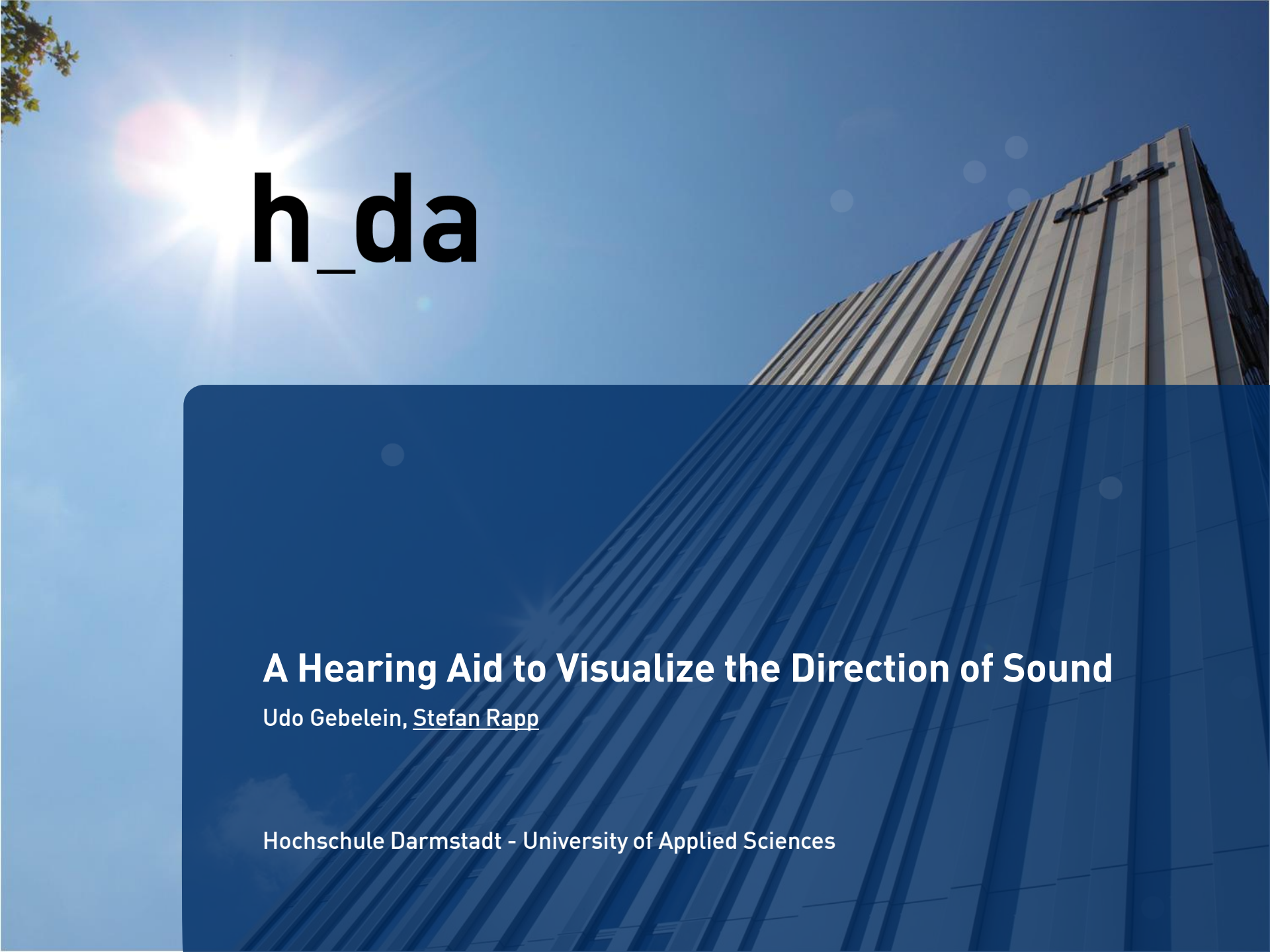

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A Hearing Aid to Visualize the Direction of Sound

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Agenda

1. Why?
2. How does Binaural Hearing Work?
3. First Prototype
4. Second Prototype
5. Future Work
6. Conclusions
7. Demo and Questions

Why?

Triggered by Udo's own experience – temporal loss of hearing in one ear

Loss of directional hearing caused by

- **One-sided deafness**
- When using **hearing aids** or **cochlear implants**

Reduction in quality of life

- Determination of direction of sound essential for **orientation**
- Spatial separation of speech is important in **discussions in groups**, presence of noise
- Threatening **situations that require instant reaction**, for example in traffic (approaching cars, emergency and warning signals)

Affected **patients** may show uneasiness and **avoid social life**.

Idea: show sound directions graphically!

How does Binaural Hearing Work?

Duplex-theory of binaural hearing

Low frequencies < 800 Hz

Head size > half wavelength

Sound travels around the head

Interaural time difference (ITD)

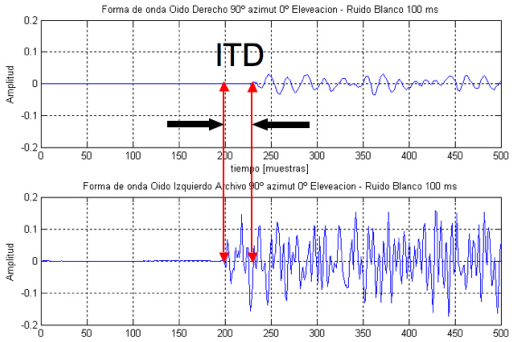


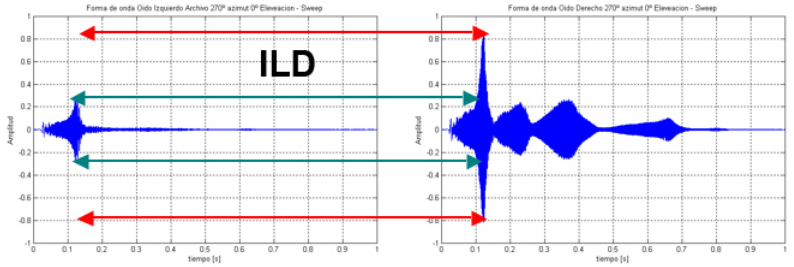
Image source Wikipedia

High frequencies > 1600 Hz

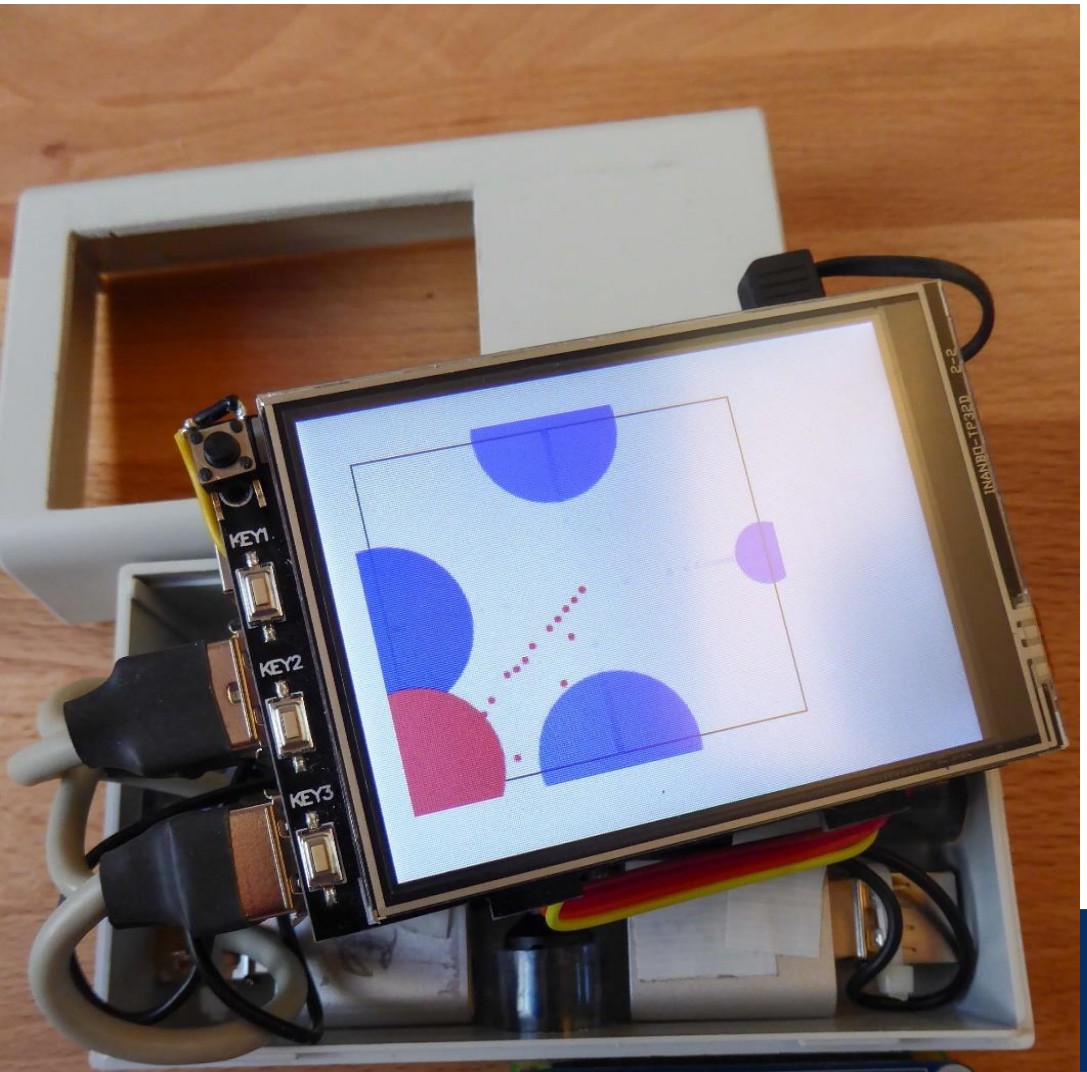
Head size < wavelength

Head shadows sound

Interaural level difference (ILD)



First Prototype



To **demonstrate feasibility**

To **communicate the idea**

Raspberry Pi

3.2 inch touch display

4 lavalier microphones and soundcards

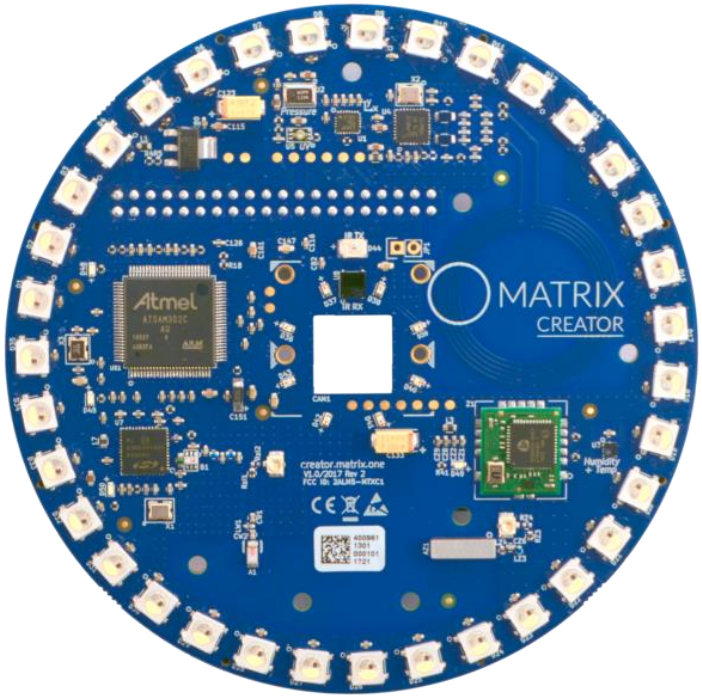
Simple signal processing in Python using maximum sound level comparisons

Visualization showing

- **Intensity at the four microphones (blue)**
- **Estimated direction (red)**
- **History (red dots)**

Issues: Microphones, visualization

Second Prototype – Microphone Array



Market search for (circular) microphone arrays: **Matrix Creator** < 100€

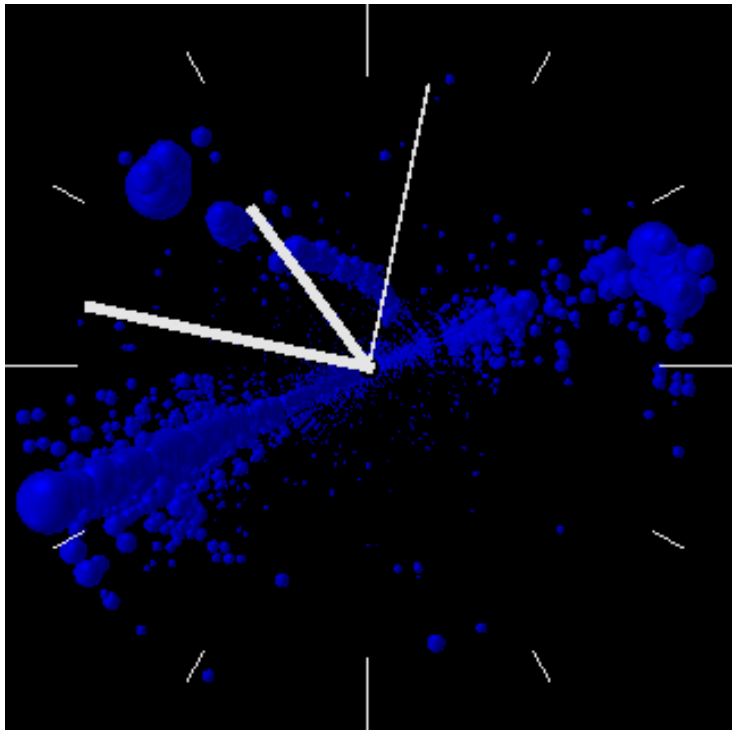
- Raspberry Pi hat
- 8 SMD microphones
- LED ring
- FPGA, µC, several sensors and connectivity
- ODAS already ported / configured for it

Open embedeD Audition System (ODAS)

Sound localization, tracking, separation from Univ. Sherbrooke, Canada

Grondin, F., & Michaud, F. (2019). Lightweight and optimized sound source localization and tracking methods for open and closed microphone array configurations. Robotics and Autonomous Systems, 113, 63-80.

Second Prototype – Visualization



Sound bubbles move towards center

May be integrated in Smartwatch for socially acceptable, unobtrusive viewing

Implementation in **OpenGL ES**

- Available on various portable devices
- Fast, energy efficient
- Current implementation on Raspberry Pi

Microphone array separated from display

Second Prototype – System Design

Three scenarios:

1. Mobile, unobtrusive device, **viewed if needed**, e.g. **smart watch / mobile phone**
2. **Continuous monitoring** during dangerous situations, e.g. **head mounted device**
3. **In car / on bike**, listening to surrounding traffic, e.g. **integrated into existing displays**

Quelle: EPSON

Microphone array separated from display

- In a baseball cap or other hat
- In clothing
- Integrated in the frame of eyeglasses (esp. Scenario 2)
- Mounted on car exterior (Scenario 3)

Quelle Fraunhofer IDMT

Future Work

Ongoing:

- Setup of experimentation environment for rigorous evaluation
  - Multiple loudspeakers behind 360° curtain
  - Optical tracking system records subject's responses (pointing stick / wand)

Planned:

- Porting to Android (and iOS), for smart phones and AR glasses (Epson Moverio BT-300)
- Separation of coordinate systems (world/head/body/display) and evaluation in experimentation environment
- Sound classification using machine learning
- Tuning parameters of ODAS or modifying their algorithms, for our use case
- 3D printed eyeglasses frame (for integration of SMD microphones)

Industrial partners welcome!

Conclusions

1. New device / application to help the hearing impaired
2. Visual display of sound source direction
3. Contains a short term history of one minute or 30 seconds
4. Implementation ready for experimentation and product development
5. Industrial partners welcome

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Thank you for your attention!

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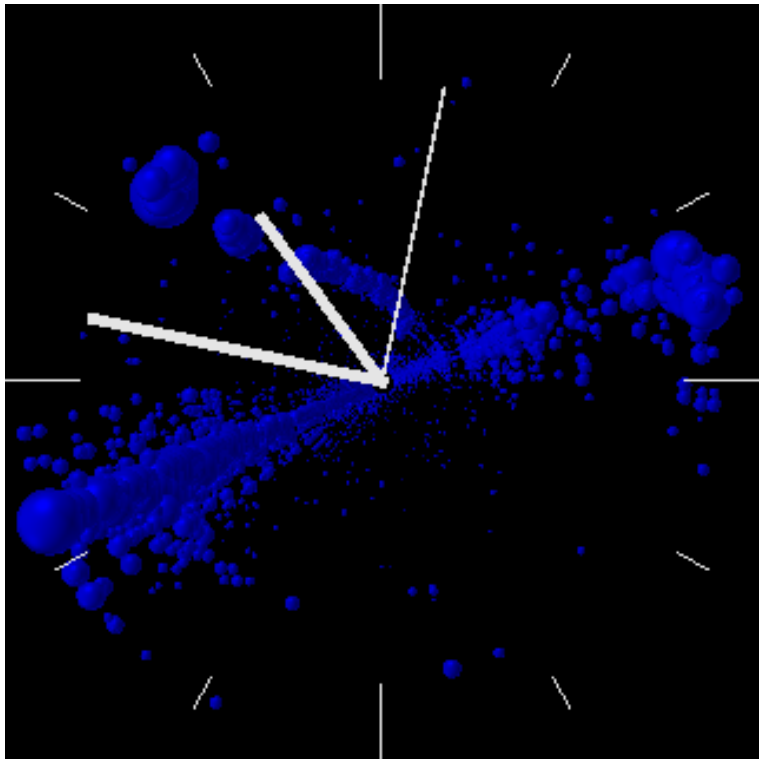
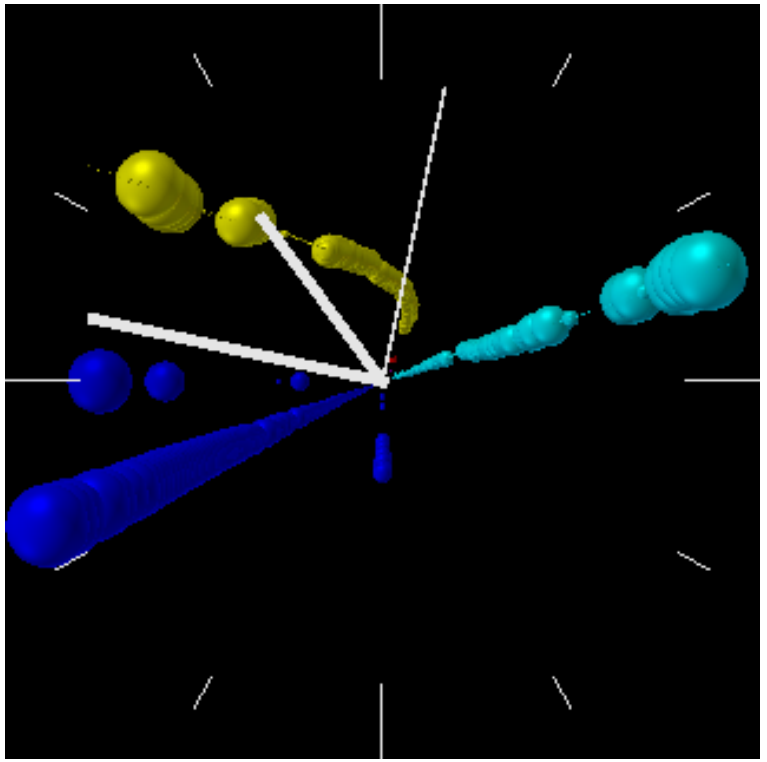
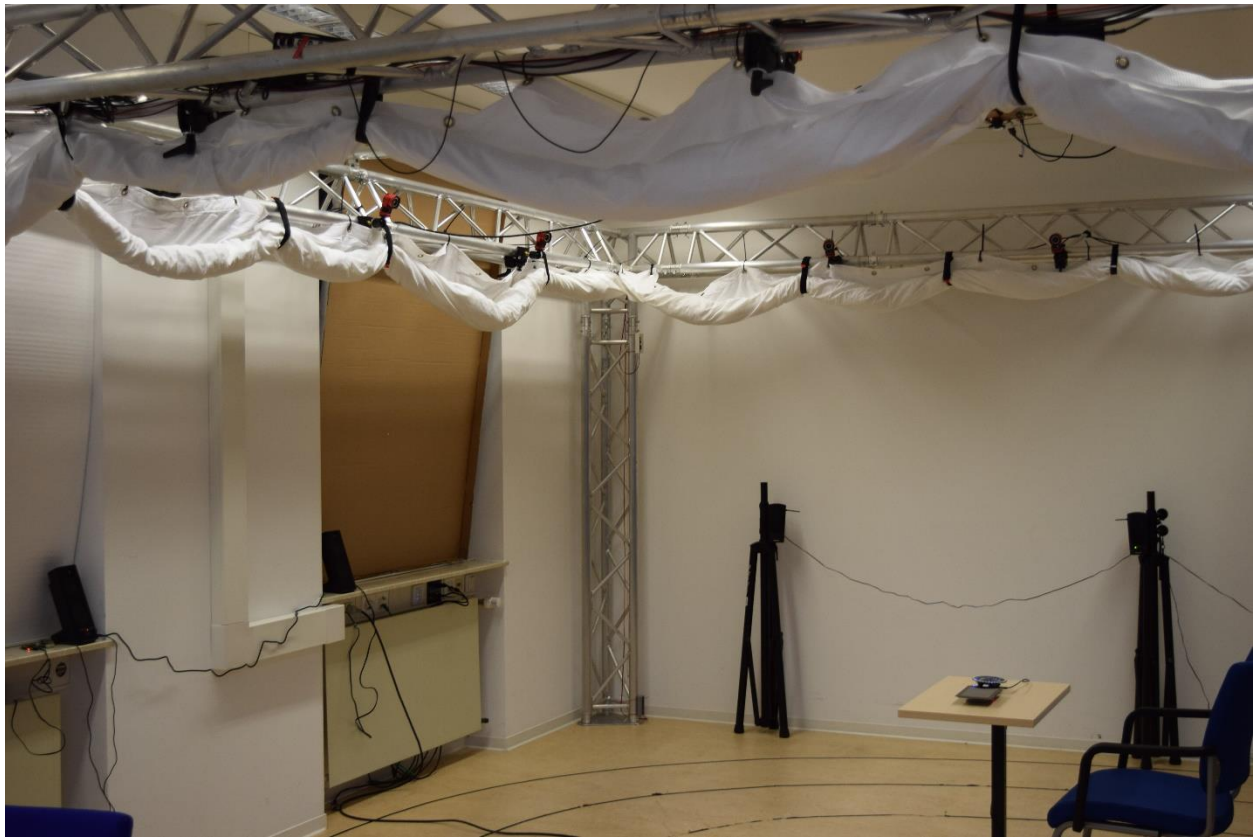
Sound Source Localization – Sound Source Tracking





Experiment setup



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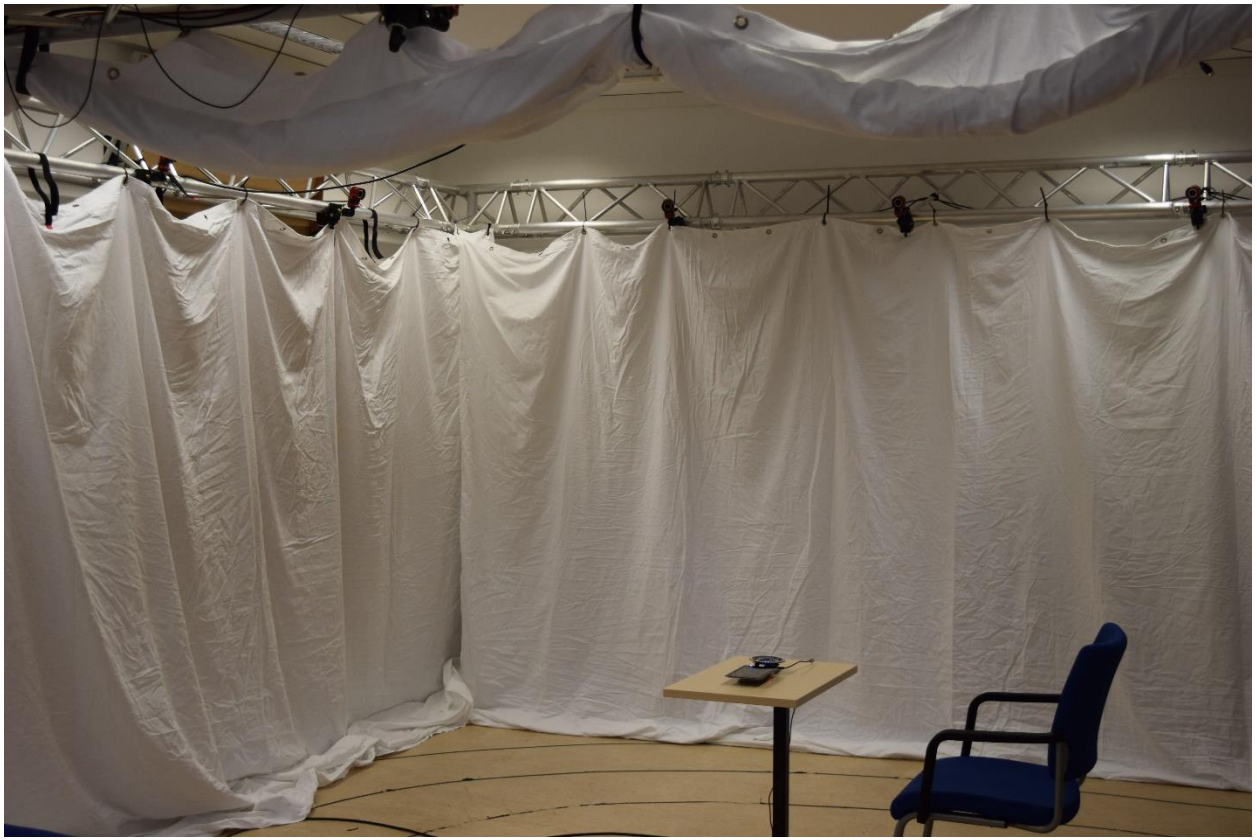
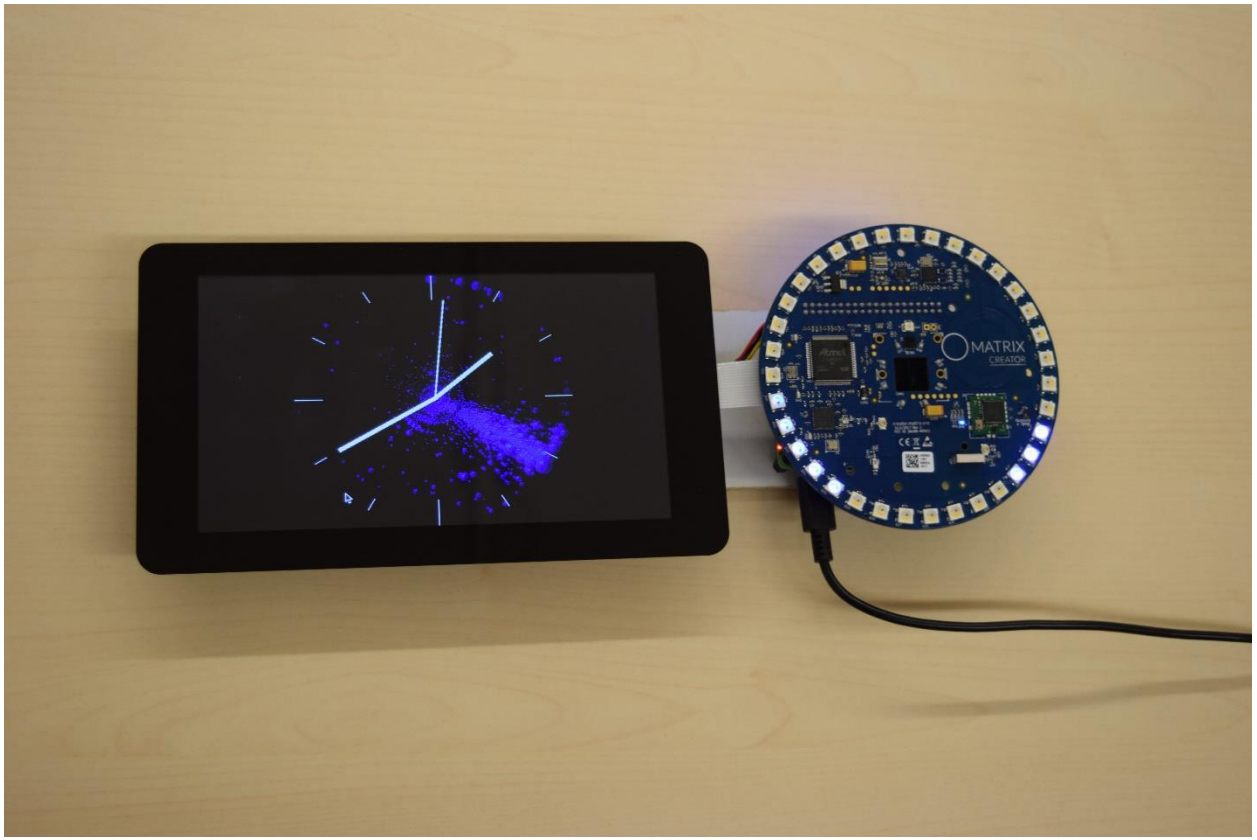


Optical Tracking System OptiTrack Flex 13

Test Object



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