Aalto University

Research projects in reproduction and synthesis of spatial sound for virtual reality

Ville Pulkki

Department of Signal Processing and Acoustics
School of Electrical Engineering
Aalto University, Helsinki, Finland

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This talk

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  - Early project with amplitude panning
  - Ambisonics recording methods
  - Parametric time-frequency-domain spatial audio tools

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- Spatial audio effects
  - Syntesis of spatial width
  - Spatial modulation of sound

A music student with MSc (Eng) needs extra income (1995)

- Sibelius Academy chamber music hall had lots of loudspeakers on walls and ceiling
- SibA wanted to have a "panning tool" for their loudspeaker system (one month salary for student)

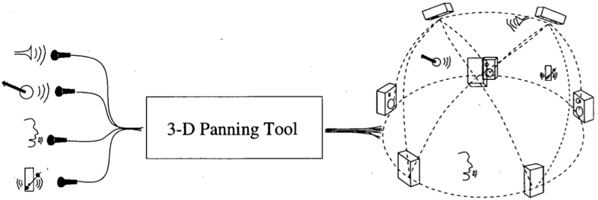

Fig. 9. Possible use of three-dimensional VBAP panning tool. Number of sound sources can vary up to eight; loudspeaker placement is arbitrary; virtual sources may be moving or stationary.

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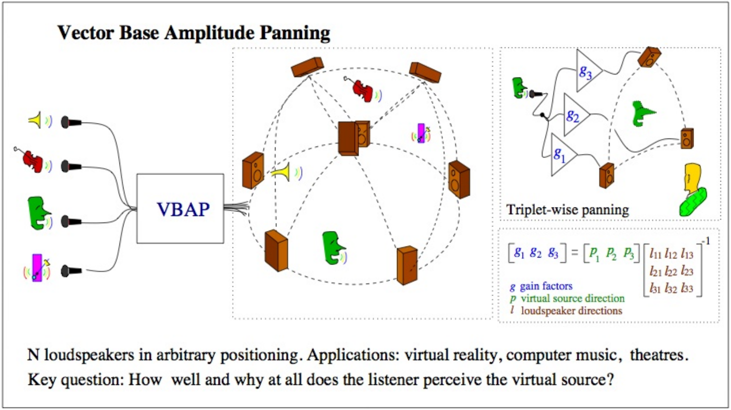
A music student with MSc (Eng) needs extra income (1995)

- Helsinki Univ Tech had a self-made 8-channel AD/DA for music instrument synthesis
- Paid student project with 1-month salary

Vector base amplitude panning



PhD degree in 2001.

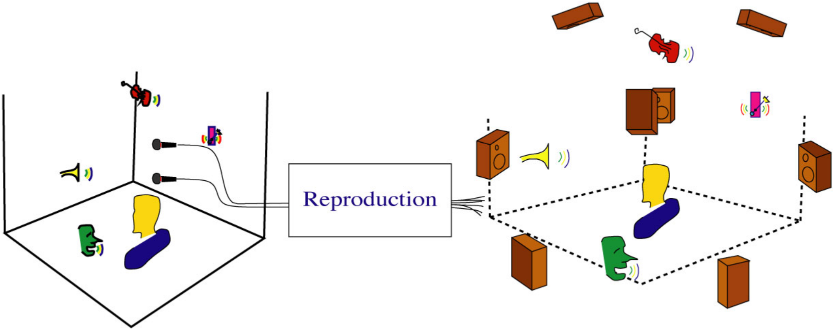
Products with "VBAP inside"

- ITU MPEG-H audio standard (broadcast)
- DTS:X audio format (cinema + blueray) (88 movies already)
- Sony Playstation VR (gaming)
- Dedicated audio programming softwares

Time after PhD (2001–)

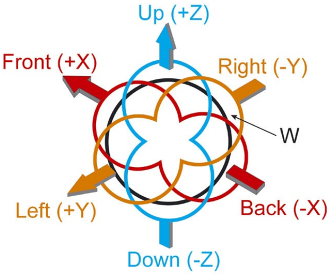
- Spatial sound recording captured my mind

How could a sound field be reproduced



Problems with existing techniques

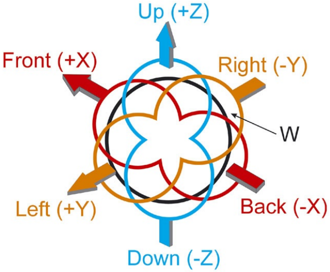
First-order B-format recording



www.soundfield.com

- Captures signals with zeroth-order and first-order spherical harmonics

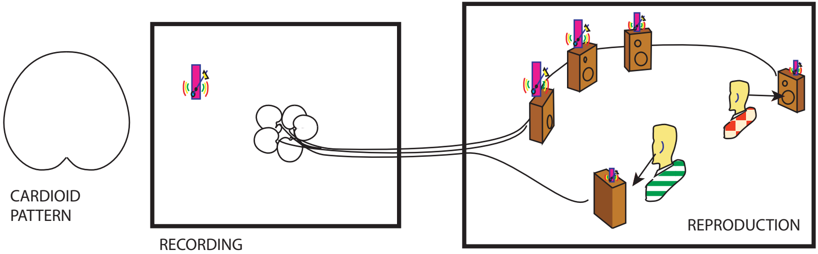
First-order B-format recording



`www.soundfield.com`

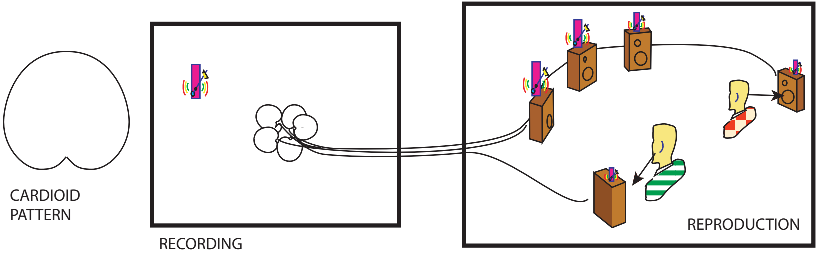
- Captures signals with zeroth-order and first-order spherical harmonics
- Pressure signal W. 3D velocity signals XYZ.

First-order Ambisonics



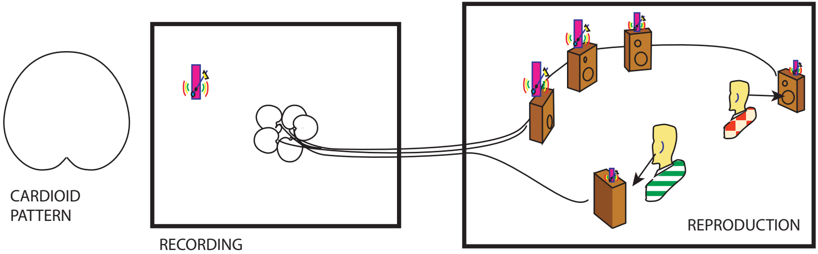
- Weighted sum of WXYZ signals (mixing, matrixing)

First-order Ambisonics



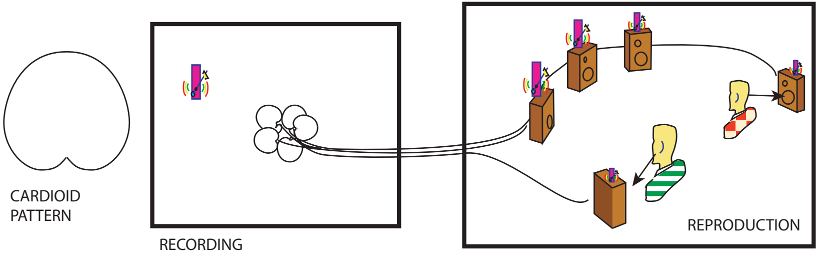
- Weighted sum of WXYZ signals (mixing, matrixing)
- High coherence between loudspeaker signals

First-order Ambisonics



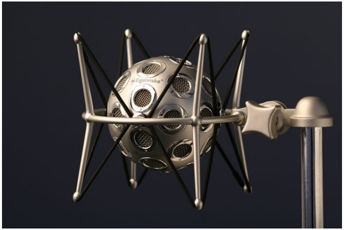
- Weighted sum of WXYZ signals (mixing, matrixing)
- High coherence between loudspeaker signals
- Spectral and spatial issues, very small listening area

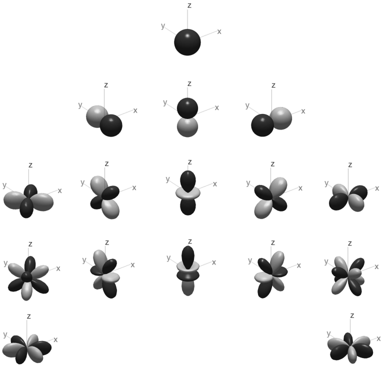
First-order Ambisonics



- Weighted sum of WXYZ signals (mixing, matrixing)
- High coherence between loudspeaker signals
- Spectral and spatial issues, very small listening area
- Blurred images in headphone listening

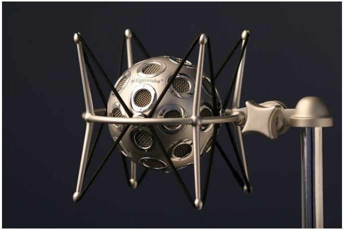
Higher-order B-format recording

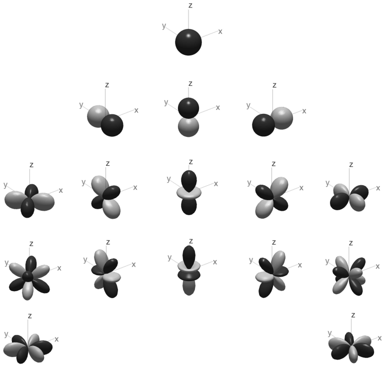




- Signals with directional patterns following to spherical harmonics

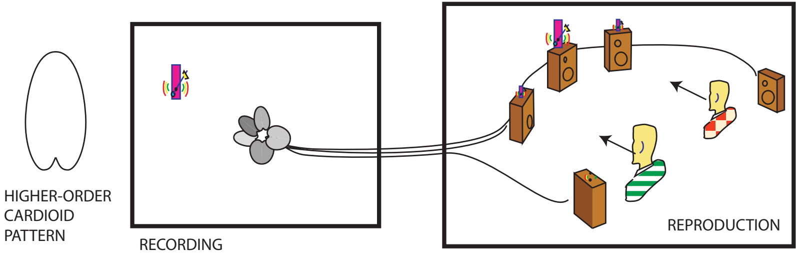
Higher-order B-format recording





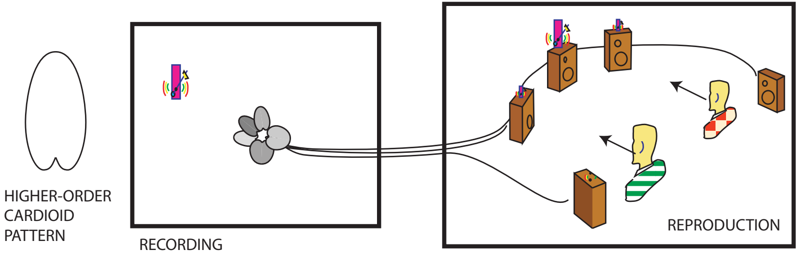
- Signals with directional patterns following to spherical harmonics
- Reproduce plane-wave expansion over loudspeakers

Higher-order Ambisonics



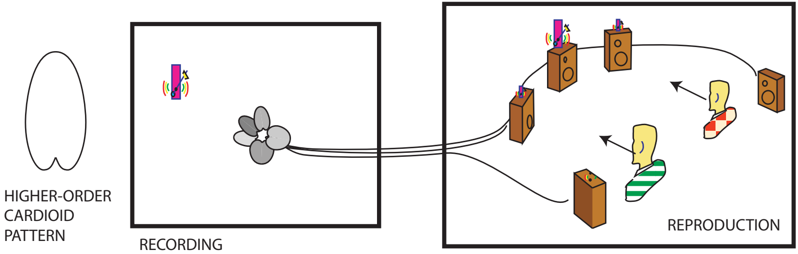
- More spherical harmonics captured

Higher-order Ambisonics



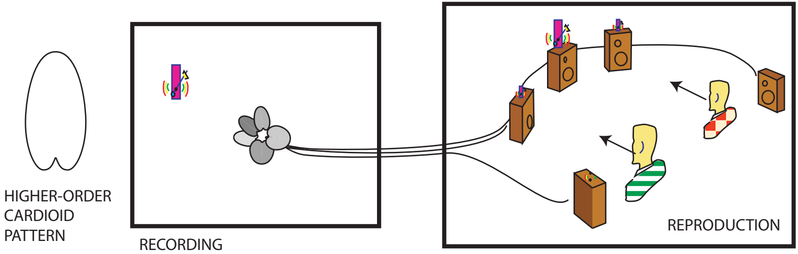
- More spherical harmonics captured
- Better resolution, more expensive devices

Higher-order Ambisonics



- More spherical harmonics captured
- Better resolution, more expensive devices
- Good quality in limited frequency window

Higher-order Ambisonics



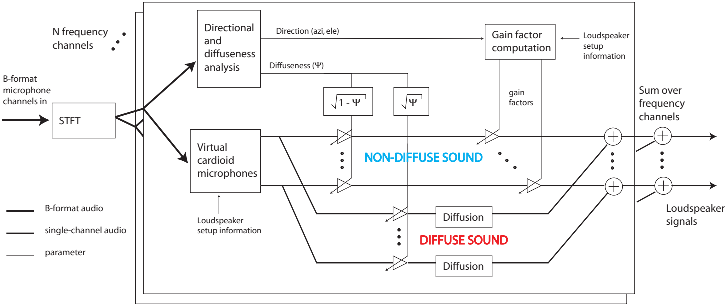
- More spherical harmonics captured
- Better resolution, more expensive devices
- Good quality in limited frequency window
- Emphasized problems with low-frequency noise and high-frequency aliasing

Parametric time-frequency-domain techniques

Directional audio coding / COMPASS / Other similar techniques

Parametric time-frequency-domain techniques

Directional audio coding / COMPASS / Other similar techniques



- Analyze/synthesize the directional parameters of sound field
- Non-linear signal-dependent signal processing method
- In 90% of recordings, the audio quality is improved prominently

Commercial application

Fraunhofer
IIS

Fraunhofer Institute for Integrated Circuits IIS

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Overview

About

The Fraunhofer spatial audio capturing algorithm has been designed to significantly improve the sound capture capabilities of professional and consumer 360° cameras and mobile devices using built-in microphones.

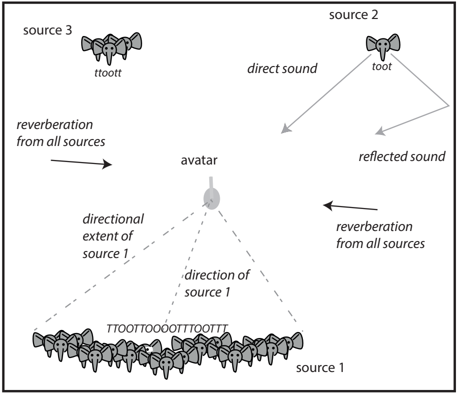
It is the first audio technology to be delivered under Fraunhofer's upHear brand of immersive audio innovations.

The algorithm automatically transforms the captured sound in real-time to any popular surround or immersive audio reproduction format, such as FOA, HOA, 5.1 channels, and 7.1+4 height channels, while preserving the authenticity of the audio scene.

Head-mounted audiovisual displays

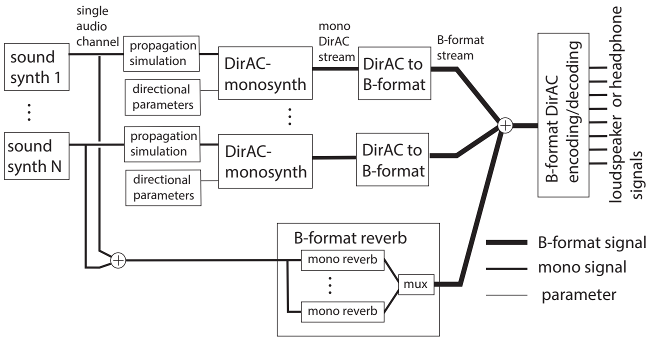
- Reproduction
  - Head-mounted visual display + headphones
  - Both video and spatial audio are updated with head tracking information
  - Generic representation of audio in DirAC is well-suited for this

Virtual reality



- Insert a B-format microphone on the position of the avatar!

Audio engine based on B-format stream



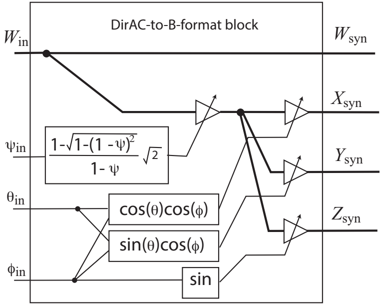
- First-order / Higher-order B-format bus

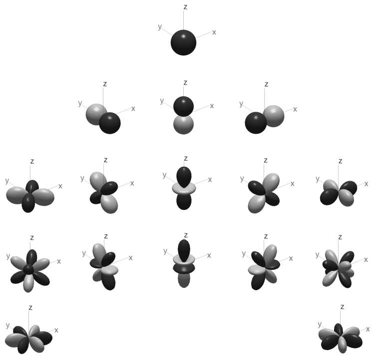
Synthesis of B-format signal

- Level
- Propagation delay
- Panning direction
- Spatial width of source
- Direct-to-reverberant ratio
- Distribution of reverberant energy (?)

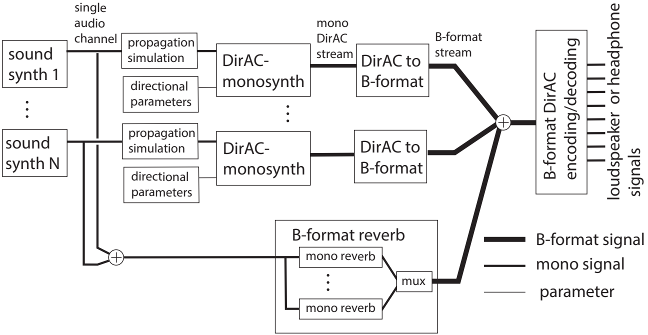
Synthesis of B-format signal

- higher-order synthesis also possible
- multiply each signal with corresponding spherical harmonic



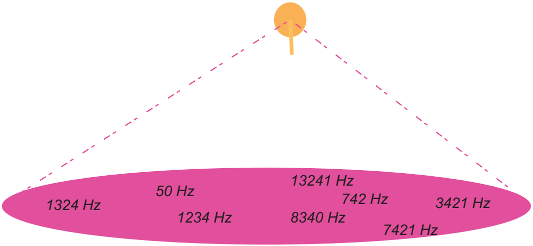


Audio engine based on B-format stream



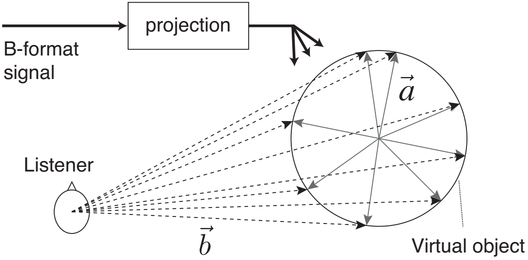
- Can perform all tasks needed in typical virtual world rendering
- *Demo*

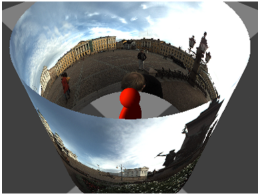
Synthesis of spatial extent of virtual sources



- Different frequencies of mono input to different directions
- *Demo*

Projection of real B-format recordings into virtual reality objects





Spatial audio effects

- Spatial modulation

Spatial audio effects

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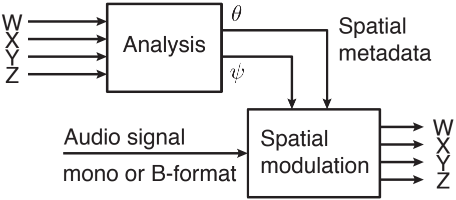
- Modification of diffuse component of sound

Spatial audio effects

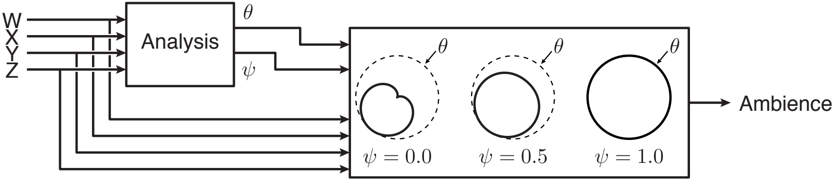
- Spatial modulation
- Modification of diffuse component of sound
- Spatial zooming, rotation,

Spatial modulation



- Spatial information comes from a real situation, and audio from another recording
- *Demo*

Ambience extraction



- Possible to effect only reverberant parts of sound
- *Demo*

A reference

- 15 chapters, 416 pages
- Matlab code
- Published in Dec 2017