A framework for dynamic spatial acoustic scene generation with Ambisonics in low delay realtime

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Outline

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2. Hearing research
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   - Acoustic scene creation and rendering

3. Music performance
   - Parametrized cyclic dynamic panning
   - Control interfaces and parameter selection
   - Monitoring
   - Concert setup

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Introduction

Venetian polyphonic style
Introduction

Venetian polychoral style
- Spatially separated sources
- Enveloping sound

⇒ We want more!

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Dynamic spatial acoustic scene generation...
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- Small sweetspot, depending on musical complexity
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Toolbox for acoustic scene creation and rendering

- New toolbox: TASCAR
  Toolbox for Acoustic Scene Creation And Rendering
- Open source (GPL/LGPL), http://linuxaudio.vegri.net/
- Inspired by existing tools:
  - SoundScapeRenderer (jack, TU Berlin)
  - AMB plugins (ladspa, Fons & Jörn)
- Focus: Dynamic spatial content creation
  - Initially developed for music performance
  - Extended within research project
Hearing Research
Research targets

- Spatial psychoacoustics, e.g.
  - Precedence effect of moving sources
  - Localization, Source tracking

- Speech perception, e.g.
  - Speech intelligibility in complex scenes
  - Effect of head- and torso movements

- Hearing aids, e.g.
  - Directional microphone algorithm evaluation
  - Gesture recognition for hearing aid control
What we would like to have:

- Realistic acoustic scenes with high spatial complexity (e.g., 'cafeteria problem', public transport)
- Physically correct sound field within a certain sweetspot (human and machine listening)
- Spatial dynamics of sources are controllable
- Contents exchangable independently from spatial configuration
Acoustic scene creation and rendering

- Create tracks (csv format: t, x, y, z): Record sound and GPS track, project to local coordinates
  \[ \rightarrow \text{tascar\_gpx2csv} \]
- Play position as jack ports, use jack transport
  \[ \rightarrow \text{tascar\_jpos} \]
- Panning module takes position and audio as jack ports
- Render to speaker given layout in several formats
  (nearest, vbap, amb\_basic, amb\_inphase, wfs, cardiod)
  \[ \rightarrow \text{tascar\_multipan} \]
- Add ambient background noise (first order ambisonics), use ambdec for rendering to speaker layout
Setup

Dynamic spatial acoustic scene generation...
Example scene: Outdoor (street) situation
Music performance
Harmony of the Spheres – concert

Harmony of the Spheres: Philosophical concept of projecting celestial relationships (renaissance)

Music theory devised from celestial motions (e.g., Bartolus 1614, Kepler 1619, Kircher 1650)

Number aesthetics and symmetry affected compositions (musical form, number of voices, rules of algorithmic composition)

Subtle deviation from regularities create musical content in minimal music

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Harmony of the Spheres – spatialization

- Create virtual sources from acoustic inputs
- Let them move around the audience
Mr. Picforth: *In Nomine (16. century)*
Perfect proportion, voices representing planets
Harmony of the Spheres – spatialization

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Harmony of the Spheres – spatialization

cycle (naïve)  epicycle (Ptolemy)  ellipse (Kepler)
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- John Cage: *Five (1988)*
  Transition from disorder to harmony and back to disorder
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  Late minimal music, 'choreography' amplifies composer’s intentions

Christopher Tye (c. 1505-1572), Giovanni Pierluigi Palestrina (1525-1594), Nicholas Strogers (*†* 1575), Arvo Pärt (*1935), Steve Reich (*1936)

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Harmony of the Spheres – signal flow
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hos_sphere: Trajectory generator

- Superposition of Kepler ellipse and epicycle
- **Ellipse**
  - $\rho$ nominal radius
  - $\varepsilon$ eccentricity
  - $\theta$ main axis rotation
  - $\omega$ nominal angular velocity
- **Epicycle**
  - $\rho_{epi}$ radius
  - $\omega_{epi}$ angular velocity
hos_sphere: Distance coding

- Stereo reverberation
  convolution reverb 'chapel' from Fons Adriaensen
- Virtual stereo source around source direction
- Distance $r$ affects
  - amount $g$ of reverberation
    \[ g(r) = \frac{r}{1+r} \]
  - width $w$ of stereo source
    \[ w(r) = w_{\text{max}} \frac{2r}{r^2+1} \]
Control interfaces and parameter selection
Parameter selection with real footswitch

- MIDI foot switch (FCB1010) connected to 'mididings'
- Invoke shell script on program change events
- Read preset files, send as OSC messages to 'hos_sphere'
- Control ardour transport with OSC messages
Parameter selection with virtual footswitch

- Viola da gamba is held between the legs
Parameter selection with virtual footswitch

- Viola da gamba is held between the legs
- Lifting the heel is difficult
Parameter selection with virtual footswitch

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⇒ Optical foot scanner
Parameter selection with virtual footswitch

- kinect game controller 3d-camera
- Track position of foot tip
- Four states can be detected:
  - empty: no foot present
  - straight: neutral foot position
  - right: increase program number
  - left: decrease program number
- Shell scripts executed on program change
Monitoring: Requirements

- Concert setup with huge distances between musicians → 'Zero latency' in-ear monitoring is necessary
- Only dry sound monitor
- Pre-recorded announcements (program change, time, count in)
- Spatial cues by interaural level differences
- Real-time modifications during sound check & concert
Monitoring: Hard- and software

- RME hdsp9652 matrix mixer
- 'hdspmixer’ is missing hardware interface and grouping features
  \(\Rightarrow\) own software
- OSC based network solution:
  - 'mm_hdsp’: access to hardware mixer
  - 'mm_midicc’: interface to MIDI controller (BCF2000)
  - 'mm_file’: load, save and manipulate mixer matrix
  - 'mm_gui’: visualize gain matrix
Monitoring: Hard- and software

- sub-set of gain matrix → no conflict with other mixing software
- Assign names to inputs and outputs
- Routes can be multi-channel
Concert setup
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Concert setup

viola da gamba
Concert setup

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Dynamic spatial acoustic scene generation...
Concert setup

3rd order horizontal Ambisonics
Concert setup

monitor & mix controller (2 BCF2000)
'virtual' footswitch (kinect)
'real' footswitch (FCB1010)
Demonstration video

today 4:45pm → listening room
Thank you and all other LADs!

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'tascar_gpx2csv'

- Tangent projection of GPS coordinates to local coordinates
- Smoothing and resampling to correct errors and jitter
- Time shift to match jack transport time

Example configuration

```xml
<origin src="trkpt" mode="tangent">
  <trkpt lat="53.151367" lon="8.200514"/>
</origin>
<scale x="1" y="1" z="0"/>
<resample dt="0.25"/>
<smooth n="11"/>
```
Multiple panning methods & render, switchable via OSC messages over UDP multicast (/*/mode):

- Nearest speaker (nearest)
- Vector based amplitude panning (vbap)
- Higher Order Ambisonics (amb_basic, amb_inphase)
- Wave field synthesis (wfs)
- Cardioid microphone array, e.g. ORTF (cardiod)
- Direct HOA output planned

Speaker/microphone configuration in XML
'tascar_multipan'

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- Speaker/microphone configuration in XML
- Distance coding with delay and gain simulation
  ⇒ Doppler effect
- Delay- and gain compensation of speaker distances
hos_sphere: Trajectory generator

Kepler ellipse with epicycle component:

\[
\rho_\varepsilon(\varphi) = \frac{\rho_0 \sqrt{1 - \varepsilon^2}}{1 - \varepsilon \cos(\varphi - \theta)}
\]

\[
z(\varphi, \varphi_{epi}) = \rho_\varepsilon e^{i\varphi} + \rho_{epi} e^{i\varphi_{epi}}
\]

\[
\Delta \varphi = \frac{\omega \rho^2}{\rho_\varepsilon^2}
\]

\[
\Delta \varphi_{epi} = \omega_{epi}
\]

Also: Random component, \( \varphi \) proportional to signal envelope
Parameter selection with virtual footswitch

- Training phase (before concert)
  - Calculating depth difference to 'empty' state
  - Find clusters with depth differences between states
Parameter selection with virtual footswitch

- **Training phase (before concert)**
  - Calculating depth difference to 'empty' state
  - Find clusters with depth differences between states

- **Test phase (during concert)**
  - Calculate error difference to training data
  - Select state with least error
  - State change: left/right detected during 0.25 seconds
  - Predefined shell command is evoked on program change
  - Shell commands trigger OSC messages