3D Loudspeaker Stereophony: Perception and Rendering

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Overview

Motivation for 3D Sound Reproduction

Spatial Hearing

Loudspeaker Reproduction

Content Creation by Upmixing
Importance of 3D Sound

Direct sound at different height:

- Flying Object
- Bird on a tree
- Talker on balcony
- Person talking
- Instrument playing
- Car passing by
- Dog barking
- Footsteps
- Surge of waves

Outdoor soundscapes are three-dimensional

Room acoustics is three-dimensional
Spatial Hearing in Enclosures

Geometric

Interaural

Perceptual
Spatial Hearing in Enclosures

Direct Sound

Geometric

Interaural

Perceptual
Spatial Hearing in Enclosures

Early Reflections

Geometric

Interaural

Perceptual
Spatial Hearing in Enclosures

Early Reflections

Geometric  Interaural  Perceptual
Spatial Hearing in Enclosures

Early Reflections

Geometric

Interaural

Perceptual
Spatial Hearing in Enclosures

Late Reflections

Geometric

Interaural

Perceptual
Modeling an Auditory Impression

Auditory impression
- can be modeled considering
  - direct sound (↑)
  - early reflections (↑↑↑↑)
  - reverberation (↑)

Reference sound field
Electroacoustical Reproduction

Direct sound (↑)
  direction, character

Discrete reflections (↑↑↑↑)
  timing, direction, amplitude

Reverberation (↑)
  isotropic, random
Loudspeaker Stereophony

Loudspeaker Stereophony ≠ Soundfield Reproduction

• Production Includes artistic step

• Reproduction Aims at:
  • reproducing the artistic intention
  • creating a pleasing sound filed
  • evoking the perception of a continuous sound field using only a discrete number of transducers
Two-Channel Reproduction (horizontal)

- Minimum for spatial sound reproduction
- Standard for many years => synonym for ‘stereo’
Drawbacks of Two-Channel Reproduction

Spatial Image instable with regard to
• off sweet spot listening
• head rotation
Five-Channel Reproduction

Benefits of five channel standard:

• better rendering of room impression

• listener can be enveloped by sound

• front image more stable

• lateral phantom sources possible with reservations (ambiguous localization)
Possibilities with Elevated Loudspeakers

• Vertical phantom sources:
  - inaccurate localization
  - large spatial extend

• Localization better on frontal plane than on median plane

References:  
Possibilities with Elevated Loudspeakers

- Overhead phantom sources
  - frontal plane: controlable location
    (with larger blur than for horizontal pair)
  - median plane: very ambiguous location and large blur
Possibilities for Envelopment

- Spatially uniform sound on a vertical semicircle possible with a minimum of 4 equally spaced loudspeakers

Reference: S. Oode et al., *Vertical Loudspeaker Arrangement for Reproducing Spatially Uniform Sound*, AES 131st Convention
Multi-Channel Stereophony Today

Just 4 Examples of a great diversity

Common 7 channel setups

Common 9 channel setups
The Content-Problem

Problem

Majority of transport formats used today are channel-based
=> 1 channel = 1 associated loudspeaker

Solution

Channel Format Conversion

- Automatically realize best possible transformation between content format and mismatching loudspeaker layout
  - Separate perceptually distinct components
  - Adapt rendering to target loudspeaker setup
Introduction to Upmix

- Wide spread of five-channel setups
- Most audio only content still two-channel stereophonic

=> automatic channel format conversion (UPMIX)
Upmix for 3D Reproduction

• Direct sound height information not assessable
  -> horizontal reproduction
• Ambience to create immersive three-dimensional envelopment
Thank you very much for your attention!