Sonic Interaction Design: New applications and challenges for Interactive Sonification

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Imagine…
Sonification – What and Why?

- Sound is a neglected modality!
- Benefits:
  - neglected resource, backgrounding, habituation, high time-resolution, holistic listening, direction of attention, highly developed listening skills, auditory gestalt formation, etc.
- Sound has a long tradition in Science
  - Stethoscope
  - Geiger Counter
  - Machine Diagnostics
- Sonification extends our listening skills to ‘normally silent’ domains
1. **Sonic Interaction Design and Sonification**
   - Definition, Taxonomy, Sonification Techniques
   - The Importance of Interaction in Sonification
   - Selected application examples

2. **Model-Based Sonification**
   - Examples: Data Sonogram Model / Particle Trajectories / GNGS

3. **Discussion**

4. **Guidelines for Designing Auditory Interface**

5. **SID & Sonification for Ambient Intelligence**
Def.: SID is the exploitation of sound as channel conveying informational, aesthetic and/or emotional content in interactive contexts.

- EU COST Action IC0601 (SID)
  www.cost-sid.org

Main areas:
1. Perceptual, cognitive, and emotional study of sonic interactions
2. Product Sound Design
3. Interactive Arts and Music
4. Sonification

Infinite possibilities for today’s artefacts!
New Definition: Sonification
(Hermann, 2008, ICAD)

A technique that
- uses data as input, and
- generates sound signals
  (eventually in response to optional additional excitation or triggering)
may be called sonification, if and only if

1. The sound reflects objective properties or relations in the input data.
2. The transformation is systematic.
3. The sonification is reproducible.
4. The system can intentionally be used with different data.
Sonification Techniques – An Overview

- **Sonification:** Generality equal to visualization!
  - **Audification:**
    - Earthquakes (Dombois)

- **Auditory Icons:**
  - Computer Desktop (Rocchesso et al.)

- **Earcons:**

- **Parameter Mapping:** data mapped to sonic features
  - Iris data set

- **MBS:** data becomes interactable ...later
Interactive Sonification

- Passive Sounds vs. **Active Sounds**
- Multiple Sonic Views (Aural Perspectives) required
  - And queried by interaction

**Interaction binds** multiple sensory signals *into perceptual multimodal units*

**Interaction embeds us into a closed-loop**
- We feel more in control
- Higher flow / satisfaction
- Increased performance / less annoyance
- The more we can interact with sound the better
Closed Interaction Loops in Auditory Displays

- World/System
- Sonification
- Data
- Monitoring
- No Action
- Interactive Sonification
- Navigation
- Auditory Biofeedback
- Human Activity (supported by sonification)
Sonification of Human EEG
[ for monitoring, diagnosis, analysis ]

- Analysis of Epileptic EEG
  - Parameter Mapping Sonification:
  - Event-based Sonification:
  - Combined Patient Observation & Data Inspection

- Vocal EEG Sonification
  - Stability: Acoustic Convergence
  - Familiar Sound Domain (memorize)
  - Built-in imitation capabilities (verbalize, point)
  - Absence: Artefact: Sleep:
  - Stable classification: dist.mat:
Tangible Interactive Sonification
[ Interactive Sonification ]

- Data channels *become* physical objects
- Parameter Selection is transformed into physical Interaction
- Goal: Intuitive Optimization of Contrast between normal / pathologic data examples

TISon
Hermann, Bovermann, Riedenklau, Ritter
2007 Bielefeld University
Weather Forecast Sonification
[ rapid overview ]

- “Wettervorhörsage”
- Broadcasted 6 months daily on Hertz 87.9
- Complex information conveyed in 12 s
- Mapping & Auditory Icons
- Examples:
  - Nice spring day
  - Ugly November day
- Data-driven Emoticons
Sonic Function
[ navigation / exploration ]
with Florian Grond & Trixi Drossard

- Sonification of Mathematical Functions for Visually Impaired Pupils
- Pedagogic Applications
- Pupils are able to detect / count / identify extrema in functions
- Suitable for other data, e.g. stock market data

\[ y = -4x^2 + 0.2x^4 + 5 \]
CLAIMT – Closed-Loop Auditory Interaction
[ auditory biofeedback ]

How can users profit from auditory biofeedback?

- Skill Learning in Dance and Music
- Support Physiotherapy
- Basic Research in Closed-Loop Interaction
- Augmented Tools
German Wheel Sonification

Jessica Hummel

- Can sonification of the wheel status support the accuracy of movement executions? YES!
Model-based Sonification for non-time-indexed complex data

How to sonify high-dim. data?

How do we hear?

MBS Ingredients
- Model Setup
- Model Dynamics
- Initial Conditions
- Excitation / Interfaces
- Link-Variables
- Listener Characteristics
Data Sonogram Sonification Model

- **Model Setup:**
  - Point Masses in Data Space

- **Dynamics: Newton’s laws**
  - Wave Propagation
  - Spring Forces

- **Excitation:**
  - Shock Wave (pressure wave)

- **Link-Variables:**
  - Point mass elongations

- **Listener Characteristics:**
  - binaural
  - Orientation along PCA#1

![Diagram of shock wave center and listener position with classes 1 and 2, and physical properties like spring stiffness and mass cross section with friction constant.](image)
Data Sonogram Examples

- **Breast Cancer Diagnosis**
  - $N = 700$, $d = 10$
  - Distances in high.dim. spaces

- **Iris data set**
  - $N = 150$, $d = 5$
  - 3 sorts of plants
  - Audible class separation

- **Clustered data in $R^3$**
  - Audible cluster variance
Tangible Data Scanning (TDS)

with Bovermann, Riedenklau

- Data become real localized physical objects
- TDS exploits human manipulation capabilities
- Spatial memory helps to interpret data
Particle Trajectory Sonification Model for Cluster Analysis

- **Setup: Particles in Data Potential**
  \[ V(x) = \sum_{\alpha=1}^{M} \phi(\|x - x_{\alpha}\|) , \quad \phi(r) = -N \exp \left( -\frac{r^2}{2\sigma^2} \right) \]

- **Dynamics: Newton’s Law + damping**
  \[ m\ddot{x}(t) = -\nabla_x V(x) - \gamma \dot{x}(t) \]

- **Excitation:**
  - Particle Injection
  - Energy Injection (shake, hammer)

- **Link-Variables:**
  - Sum of particles' kinetic energy
Particle Trajectory Sonification Model (cont.)

- Typical Particle behavior: 

- Model Parameters:
  - Data mass \( m_d \) and particle mass \( m_p \)
  - Bandwidth \( \sigma \)
  - Friction constant \( \gamma \)

- Sound represents \( V \) on multiple scales in time
  chaotic \( \rightarrow \) timbral \( \rightarrow \) pure harmonic \( \rightarrow \) sinusoid

- Sound depends on clustering properties
  - Ensemble 1 cluster:  
  - 3 clusters:
- Holistic multi-scale encoding of V

- Single particles are not very informative

- Sigma sweeps:
  - Decrease sigma and inject particles
  - Multi-scale analysis: pitch plateaus emerge
  - Auditory Gestalt Formation
Growing Neural Gas (GNG) Sonification for Data Dimensionality Analysis

- "Shaking/Hitting" Data using the Growing Neural Gas
- The invisible feature of intrinsic dimensionality becomes audible
- 2d: 🌟 4d: 🌟 8d: 🌟
- Network Growth Sonification for convergence monitoring:

\[
\frac{dE_i}{dt} = -gE(t) - \sum_{j \in I_N(i)} q(E_i(t) - E_j(t))
\]
Multi-Touch Interaction with Growing Neural Gas Sonifications

with Kolbe & Tünnermann
Discussion (MBS)

- **Benefits of MBS**
  - **Generality**: applicable to different data sets
  - Excitatory *Interaction built-in*
  - Design-once-Use-often
  - Fewer Control Parameters than in ParMap
  - Supports *Auditory Learning*
  - Naturally complex sonic responses

- **Comparison to ParMap and Physical Models**
  - Whereas in ParMap, Data *controls* a Sounding Object, in MBS, Data *becomes* the Sounding Object *(and playing is left to the exploring user)*

- **Discussion: MBS vs ParMap vs Physical Models**
GUIDELINES: Interdisciplinary Dialogue

- Application Domain Experts
- Sonification Experts
- Users
- Programmers

But also:
- Designers
- Psychologists for Evaluation
- Interactional Linguistics
- Cultural Studies

Functional Aspects

Asthethic / Emotional / Holistic Aspects
GUIDELINE
Aim at Holistic and Balanced Multimodal Displays

- Interweave Modalities
  - Partial Redundancy
  - Coherence / Coupling

- Acknowledge Human Dynamic Attention Allocation during task-oriented procedures

- Consider that sound is only a part of the multimodal experience
GUIDELINE
Address the Users’ Learning Capacity

- Develop Sonifications that are useful even for beginners
  - But also provide the richness enabling users to improve their interaction skills infinitely…

- Accomplished by:
  - Stability of the interface
  - Signal-near representation
  - Close coupling to interaction
  - Sonic complexity
  - Model-based approaches (MBS)

Musical Instrument Interaction as good example
Outlook: SID & Sonification for Ambient Intelligence

- Aml refers to electronic environments that are sensitive and responsive to the presence of people

  adaptive ubiquitous multimodal context-aware
  unobtrusive calm technology personalized
  anticipatory embedded
Perspectives of SID for Ambient Intelligence

- Smart Rooms, Future Living
- Ambient Information Awareness
- Shared Presence
- Sound for Augmented-Reality
- Sound for Human-Robot Interaction
Acoustic Augmentation for Ambient Information Awareness

Bovermann, Tünnermann
tacTiles – tactile sensitive furniture

- Flexible smart skin for furniture, Low-cost Open Hardware
- Monitoring Activity in large office spaces
- Application: avoid rigid working style
Conclusion: Synergies between DAFx & SID / Sonification

- SID needs DAFx for efficient, high quality sound
  - Physical Modelling for better Parameterized Auditory Icons
- MBS can profit from DAFx
  - Physical model developers candidate MBS developers
  - MBS is still too computationally expensive: DAFx-Know-How for real-time implementations
- DAFx can profit from SID know-how to evaluate sound in interactive contexts
- ‘Data Aesthetics’: Models do not necessarily need to sound like real-world sound
  - This opens a new dimension for physical model design
Thank you for your Attention!

Questions? Comments?