• Contents: Two main questions:

– For a 3D-Audio reproduction, how real does the sound field have to be?  
  When do we want to copy the sound field?  
  How much likeness/similarity to the sound field in the recording room do we need?

– Which 3D microphone recording techniques are appropriate for recording a spatial sound field?
Spatial sound reproduction techniques:

- Real source
- Stereophony
- Sound field reconstruction
- Binaural
Spatial sound reproduction techniques:

- **Real source**
- **Stereophony**
- **Sound field reconstruction**
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- Binaural

* *3D-Audio formats*  
* Copying the sound field*  
* The „Uncanny Valley”*  
* Stereo layers for 3D*  
* Stereo basics*  
* ORTF-3D*
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* The term „Sound field reconstruction“ includes techniques like WFS or HOA
- Copying the sound field: Spatial Sampling → Spatial Reproduction

- WFS:

Verheijen, 1998
• Copying the sound field: Spatial Sampling → Spatial Reproduction

• WFS:
• Copying the sound field: Spatial Sampling → Spatial Reproduction

• Ambisonics:
• Copying the sound field: Spatial Sampling → Spatial Reproduction

• Ambisonics:

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• Copying the sound field: Spatial Sampling → Spatial Reproduction

• Spatial Sampling does never work 100%

• Artefacts of „spatial sampling“ recording techniques:
  – Too low resolution
  – Small space: compromised hardware
  – Perceptually not sufficient
  – No aesthetic mix, no sound engineering involved
• The „Uncanny Valley”
  – Formulated for Graphical Design in 1970 by Dr. M. Mori
  – Suggested for Spatial Audio by Francis Rumsey
• 0% likeness, 0% familiarity
- 3D-Audio formats
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• 10% likeness, 50% familiarity
- 50% likeness, 80% familiarity
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• 90% likeness, -50% familiarity
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- 100% likeness, 100% familiarity
The „Uncanny Valley“

- Formulated in 1970 by Dr. Masahiro Mori
- Suggested for Spatial Audio by Francis Rumsey (ICSA, 2013)
• The „Uncanny Valley“ of 3D-Audio recording: (unproven hypothesis!)
• Alternative:
  – „Stereophonic sublayer“ under any 3D-Audio format („Virtual Panning Spots“)
  – Avoid **trying to copy** the sound field, instead use proper stereophonic spatial imaging

• Ambisonics, 1st orde or HOA:
  – Inappropriate copying of the sound field leads to undesired artefacts:
    • **1st order** Ambisonics is physically inappropriate, but it also can be interpreted as coincident Stereo → the artefacts are: narrow spatial sound
    • Capturing HOA („Higher Order Ambisonics“) with a high enough order **at the whole frequency spectrum** would be appropriate → however there is no microphone capturing system of this kind available
    • HOA as a storage and mixing system is appropriate!
• Alternative: Stereophonic sublayer = Virtual Panning Spots
• Alternative: Stereophonic sublayer = Virtual Panning Spots
Spatial sound reproduction techniques:

- Real source
- Stereophony
- Sound field reconstruction
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• Copying the sound field: Spatial Sampling → Spatial Reproduction

• Binaural without headtracking:
• Head rotations/tracking required for appropriate reproduction

• Direct sound:
  – $\Delta t = 0 \text{ ms}$
  – $\Delta L = 0 \text{ dB}$

• Lateral reflections:
  – $\Delta t, \Delta L (\phi)$
• Head rotations/tracking required for appropriate reproduction

• Direct sound:
  – $\Delta t > 0$ ms
  – $\Delta L < 0$ dB

• Lateral reflections:
  – $\Delta t, \Delta L (\phi)$
• Head rotations/tracking required for appropriate reproduction

• Direct sound:
  – $\Delta t < 0$ ms
  – $\Delta L > 0$ dB

• Lateral reflections:
  – $\Delta t$, $\Delta L (\phi)$
• Stereo sublayer or „Virtual Panning Spots“ in Binaural
• Similar to IRTs invention „Binaural Room Synthesis“
  = **Binauralizing** a stereo setup)

![Diagram of Binaural Rendering with HRTF/BRIR and Virtual Listening Room](image-url)
• Stereo sublayer or „Virtual Panning Spots“ in Binaural
  – Cubical Virtual Loudspeaker array
• Stereo sublayer or „Virtual Panning Spots“ in Binaural
  – Cubical Virtual Loudspeaker array

Audio objects within the Game-Software „Unity“
• „ORTF-3D, First Prototype“ (© Theile, Wittek)
• „ORTF-3D“ (© Theile, Wittek)
• Working for Stereo+Height, Dolby Atmos, Auro3D, …
Binauralized „ORTF-3D“ at the BBC Proms
Binauralized „ORTF-3D“ at the BBC Proms
Spatial sound reproduction techniques:

- Real source
- **Stereophony**
- Sound field reconstruction
- Binaural
• Signal separation!
• SCHOEPS-App “Image Assistant”: App Store or ima.schoeps.de

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- 3D-Audio: Stereo+Height
- Auro3D 9.1
- Dolby Atmos 5.1.4
• Δt or ΔL

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• $\Delta t$ or $\Delta L$

- ORTF - type techniques
- A/B - type techniques

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• „ORTF-3D“ (© Theile, Wittek)
• Conclusions
  – Sound engineers: **trust your ears**, don’t believe in „scientific“ approaches without skepticism
  – Better make **good Stereo** than bad unperfect physical reproduction
  – An unperfect physical reproduction can sound much worse than a good Stereo recording (Example: First Order Ambisonics is worse than a good 9.1 Decca Tree)
  – Use **Stereo layers** for ambient sources and spatial recording in a WFS/Ambisonics/Binaural reproduction (Example: 9ch Decca-Tree recording on a Auro3D 9.1 preset put in a binaural renderer)
  – Use Stereo to be able to work in a sound engineering way, caring for **aesthetical** aspects
  – The **ORTF-3D** microphone is a good approach for recording a 3D ambience for all formats
Thank you!

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