

Loudspeakers and Space (a.k.a Spatialization)

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Advanced Mixed Music Composition

“The presence of spatialization can be recognized in every situation in which spatial extensions, positions (directions and distances) of the sound sources as well as the acoustic quality of the performance space are given compositional significance.” – Maris Anna Harley

Source: Harley, Maria Anna. *Space and Spatialization in Contemporary Music: History and Analysis, Ideas and Implementations*. Doctoral Thesis.

Loudspeakers and Space

- 1) Main Challenges
- 2) Different Approaches

1) Main Challenges: Localization

We determine the **angular position** of sound using three types of aural cues:

1) Interaural Time Differences (ITD)

Mostly contribute between 270Hz and 1400Hz (dominates between 270Hz and 500Hz)

2) Inter-aural Intensity Differences (IID)

Mostly contribute between 500Hz and higher (dominate above 1400Hz)

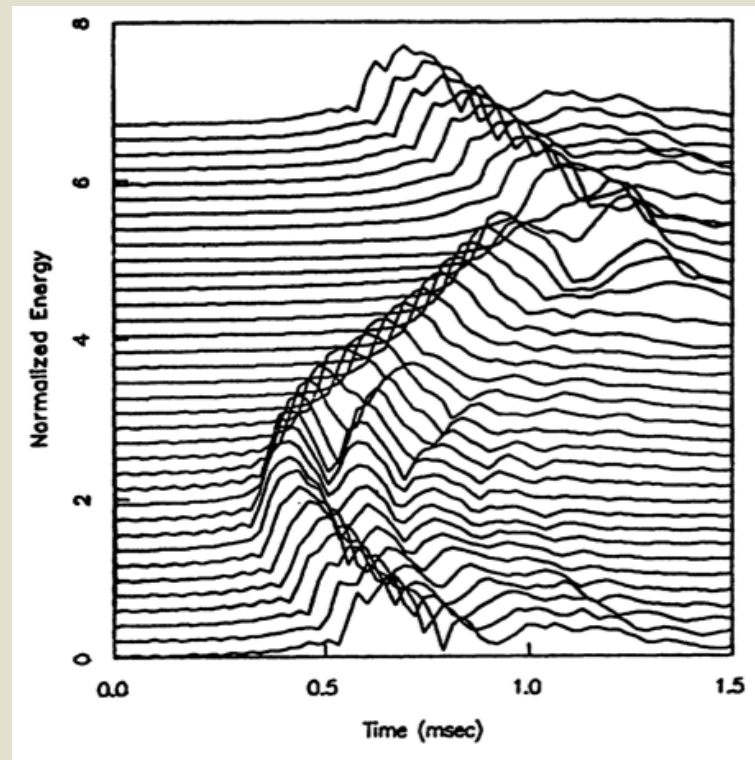
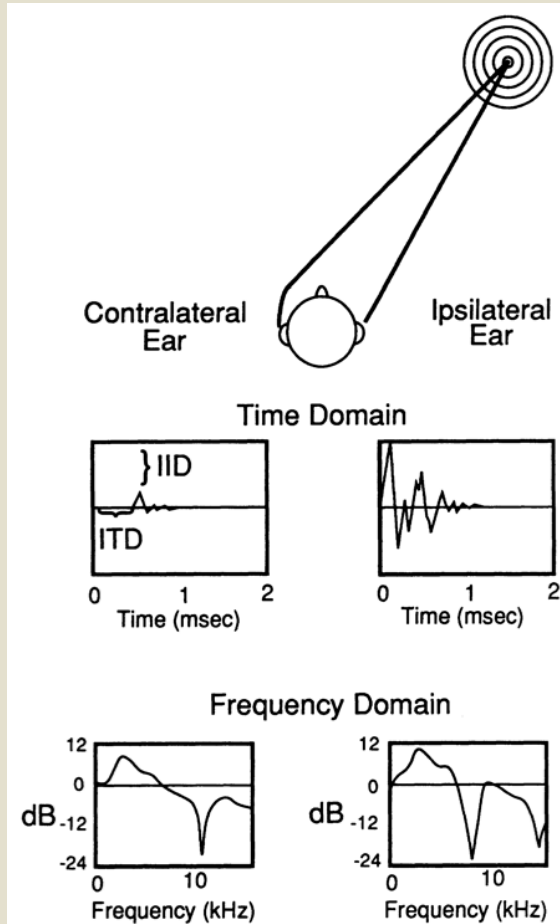
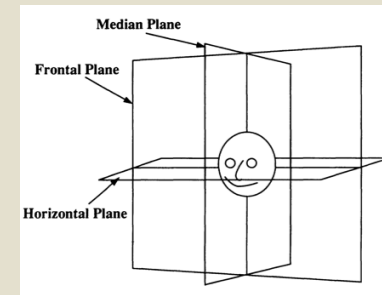
3) Head Related Filtering

Filtering caused by the shape of our ears

* Note that ITDs and IIDs have very little to no effect on our perception of sounds lower than 270Hz

1) Main Challenges: Localization

Knowles Electronics Mannequin for Acoustics Research (KEMAR) for Head Related Transfer Functions measurements



Source: Kendall, Gary S. A 3-D Sound Primer: Directional Hearing and Stereo Reproduction. *Computer Music Journal*, Vol. 19, No. 4, 26.

1) Main Challenges: Localization

We determine **distance** of sound using three types of aural cues:

1) Intensity of a sounds

2) Ratio of reverberated to direct sound (R/D ratio) in a given space

Critical Distance $\Rightarrow R/D = 1$

3) The amount of high frequency in a sound

1) Main Challenges: Localization

Resolution of spatial hearing:

In sum:

- We localize more precisely in front of us than in back
- We hear very well at head level on the horizontal plane

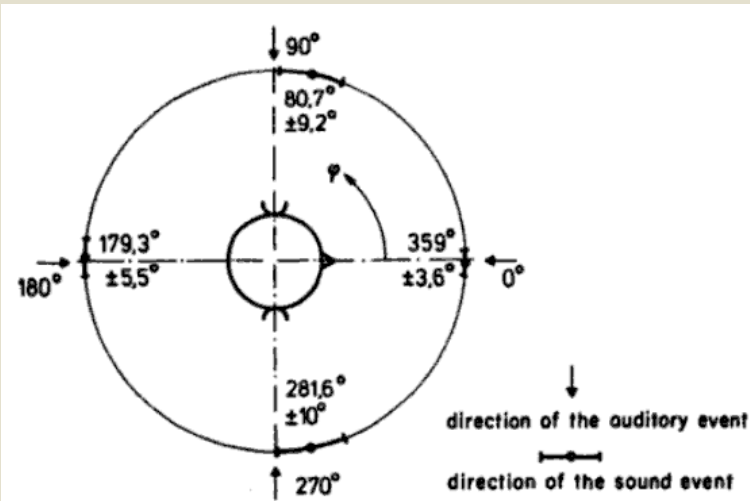


Figure 2.2

Localization blur $\Delta\varphi_{min}$ and localization in the horizontal plane (after Preibisch-Effenberger 1966a and Haustein and Schirmer 1970; 600–900 subjects, white-noise pulses of 100 ms duration, approximately 70 phon, head immobilized).

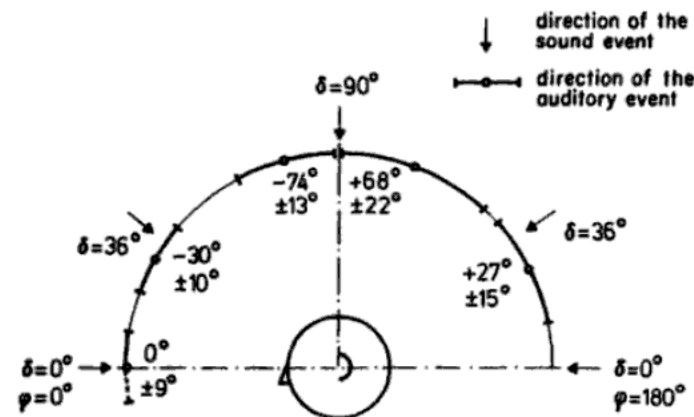


Figure 2.5

Localization and localization blur in the median plane for continuous speech by a familiar person (after Damaske and Wagener 1969; 7 subjects, 65 phon, head immobilized). Note that the view is different from that in figure 2.2.

1) Main Challenges: Localization

More recent
experiment on
human
localization
ability

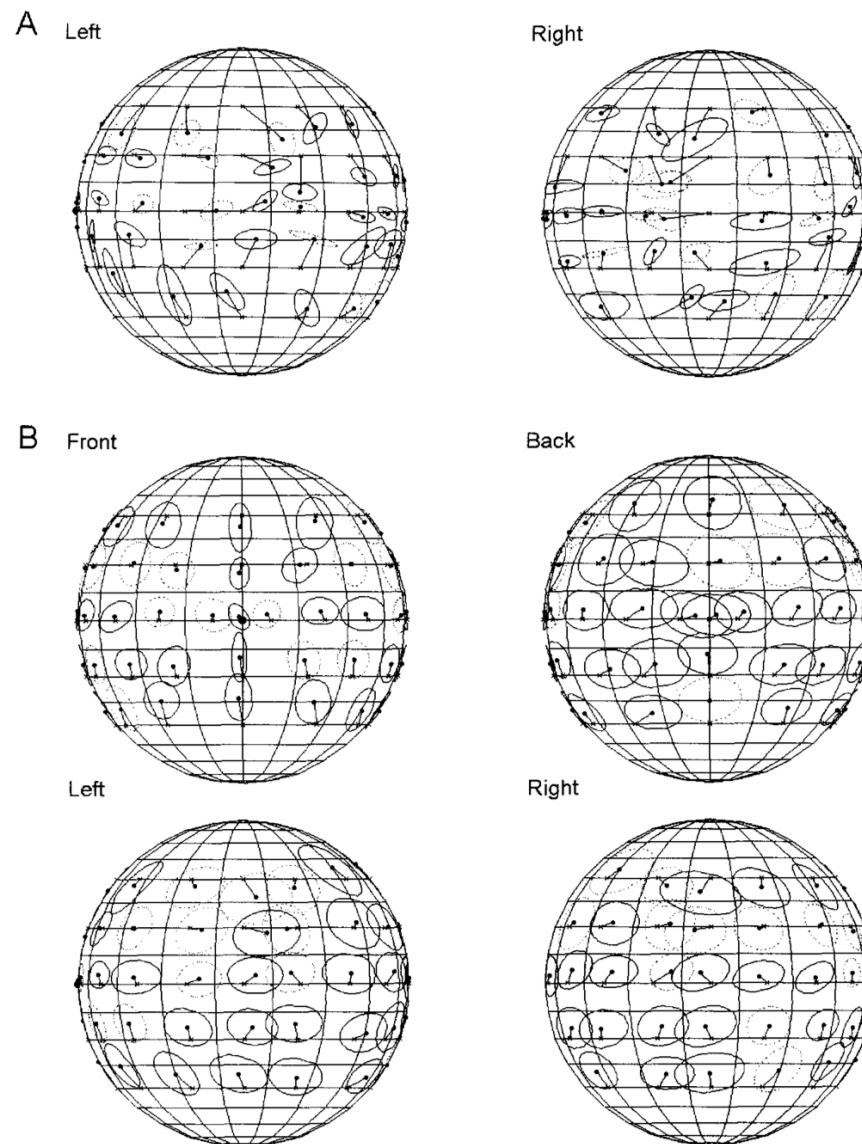


Fig. 6. The centroids and the standard deviations of the localization estimates of 76 target locations are plotted for (A) one subject on spherical plots for the right and left hemispheres and (B) pooled from 19 subjects and plotted for the front, back, left and right hemispheres. All other details as for Fig. 5.

1) Main Challenges: Localization

Other issue: *Precedence Effect* (a.k.a., *Hass effect*, or law of the first wavefront)

“...the ear and brain have the ability to gather all the reflections arriving within about 35ms after the direct sound, and combine (integrate) them to give the impression that all this sound is coming from the direction of the original source, even though the reflections from other directions are involved. **The sound that arrives first establishes the perceptual source location of later sounds.**”

Source: Everest, F. Alton, and Ken C. Pohlmann. *Master Handbook of Acoustics (fifth edition)*. New York : McGraw Hill, 2009, p.60

Other issue: *Franssen Effect*

“(...) auditory **memory** can sometimes confuse direction (...) Two loudspeakers are placed to the left and right of a listener in a live room. The loudspeakers are about 3 ft from the listener at about 45deg angles. A **sine wave** is played through the left loudspeaker, and the signal is immediately faded out and simultaneously faded in at the right loudspeaker, so there is no appreciable change in overall level. Most listener will continue to locate the signal in the left loudspeaker.”

NOTE: The Franssen effect fails in anechoic environments and with dense sound spectrums

Source: Everest, F. Alton, and Ken C. Pohlmann. *Master Handbook of Acoustics (fifth edition)*. New York : McGraw Hill, 2009, p.60

1) Main Challenges: Source Bonding

Source Bonding: “The natural tendency to relate sounds to supposed sources and causes, and to relate sounds to each other because they appear to have shared or associated origins.”

-Smalley, Denis. Spectromorphology: Explaining Sound-Shapes. *Organised Sound* 2(2): 107-126.

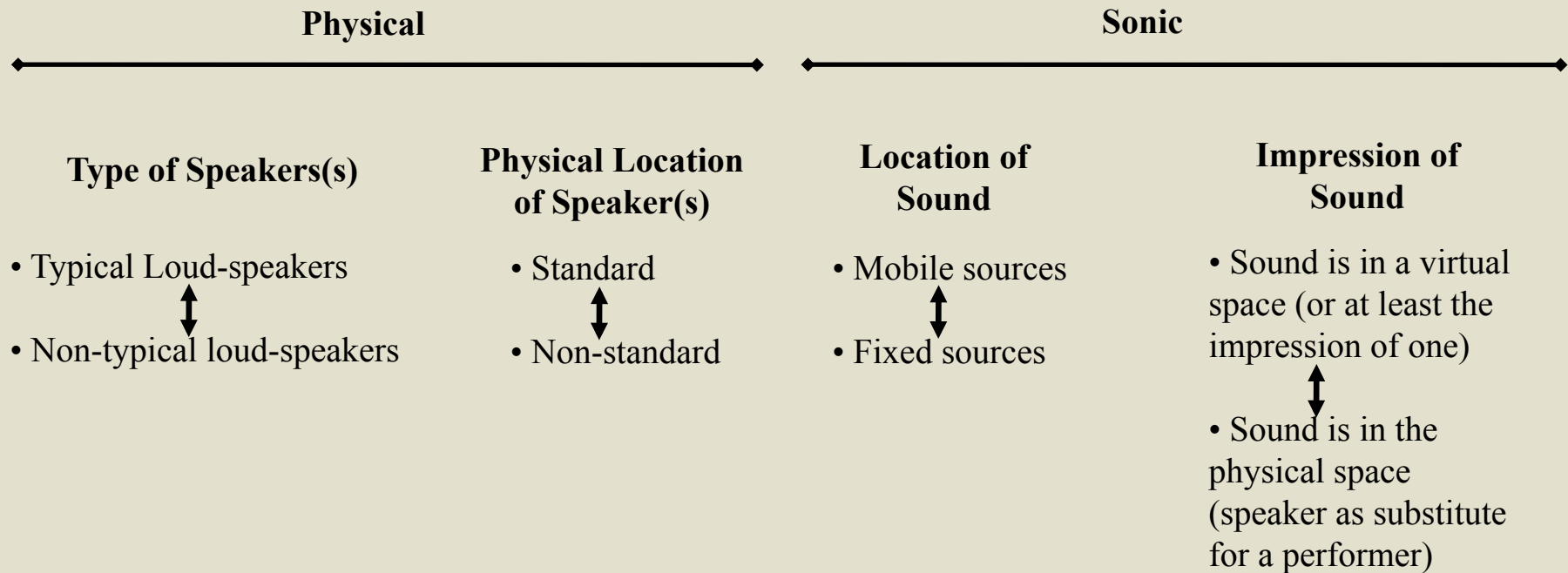
1) Main Challenges: Summary

- Low sounds (<200Hz) are harder to locate -> phase (ITD) and level (IID) differences are less important as frequency goes down
- Moving sounds (especially very pure sounds) are easier to locate when they have many onsets (Franssen Effect)
- Virtual sources hard to perceive if listener not in proper position (Precedence Effect)
- We tend to bond source with what we see or expect (Source Bonding)

Loudspeakers and Space

- 1) Main Challenges
- 2) **Different Approaches**

2) Different Approaches: Classification



2) Different Approaches: Use of Typical Loudspeakers with **Standard** Configurations

Standard commercial configurations:

Stereo

Quad

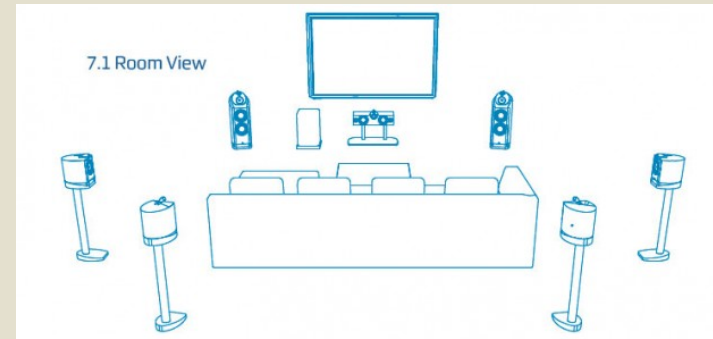
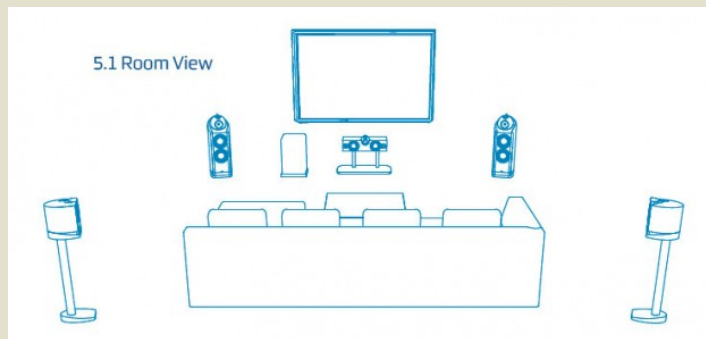
5.1

6.1

7.1 > Blu-ray (Dolby True-HD, DTS-HD, Linear PCM; all lossless formats)

...

and more



Source: dolby.com

These formats all seem very aware of source bonding...

2) Different Approaches: Use of Typical Loudspeakers with **Standard** Configurations

Standard “concert-music” configurations:

Stereo

Quad

Hexaphonic (6 channels)

Heptaphonic (6 surround channels +1 center channel)

Octaphonic (8 channels)

Dome-type configurations

- BEAST (Birmingham Electro-Acoustic Sound Theatre)
- Audium (San Francisco)
- Klangdom (Germany, ZKM)
- Hydra (Boston, Harvard U. -> Hans Tutschku)

WFS (Wave Field Synthesis) ~ not really standard yet

Speaker orchestra (not all similar speakers)

- Acousmonium (France, related to GRM)
- Motus (France, descendant of acousmonium)

Musical Examples:

- Leroux, *Voirex* (2002)
- Erin Gee, *Mouthpiece IX*, for amplified voice and orchestra
- Hans Tutschku, *firmament – sleepless* (2010), electroacoustic composition
- Rama Gotfried, Ircam project for cello and WFS
- Haydn Project, re-synthesizing spaces



2) Different Approaches: Use of Typical Loudspeakers with **Standard** Configurations

Technical advantages of standard configurations:

- Stereo is commonplace
- Can be cheap (via commercial formats)
- Infrastructure increasingly available in music institutions

Aesthetic disadvantages of standard configurations:

- Tends to impose a preferred “sweet spot” for the listener
- Tends to conform to the standard concert protocol
- Tends to impose a common set of tools, most of which have visual interfaces
 - Ex: Spat~, ICST Ambisonics, vbap~, Zirconium, ViMic, OMPrisma, commercial panners (logic, DP, ProTools, etc.)

→ Is it possible to imagine using visual aids during a concert, to guide the listener?

→ Is space travel possible?

2) Different Approaches: Use of Typical Loudspeakers with **Non-Standard** Configurations

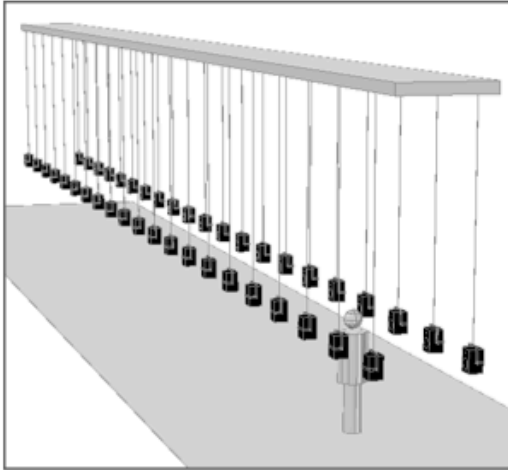


Fig. 1: Stereo corridor with 42 speakers (CAD)



Fig. 2: Auditory-Channel: stereo corridor setup

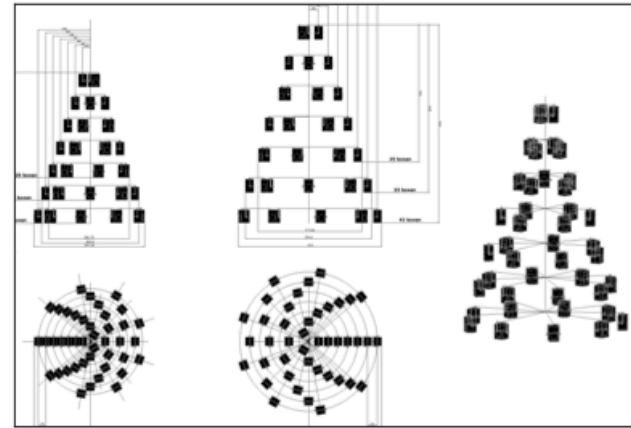


Fig. 3: Two cone/tree setups (CAD)

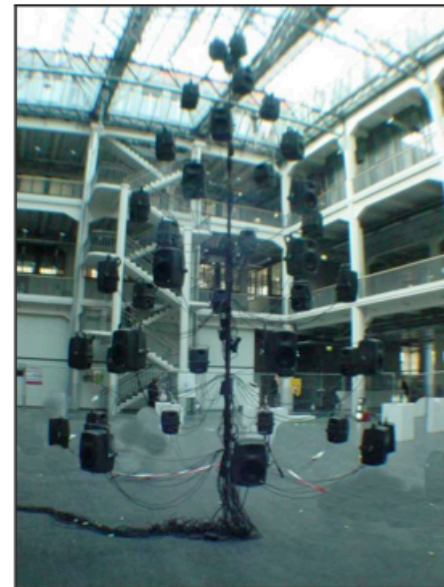


Fig. 4: Sound-Tree: Cone/Tree setup

2) Different Approaches: Use of Typical Loudspeakers with **Non-Standard** Configurations

As sound installations:

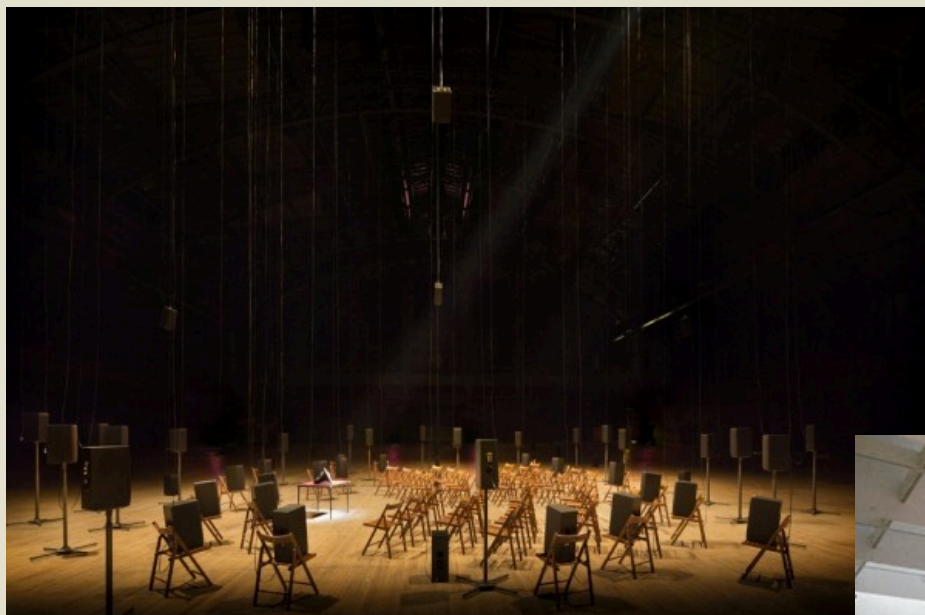
- Dionisio Gonzalez, *Transfigured Schoenberg* (2009)



2) Different Approaches: Use of Typical Loudspeakers with **Non-Standard** Configurations

As sound installations (Loudspeaker as person):

- Cardiff and Miller, *Murder of Crows* (2008), *40 Voice Motet* (2001)



2) Different Approaches: Use of Typical Loudspeakers with **Non-Standard** Configurations

As concert works which enhance what's already there

- extension instrumental properties (i.e., “meta-instrument”)

- Hans Tutschku, *Irrgärten* (2010)



2) Different Approaches: Use of **Typical** Loudspeakers with **Non-Standard** Configurations AND with **Movement** of the loudspeaker

Less typical loudspeakers...

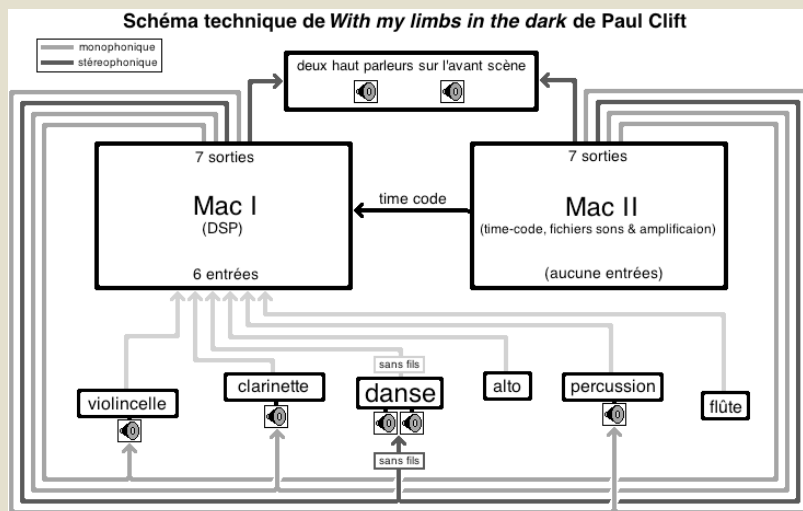
- Daniel Buren, *Excentrique(s), travail in situ* (2012)



2) Different Approaches: Use of **Typical** Loudspeakers with **Non-Standard** Configurations AND with Movement of the loudspeaker

Less typical loudspeakers... (continued)

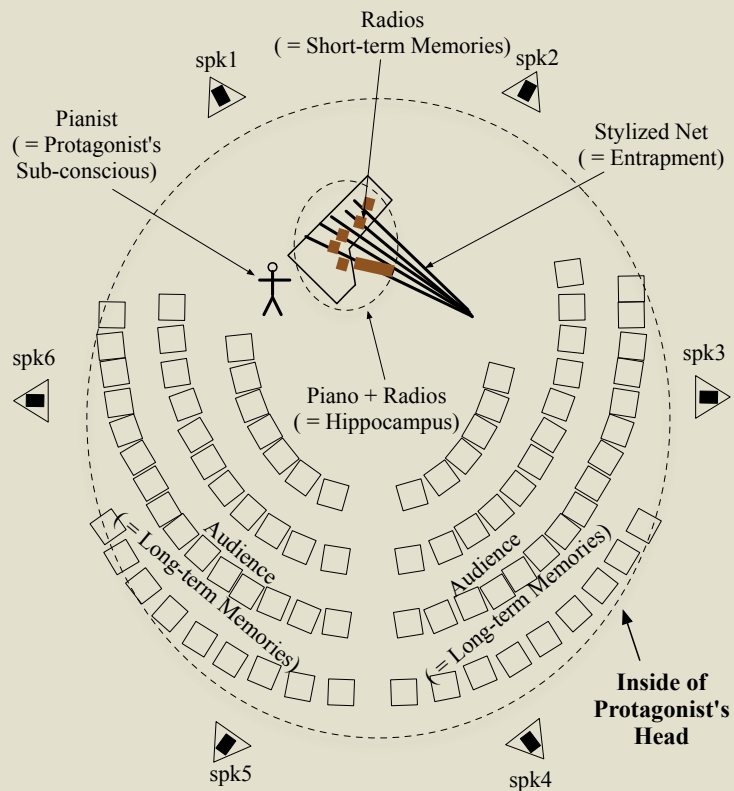
- Paul Clift, *With my limbs in the dark* (2008-09)



2) Different Approaches: Use of **Typical** Loudspeakers with **Non-Standard** Configurations AND with Movement of the loudspeaker

Less typical loudspeakers... (continued)

- David Adamcyk, *Cheval mémoire* (2011)



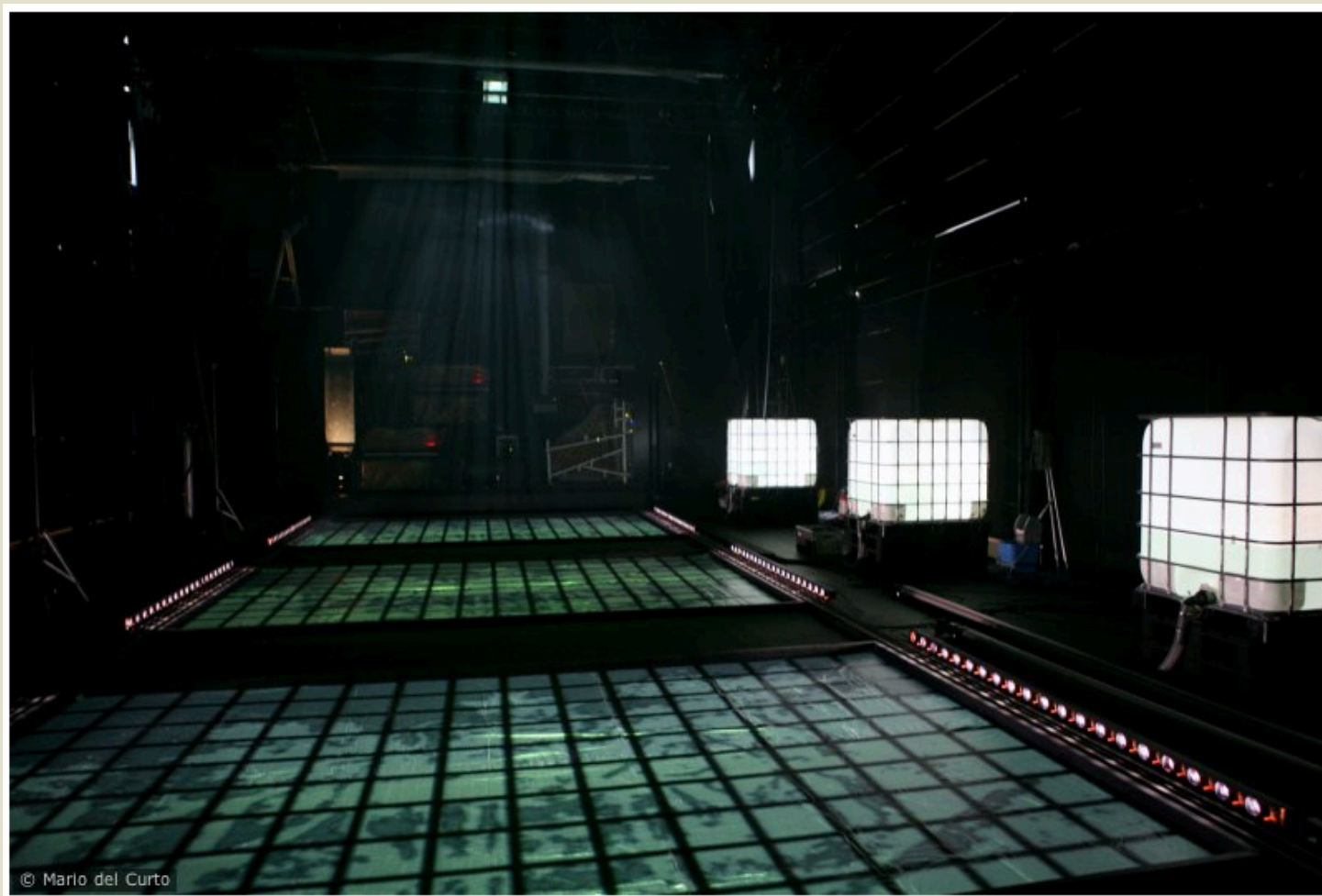
Outside Voices: loudspeakers 1-6
Protagonist's Voice: loudspeakers 1-2



2) Different Approaches: Use of **Typical** Loudspeakers with **Non-Standard** Configurations AND with Movement of the loudspeaker

Performative installation

- Heiner Goebbels, *Stifters Dinge* (2007)



2) Different Approaches: Use of Typical Loudspeakers with Non-Standard Configurations AND with Movement of the loudspeaker

A very old idea...

- David Tudor, *Bandomeon (a combine!)* (1966)



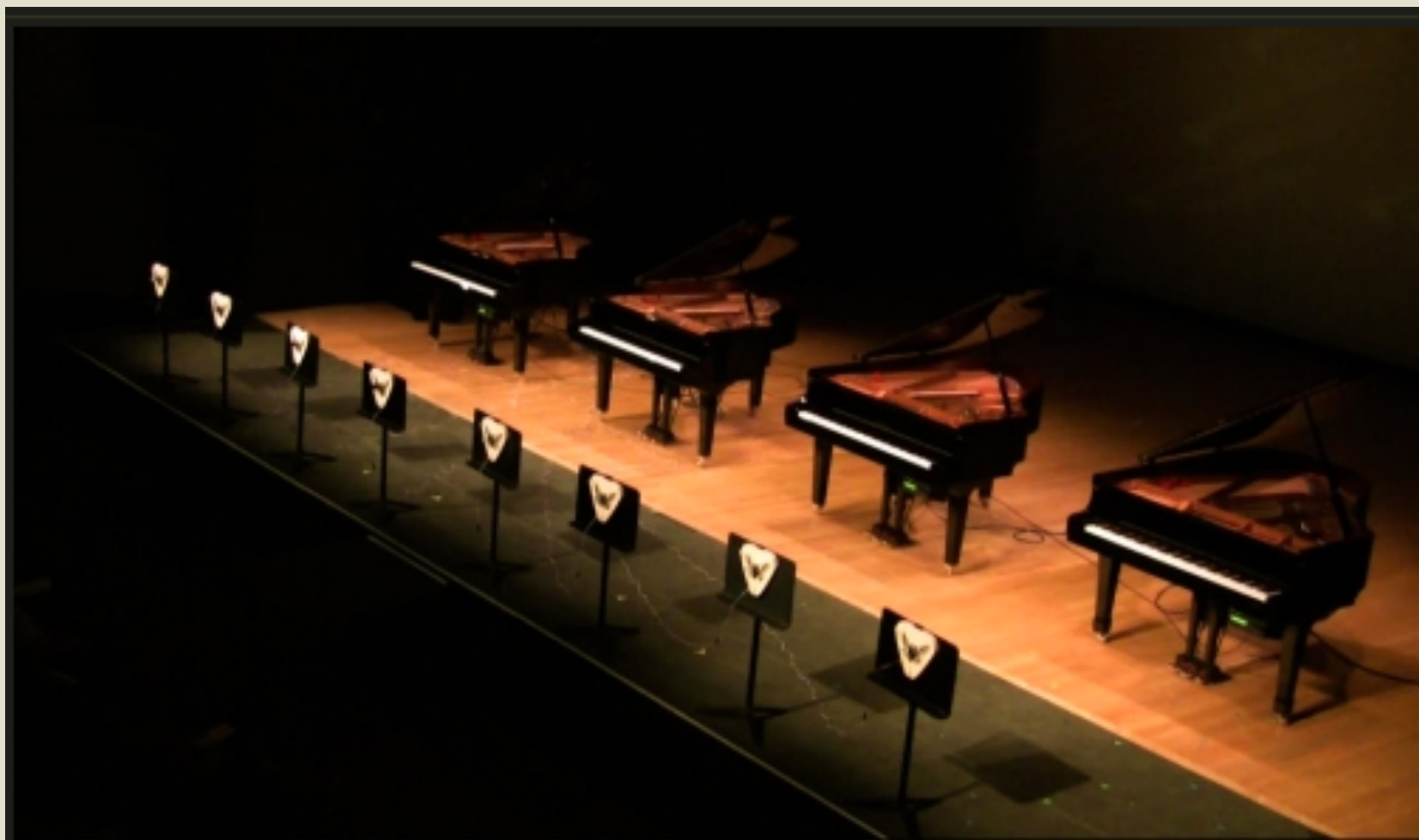
2) Different Approaches: Use of **Non-Typical** Loudspeakers with **Non-Standard** Configurations

- David Coll, *Position, Influence* (2007)



2) Different Approaches: Use of **Non-Typical** Loudspeakers with **Non-Standard** Configurations

- Victor Adan, *Fonoptera* (2009) doctoral project



2) Different Approaches: Use of **Non-Typical** Loudspeakers with **Non-Standard** Configurations

- Paul DeMarinis, *Firebirds* (2004)



Postlude: Short survey of “sound tools” used for spatialization

- **Vbap** (2D and 3D panning, for MaxMSP; It’s free! By Vile Pulkki)
<http://www.acoustics.hut.fi/~ville/>
- **ViMic** (Microphone position based spatilization, for MaxMSP, part of Jamoma; It’s free! By Nils Peters)
<http://nilspeters.info/archives/tag/vimic>
- **Spat~** (2D and 3D panning with room simulation, for MaxMSP)
Part of Ircam Forum
- **Sequencer panners** (Logic, DP, ProTools, Cubase, etc.; watch out for pan laws!)
- **Ambisonics** (many different versions, MaxMSP version most versatile, by ICST; It’s free!)
- **Reverbs Units**
 - Algorithmic
 - Kjaerhus Audio Classic Reverb (only VST; It’s free!)
 - Waves True Verb and Renaissance Verb (very good, expensive)
 - Lexicon PCM Native Reverb Bundle (very expensive)
 - Bricasti M7 (rackmount hardware only, very expensive)
 - Valhalla Room (AU and VST, cheap and good)
 - Impulse Response
 - Space Designer (part of Logic, Mainstage)
 - Altiverb (by Audio Ease, very expensive, industry standard)
 - Knufinke SIR1 (only VST; It’s free!)
 - Waves IR1 (good)
 - Tconvolution (MaxMSP object; it’s free!)



Soundfield mic, for Ambisonics recording