grimm Joanna Luberadzka
Tobias Herzke Volker Hohmann

Digital Hearing Devices
Medical Physics Group and Cluster of Excellence Hearing4all
Carl-von-Ossietzky Universität Oldenburg

HörTech gGmbH, Oldenburg

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Virtual reality

Virtual reality

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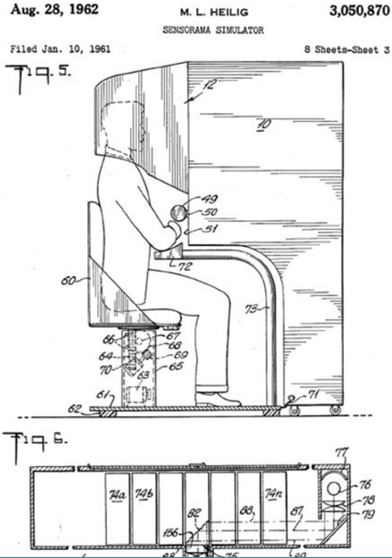

Virtual reality

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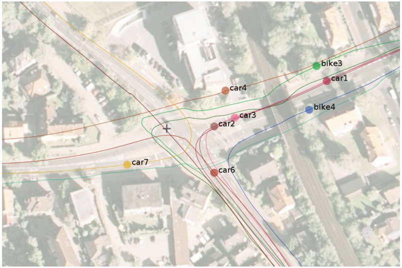
TASCAR

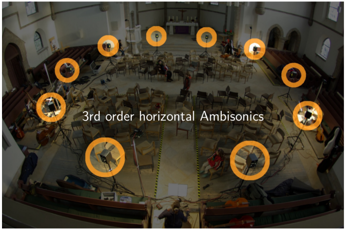
Toolbox for Acoustic Scene Creation And Rendering

- Linux Software
- Acoustic Environments
- Scenes Design
- Real Time Rendering
- Moving sources, Acoustic modelling
- Interactive



TASCAR - origin

- Initial idea: **Music Performance** (Harmony of the Spheres)
- **Inspiration**: Sound Scape Renderer
- Further development in **Research Project**



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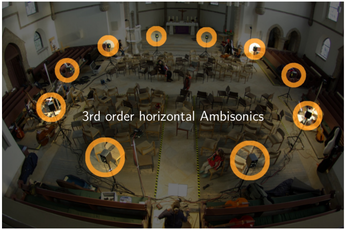
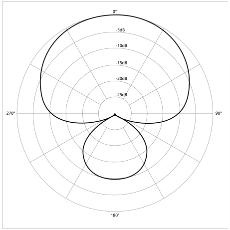
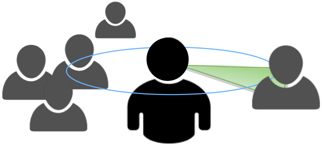


TASCAR in Hearing Research - Motivation?

Evolving hearing aids

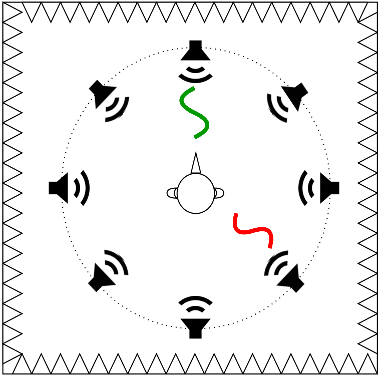
- Much more than simple amplification
- Space-aware signal processors
- Noise and feedback cancellation
- Directivity patterns, source localisation
- New methods for evaluating spatial properties are needed





TASCAR in Hearing Research

Example : *how directionality in hearing aid improves the speech intelligibility?*



- Typical test set up
- Two separate sources
- For some directions noise can be fully suppressed
- Result: High gain from using directional hearing aid.
- Oversimplification
- Subject behaviour is unnatural
- Unrealistic

TASCAR in Hearing Research

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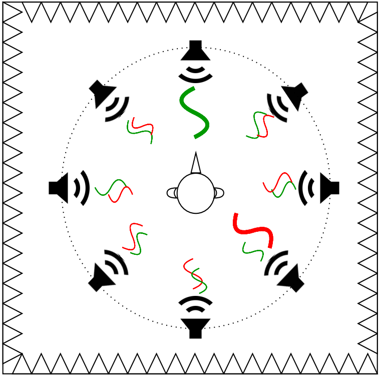

- simulation of an acoustic environment
- all channels active - reflections, reverberation
- much more realistic
- moving sources
- Result: Benefit from using directional hearing aid is not that big anymore
- Results correspond to the real-life situation

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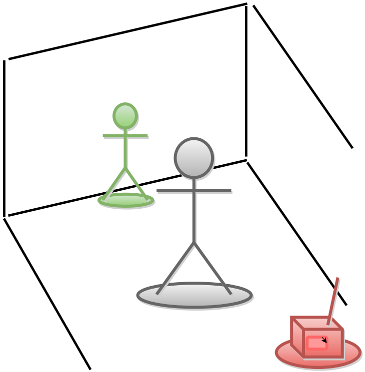

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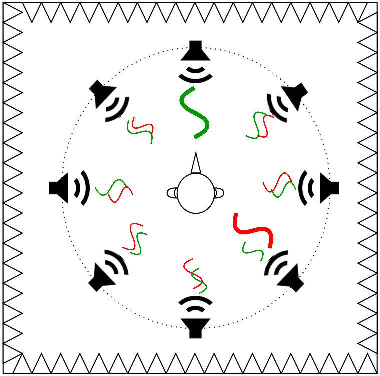

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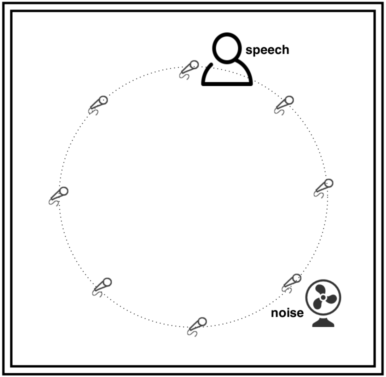

- Realistic, but...
- not scalable
- uncontrollable
- costs time and effort

TASCAR in Hearing Research

Large discrepancies between laboratory and real-life conditions!

- **Need**:

TASCAR in Hearing Research

Large discrepancies between laboratory and real-life conditions!

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  - *complex*, *realistic*
  - *controllable* and *reproducible* test environments

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  - *Physically correct* simulation for listening with a hearing aid

TASCAR in Hearing Research

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Bring the real life into the lab!

TASCAR: How does it work?
Modular structure

Audio content

sound files or real-time audio

Geometry

dynamic objects, image source positions

Acoustic model

transmission and reflection model, rendering to output format

Built upon jack audio connection kit:

Audio content
sound files or real-time audio

Geometry
dynamic objects, image source positions

Acoustic model
transmission and reflection model, rendering to output format

jack ports

jack time line

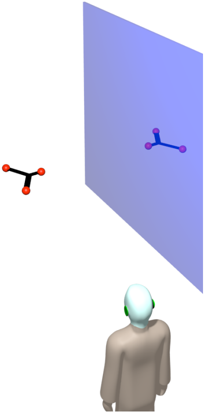
Acoustic model: Source objects

- Built from one or more “sound vertices”
- Each sound vertex is omni-directional radiator
- Each sound vertex is a jack input port

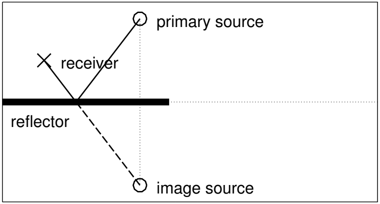
Acoustic model: Receiver

- Encode direction into audio signal
- jack output ports
- Various output formats:
  - omni and cardioid virtual microphones
  - 3rd order ambisonics, horizontal and full-periphonic
  - Horizontal ambisonic panning, arbitrary order, 'basic' and 'in-phase'
- Binaural rendering with virtual loudspeakers and head-related transfer functions
- Reproduction methods validated with different classes of hearing aid algorithms.

Acoustic model: Image source model



- Polygon-mesh reflectors, dynamic location and orientation
- Surface properties approximated by 1st order low-pass filter
- Time-domain processing:
  no pre-calculation of impulse responses
- Soft fades at reflector boundaries:



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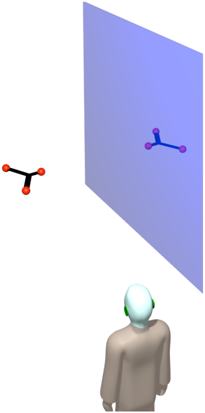

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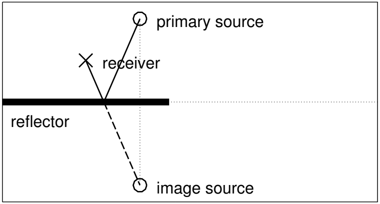

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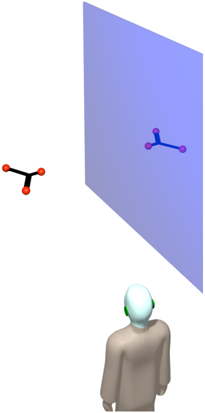

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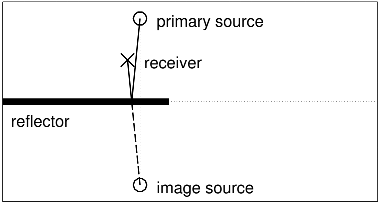

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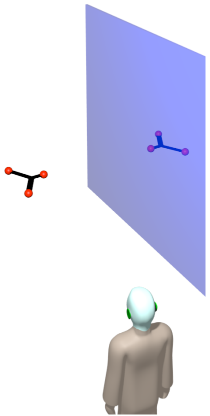

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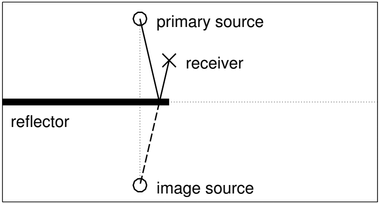

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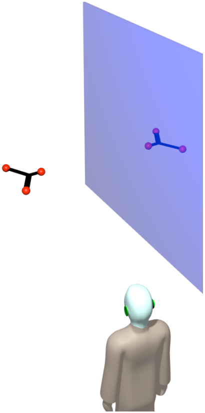

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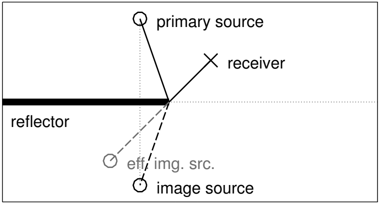

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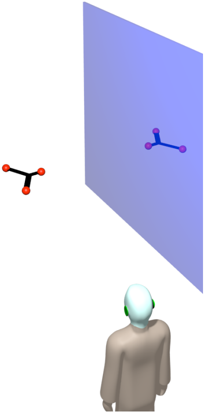

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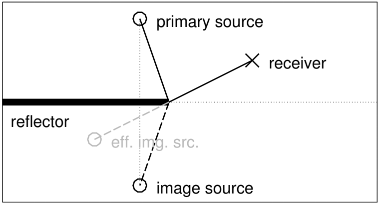

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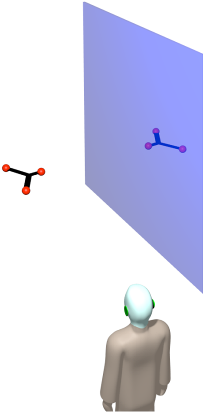

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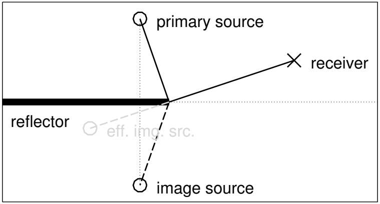
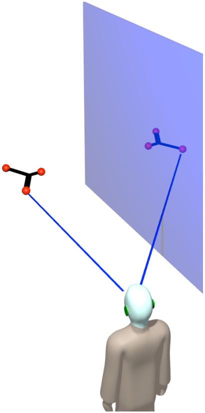
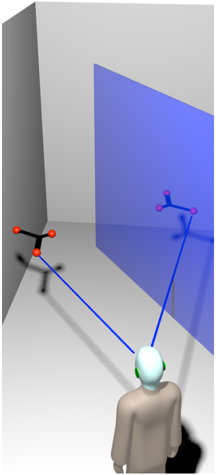


Acoustic model: Transmission model



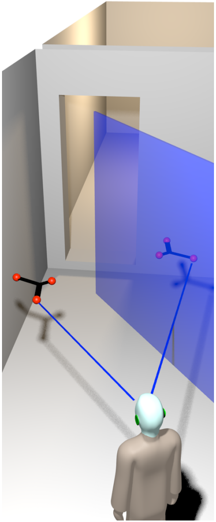
- Time variant delay line
  - Delay line for each image source
  - Doppler shift for fast movements
  - Time varying comb filter effects for slow movements
- Air absorption model
  - Simplification: 1st order low-pass with distance-dependent filter coefficients
  - Good match up to 100 m
  - 18°C, 60% rel. humidity

Acoustic model: Boundary volume masks

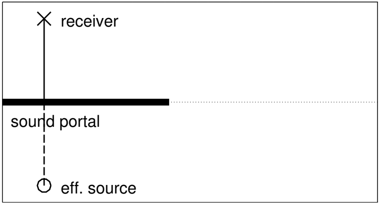


- Allow to split large scenes into sub-spaces
- Zero-gain if receiver is within ("inner" masks) or outside ("outer" masks) masks
- Soft boundaries, von-Hann ramp

Acoustic model: Room coupling simulation



- Sound portals = dedicated sound sources
- Input: output of microphone in adjacent room
- Rectangular area, always radiating from closest point to receiver
- Increased effective distance to avoid proximity effect



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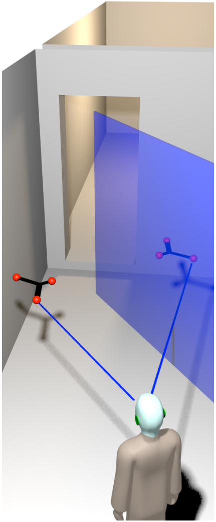

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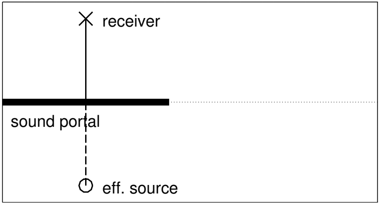

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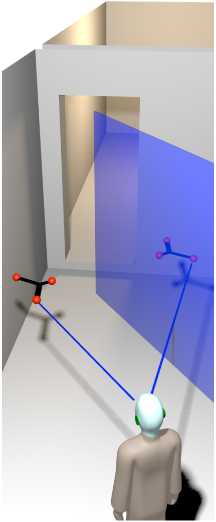

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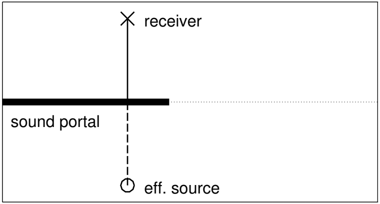

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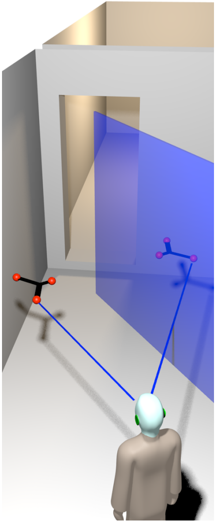

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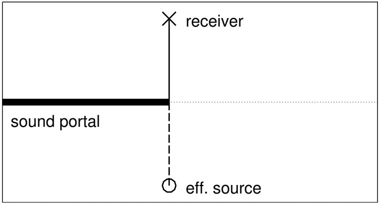

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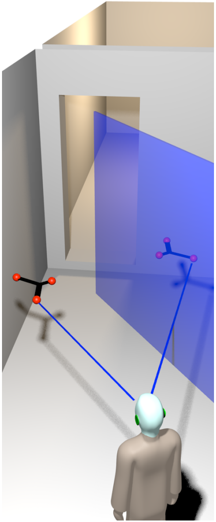

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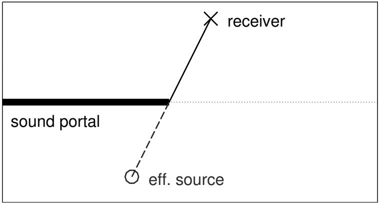

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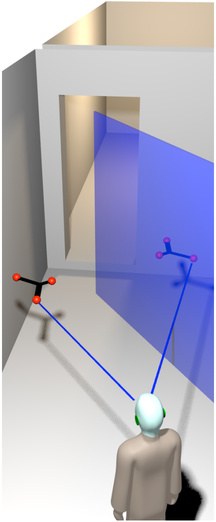

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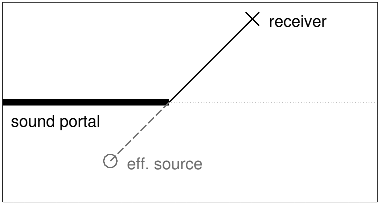

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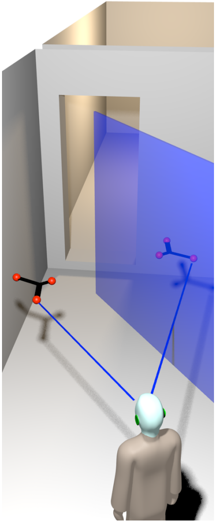

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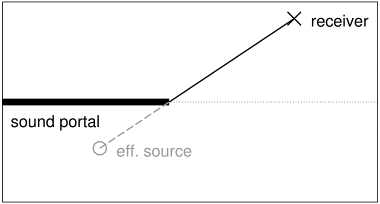
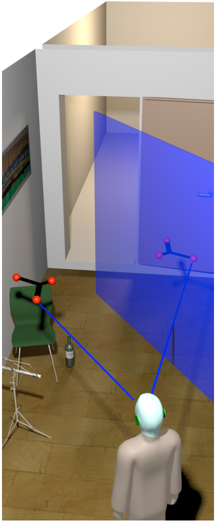


Acoustic model: Diffuse source model



- First order ambisonics (FOA) recordings for diffuse background sounds
- Diffuse reverberation in first order ambisonics with external tools:
  - Convolution reverb
  - Feedback delay networks
- No transmission model:
  - Constant gain
  - No Doppler shift
- Requires FOA decoder for each receiver type

Geometry processing

- **Trajectories**
  defined by sampled *location* and *orientation*
- **Delta transforms**
  controlled via OSC or geometry modifier plugins

- Updated on each processing cycle
- Derived parameters interpolated within processing blocks
- All objects can be dynamic:
  sources, receivers, reflectors, volume masks

Tradeoffs, bugs and limitations

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TASCAR is *not* a room acoustic simulator

- Simplifications of reflections and sound propagation:
  - Missing/simplified diffraction model
  - Missing absorbers and obstacles
- Real-time processing limits complexity

Tradeoffs, bugs and limitations

TASCAR is *not* a room acoustic simulator

Motion blurs and displaces sources

- Linear interpolation of panning coefficients, e.g., ambisonics weights, within blocks
- Acoustic travel time not taken into account in trajectory processing

Tradeoffs, bugs and limitations

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Motion blurs and displaces sources

Acoustic artifacts

- Delay lines use nearest neighbor interpolation
- Reproduction methods may not create correct physical sound field

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Acoustic artifacts

Huge code base

- Undiscovered bugs are likely

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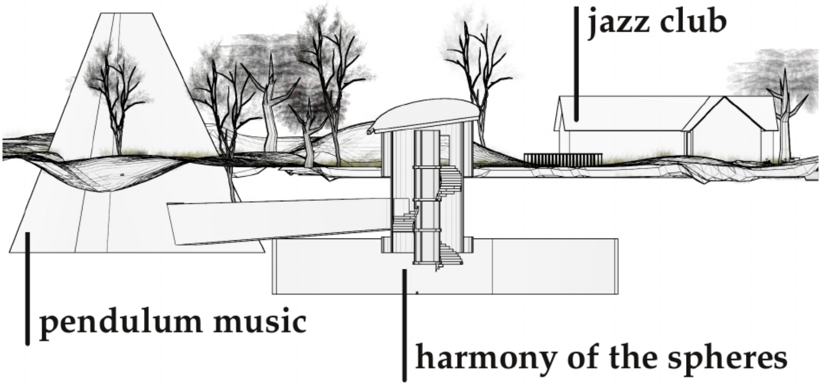
Transparent system:

- Impact on research applications is continuously assessed.
- Awareness of limitations is shared with users.

Demonstrator

- Interactive virtual acoustic environment
- Coupling to computer graphics (blender game engine):
  - Game logic processing:
    blender $\rightarrow$ TASCAR (e.g., receiver position)
  - Visual representation:
    TASCAR $\rightarrow$ blender (e.g., generated positions)
- Demonstrating all described aspects of TASCAR

Demonstrator



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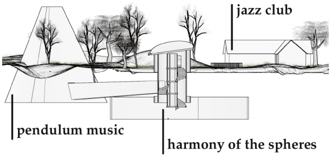
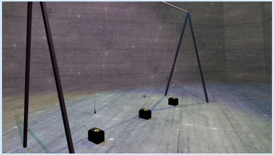


jazz club

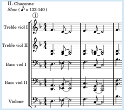
Explore the stage and room acoustics

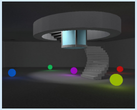
pendulum music



Dynamic feedback loop simulation

harmony of the spheres





Doppler shift and distance perception

Demonstrator

- Today 15:30 (Installation space):
  Hands-on workshop, 8 channel loudspeaker reproduction
- Saturday 11:30 (poster session, Foyer):
  Play and learn, headphone system
- Any other time:
  Ask Joanna or Giso

Where to get TASCAR

- **Universität Oldenburg:**
  Core development
  Open source; undocumented but functional
  `https://github.com/gisogrimm/tascar`

- **HörTech gGmbH:**
  Maintenance and support
  User interfaces, data logging, customization
  Commercial license or project participation
  `http://www.hoertech.de/`

Conclusions

- Tool for rendering dynamic spatially complex acoustic environments
- Include movement of sources and listeners
- Full control, scalable and reproducible
- Focus on plausibility and basic acoustic properties for hearing aid research

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- Tool for rendering dynamic spatially complex acoustic environments
- Include movement of sources and listeners
- Full control, scalable and reproducible
- Focus on plausibility and basic acoustic properties for hearing aid research

Outlook

- Diffraction model, directional sources

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- Many more TASCAR-based studies in hearing aid research

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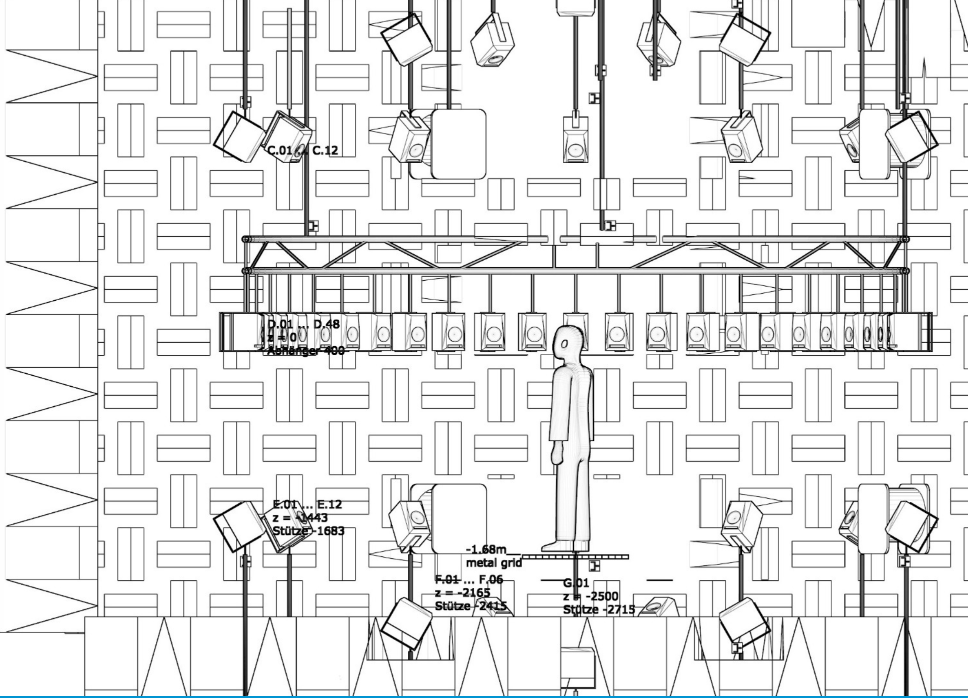
Outlook

- Diffraction model, directional sources
- Many more TASCAR-based studies in hearing aid research
- Large VR lab in Oldenburg, powered by TASCAR


C.01 ... C.12
D.01 ... D.48
z = 0
Abhänger 400
E.01 ... E.12
z = -1443
Stütze -1683
-1.68m
metal grid
F.01 ... F.06
z = -2165
Stütze -2415
G.01
z = -2500
Stütze -2715

Thank you for your attention!

Examples of research applications

#1: Space-aware hearing aids and head motion
(PhD project Maartje Hendrikse)

#2: The Influence of Dynamic Binaural Cues on Speech Intelligibility
(Diploma thesis Jan Heeren)

#3: Spatial dynamics and postural stability
(Bachelor thesis Isabel Büsing)

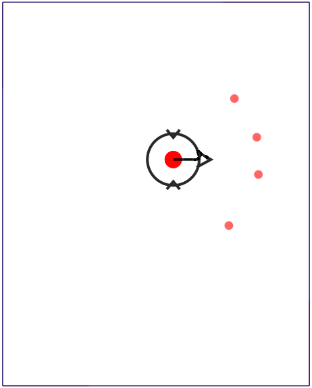
Example 1:
Space-aware hearing aids and head motion

- Can we identify individual head movement strategies?
- Are individual head movement strategies task dependent?
- Will hearing aid performance be affected?
- Apparatus:
  - 8 channel loudspeaker array
  - 9 DOF wireless head motion sensor
  - ’kinect’ depth camera (skeleton tracker)
  - Electro-oculography (gaze direction)

Work in progress, preliminary data.

Example 1:
Space-aware hearing aids and head motion

- Panel discussion
- Early reflections
- Task:
  Carefully listen to the discussion.
- Recording of head orientation



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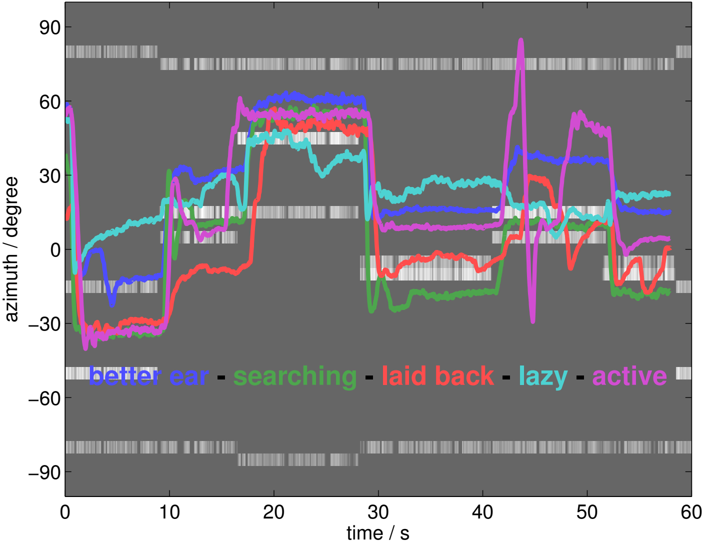
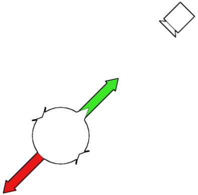
Space-aware hearing aids and head motion



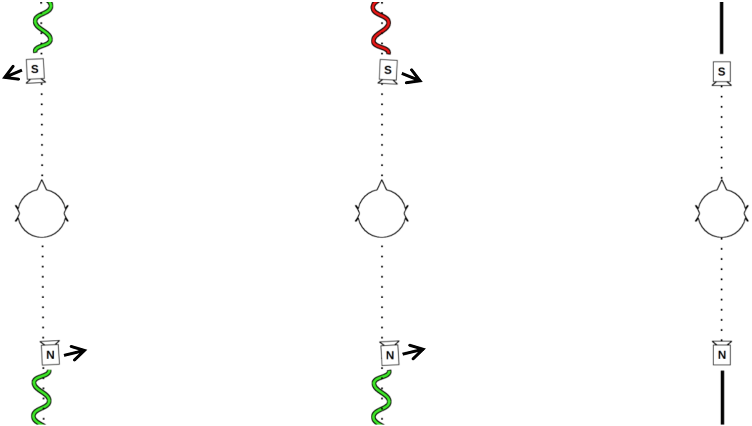
Example 2: “The Influence of Dynamic Binaural Cues on Speech Intelligibility”

- **Binaurally ambiguous listening positions** - Small binaural cues like ITD or ILD
- **Assumption:** Dynamic cues e.g. minimal head or source movements contribute to a better spatial resolution in complex listening situations.
  - Better localisation
  - Better speech intelligibility



- *What is the effect of the dynamic binaural cues?* - measuring SRT in dynamic conditions

Example 2: “The Influence of Dynamic Binaural Cues on Speech Intelligibility”



Rotational

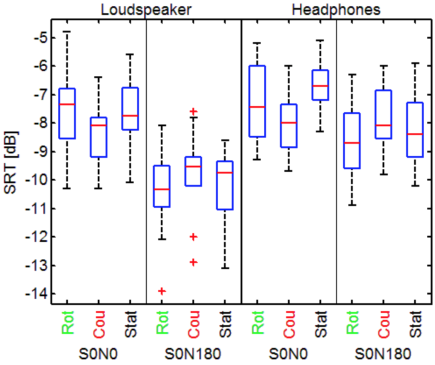
Counter-rotational

Static

Example 2: "The Influence of Dynamic Binaural Cues on Speech Intelligibility"

Hypotheses proved:

- Speech intelligibility increases if sources move towards different ears(Rot by S0N180 and Cou by S0N0)
- Speech intelligibility decreases if sources move towards the same ear (Cou by S0N180 and Rot by S0N180)



Example 3:
Spatial dynamics and postural stability

Context	Some HA users feel disturbed by fast-acting automatics
Literature	Static acoustic information supports sense of balance
Goal	Explore impact of spatially dynamic acoustic information

Example 3: Spatial dynamics and postural stability

Context Some HA users feel disturbed by fast-acting automatics

Literature Static acoustic information supports sense of balance

Goal Explore impact of spatially dynamic acoustic information

Test conditions

- 10 young participants with normal vision and hearing
- Task (clinical): “Fukuda Stepping Test”
- Test setup: TASCAR with Kinect camera
- Three control parameters:

Complexity	Dynamics	Vision
simple	static	eyes open
complex	dynamic	eyes closed

Example 3:
Spatial dynamics and postural stability