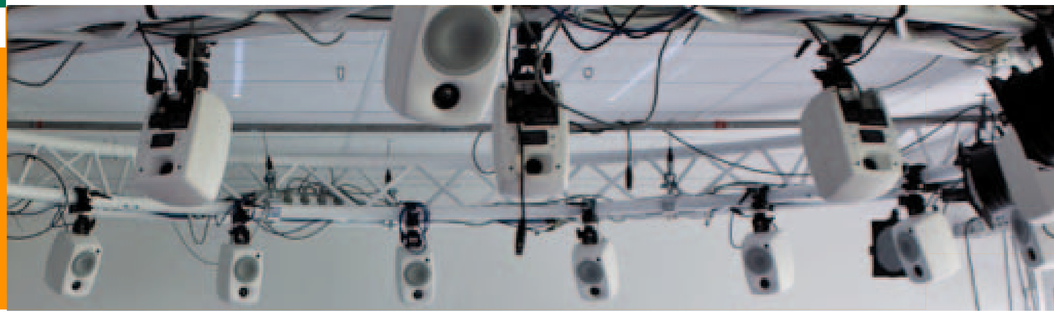


Sonic Interaction Design: New applications and challenges for Interactive Sonification

Thomas Hermann

Ambient Intelligence Group – CITEC

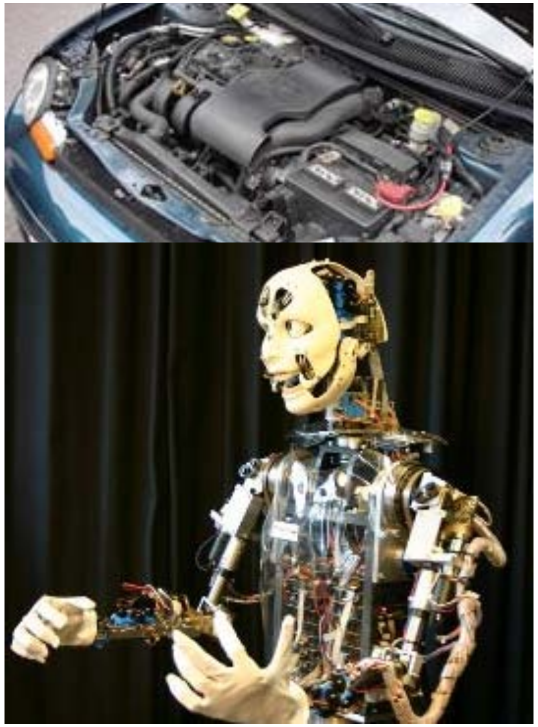
Bielefeld University · Germany

Keynote presentation – DAFx 2010 – Graz – 2010-09-07

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 'normaly silent' domains**



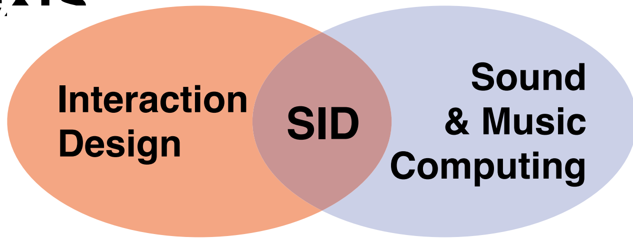
Outline

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**

Sonic Interaction Design

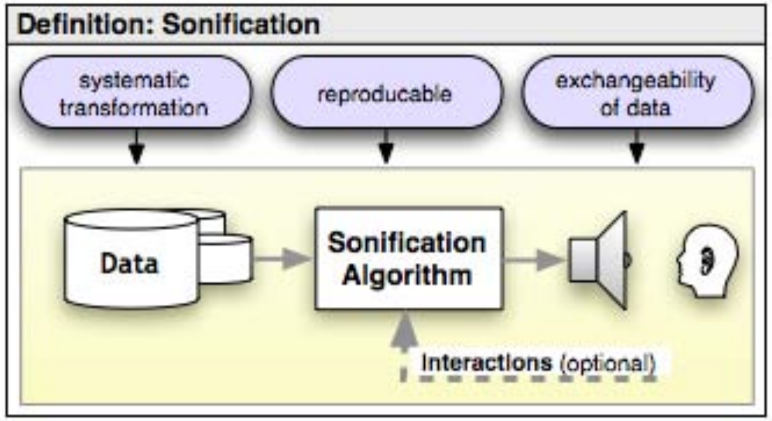
Sonic Interaction Design SID

- **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

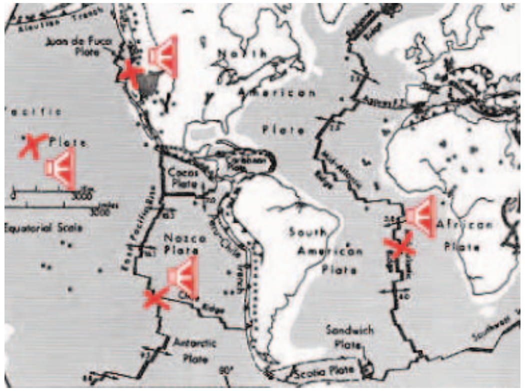
- uses **data as input**, and
- generates sound signals
(eventually in response to optional additional excitation or triggering)

may be called sonification, if and only if

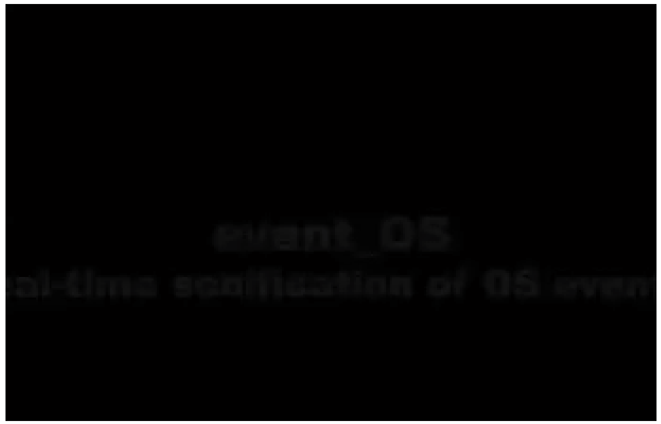
1. **The sound reflects objective properties or relations in the input data.**
2. **The transformation is systematic.**
3. **The sonification is reproducible.**
4. **The system can intentionally be used with different data.**

Sonification Techniques – An Overview

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



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

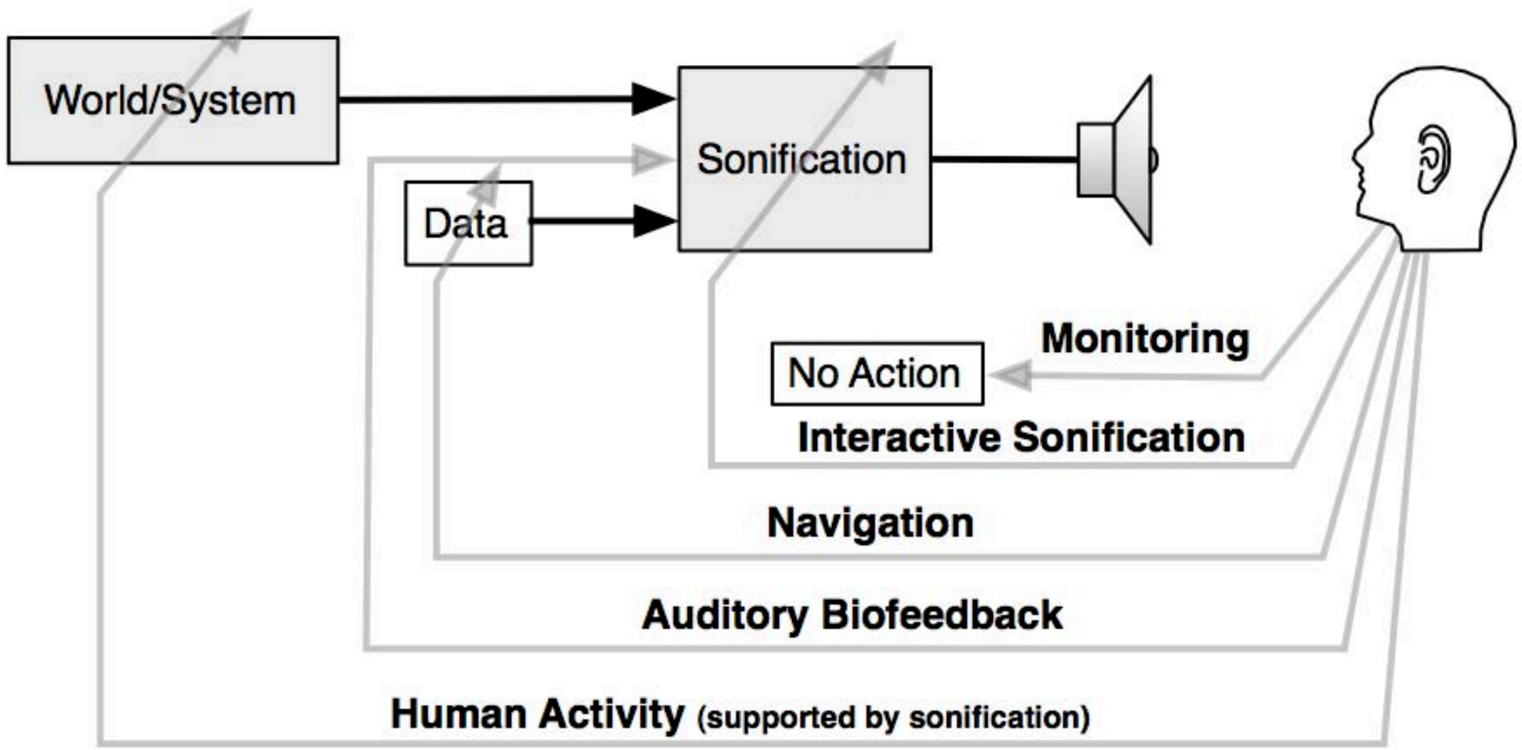


  - **Earcons:**
  - **Parameter Mapping:** data mapped to sonic features
    - Iris data set
  - **MBS:** data becomes interactable **...later**

Interactive Sonification

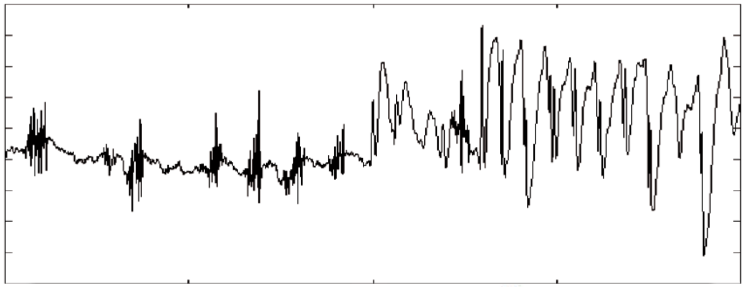

- **Passive Sounds vs. Active Sounds**
- **Multiple Sonic Views (Aural Perspectives) required**
  - And queried by interaction
- **Interaction binds multiple sensory signals into perceptual multimodal units**
- **Interaction embeds us into a closed-loop**
  - We feel more in control
  - Higher flow / satisfaction
  - Increased performance / less annoyance
  - The more we can interact with sound the better

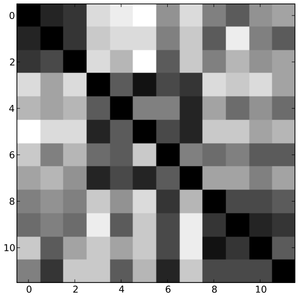
Closed Interaction Loops in Auditory Displays

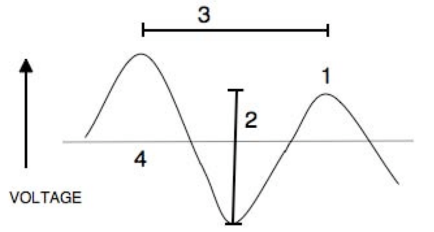


Sonification of Human EEG
[for monitoring, diagnosis, analysis]

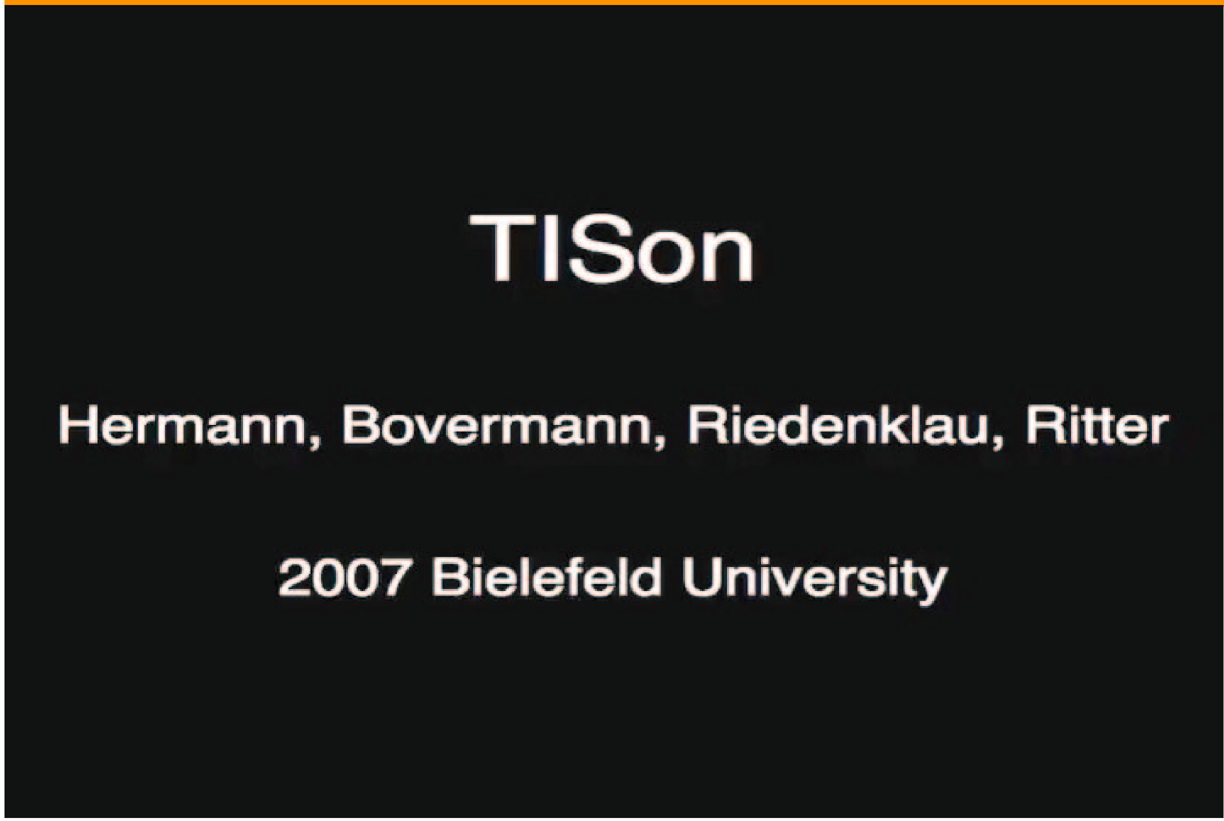
- **Analysis of Epileptic EEG**
  - Parameter Mapping Sonification:
  - Event-based Sonification:
  - Combined Patient Observation & Data Inspection
- **Vocal EEG Sonification**
  - Stability: Acoustic Convergence
  - Familiar Sound Domain **(memorize)**
  - Built-in imitation capabilities **(verbalize, point)**
  - Absence: Artefact: Sleep:
  - Stable classification: dist.mat:







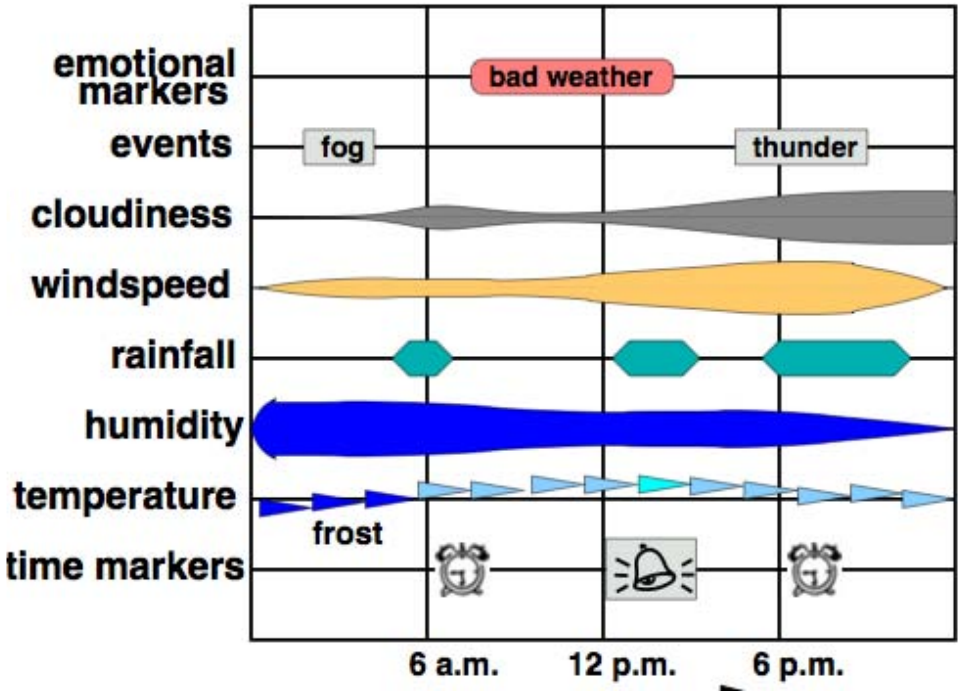
Tangible Interactive Sonification
[Interactive Sonification]



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

Weather Forecast Sonification
[rapid overview]

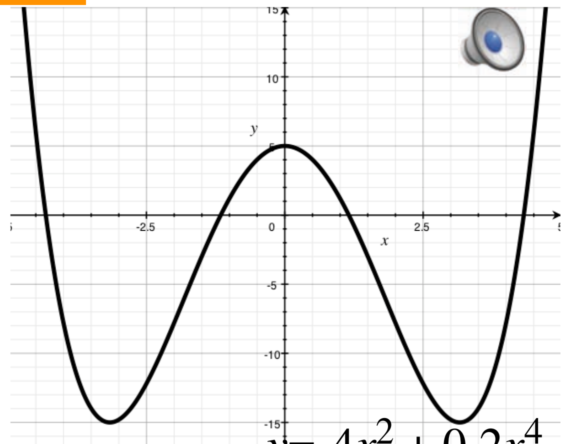
- **“Wettervor**hör**sage”**
- **Broadcasted 6 months daily on Hertz 87.9**
- **Complex information conveyed in 12 s**
- **Mapping & Auditory Icons**
- **Examples:**
  - Nice spring day
  - Ugly November day
- **Data-driven Emoticons**



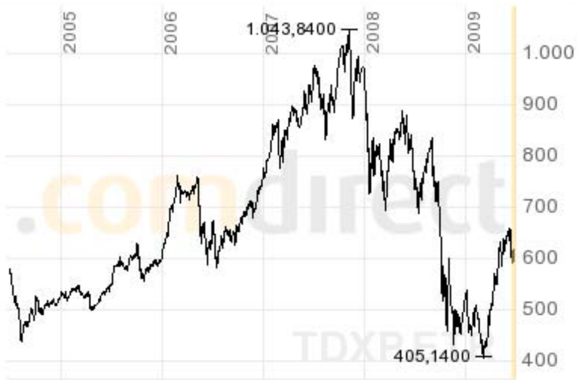
Sonic Function
[navigation / exploration]

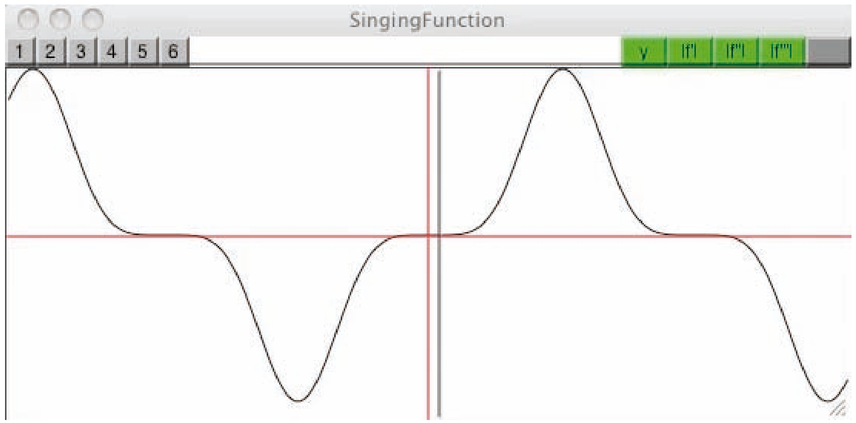
with Florian Grond & Trixi Drossard

- **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**



$y = -4x^2 + 0.2x^4 + 5$





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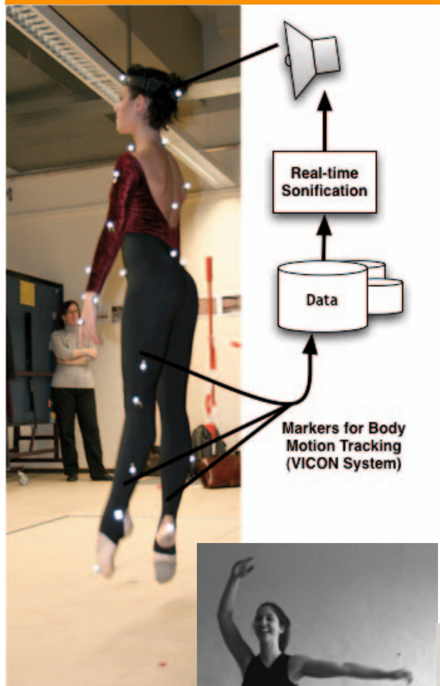
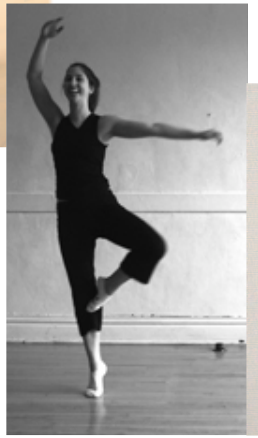
CLAINT – Closed-Loop Auditory Interaction [auditory biofeedback]

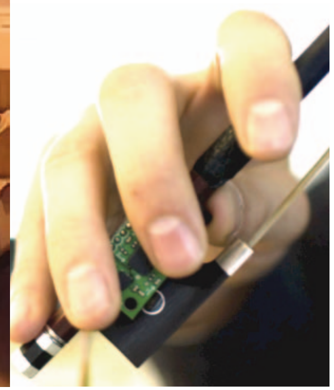
Tobias Grosshauser



How can users profit from auditory biofeedback?

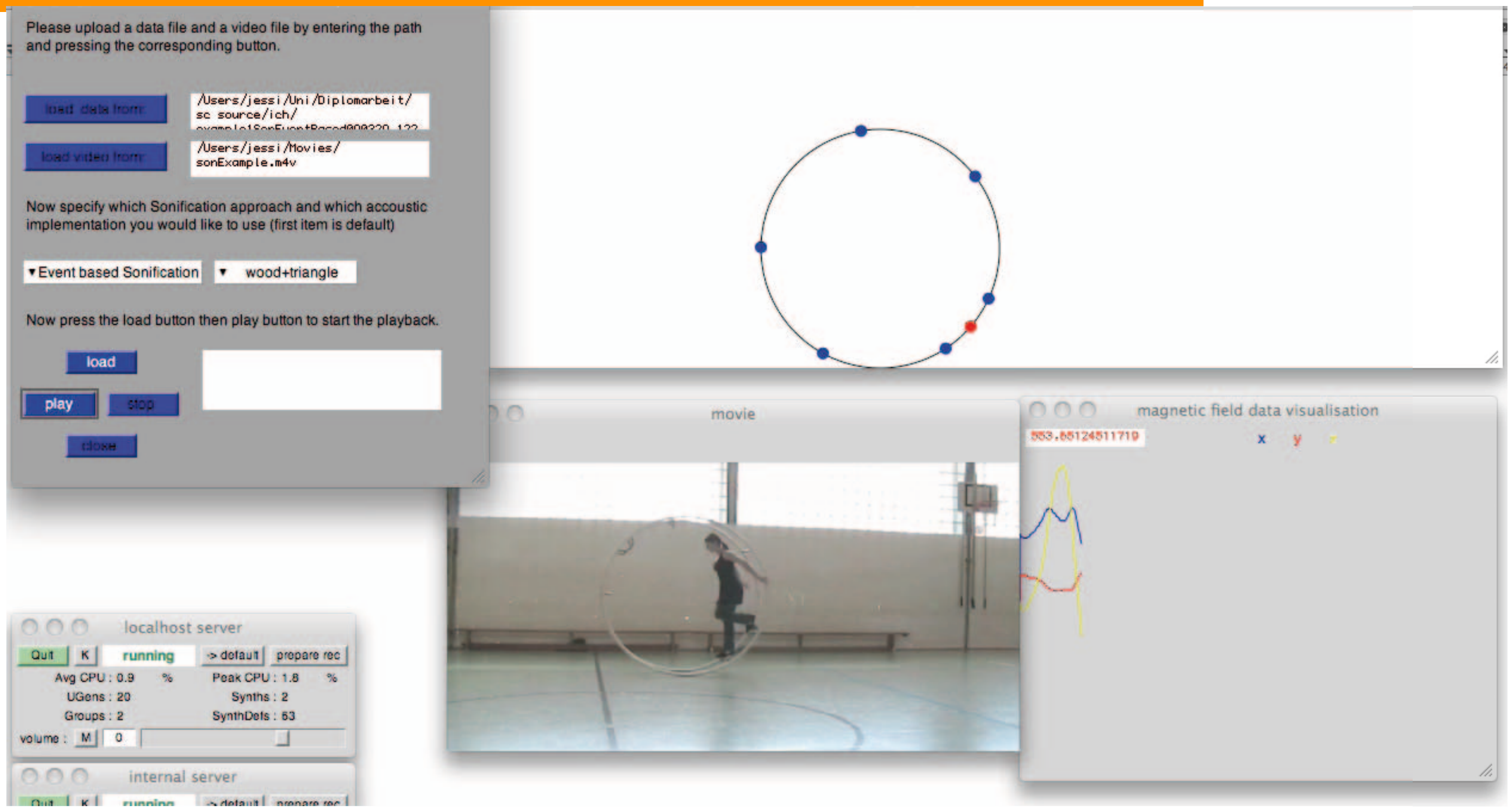
- **Skill Learning in Dance and Music**
- **Support Physiotherapy**
- **Basic Research in Closed-Loop Interaction**
- **Augmented Tools**





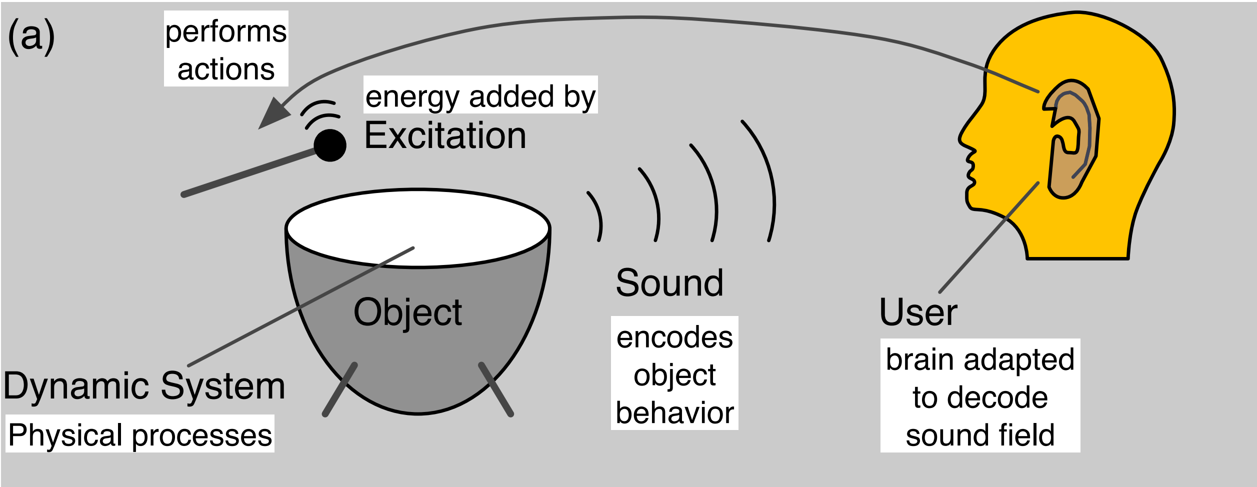
German Wheel Sonification

Jessica Hummel



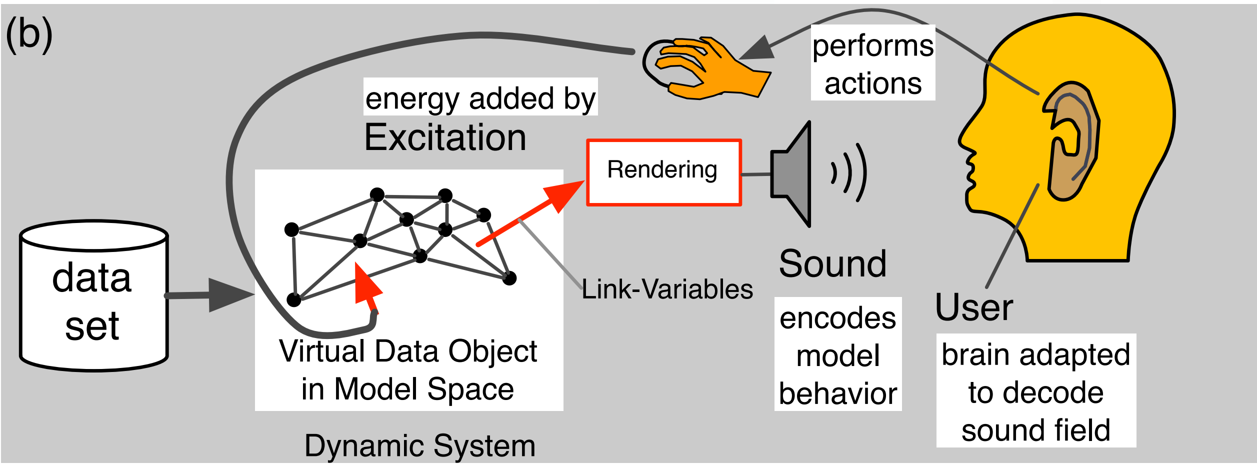
- **Can sonification of the wheel status support the accuracy of movement executions?** **YES!**

Model-based Sonification for non-time-indexed complex data



How to sonify high-dim. data?

How do we hear?

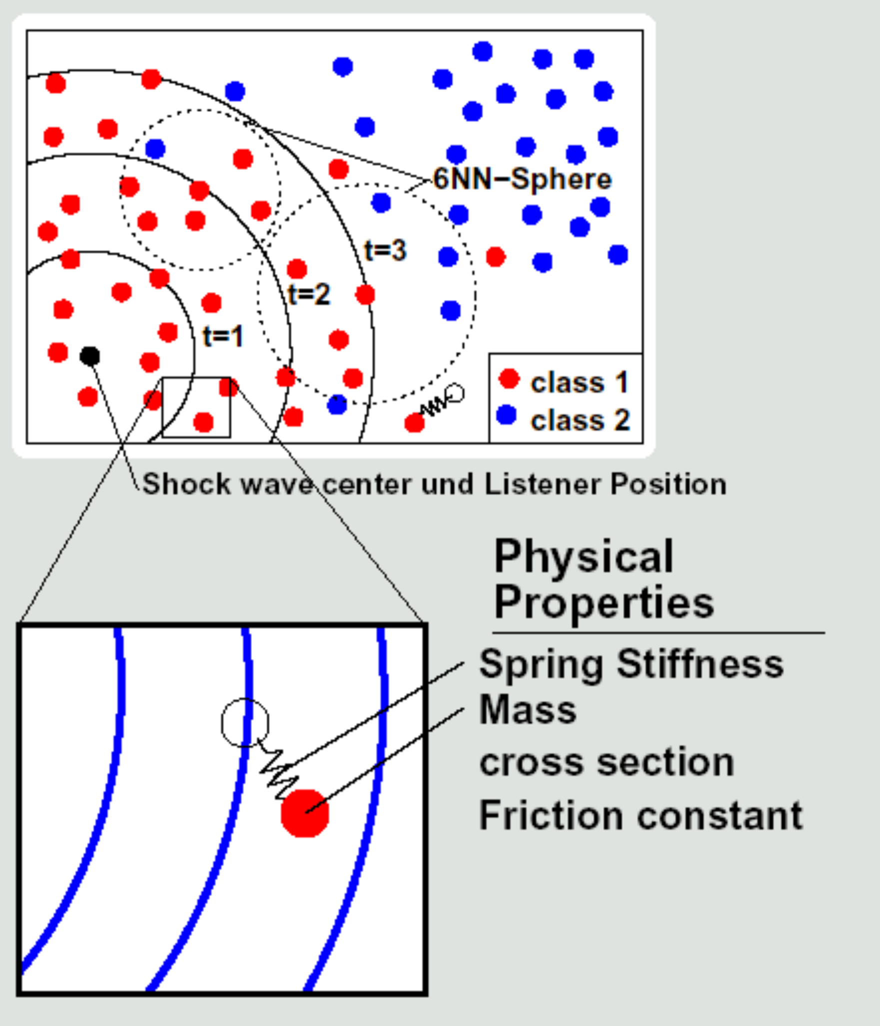


MBS Ingredients

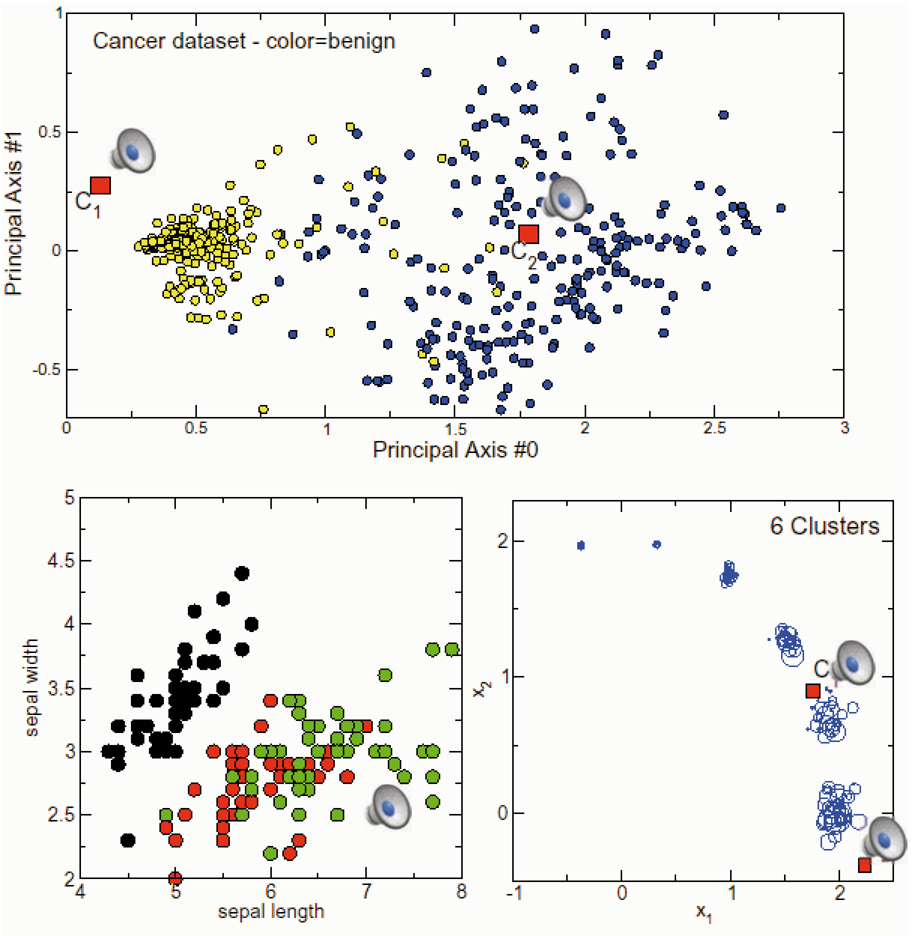
- Model Setup
- Model Dynamics
- Initial Conditions
- Excitation / Interfaces
- Link-Variables
- Listener Characteristics

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



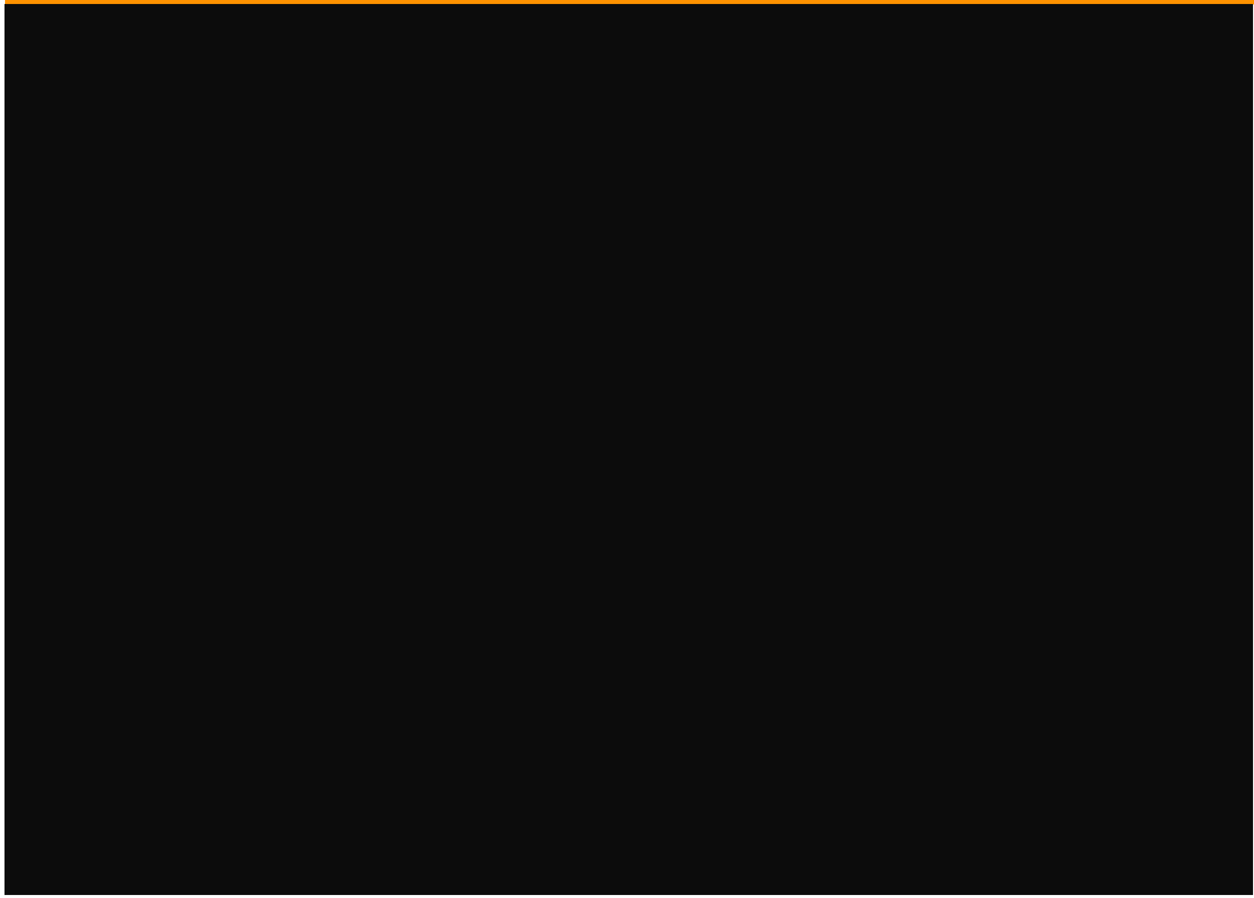
Data Sonogram Examples



- **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

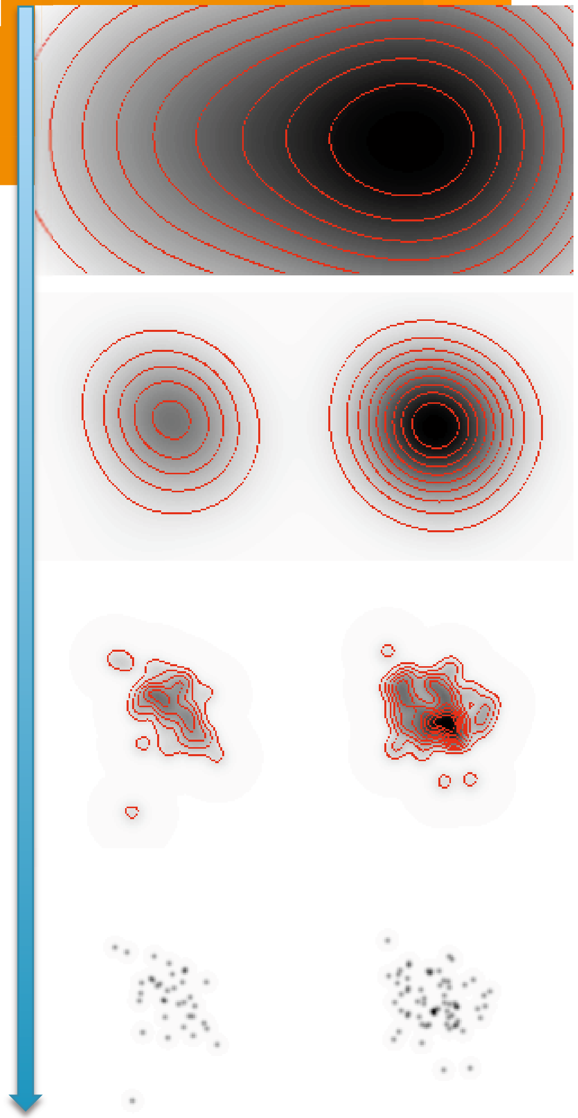
Tangible Data Scanning (TDS)

with Bovermann, Riedenklau



- Data become real localized physical objects
- TDS exploits human manipulation capabilities
- Spatial memory helps to interprete data

Particle Trajectory Sonification Model for Cluster Analysis



- **Setup: Particles in Data Potential**

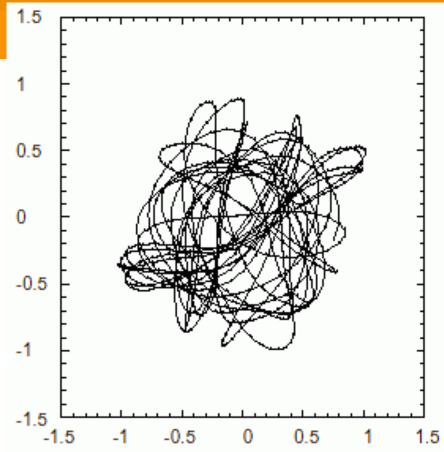
$$V(\mathbf{x}) = \sum_{\alpha=1}^{M} \phi(\|\mathbf{x} - \mathbf{x}_i\|) \quad , \quad \phi(r) = -N \exp\left(-\frac{r^2}{2\sigma^2}\right)$$

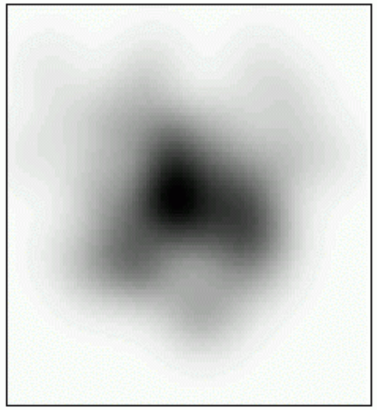
- **Dynamics: Newton's Law + damping**

$$m\ddot{\mathbf{x}}(t) = -\nabla_x V(\mathbf{x}) - \gamma\dot{\mathbf{x}}(t)$$

- **Excitation:**
  - Particle Injection
  - Energy Injection (shake, hammer)
- **Link-Variables:**
  - Sum of particles' kinetic energy

Particle Trajectory Sonification Model (cont.)

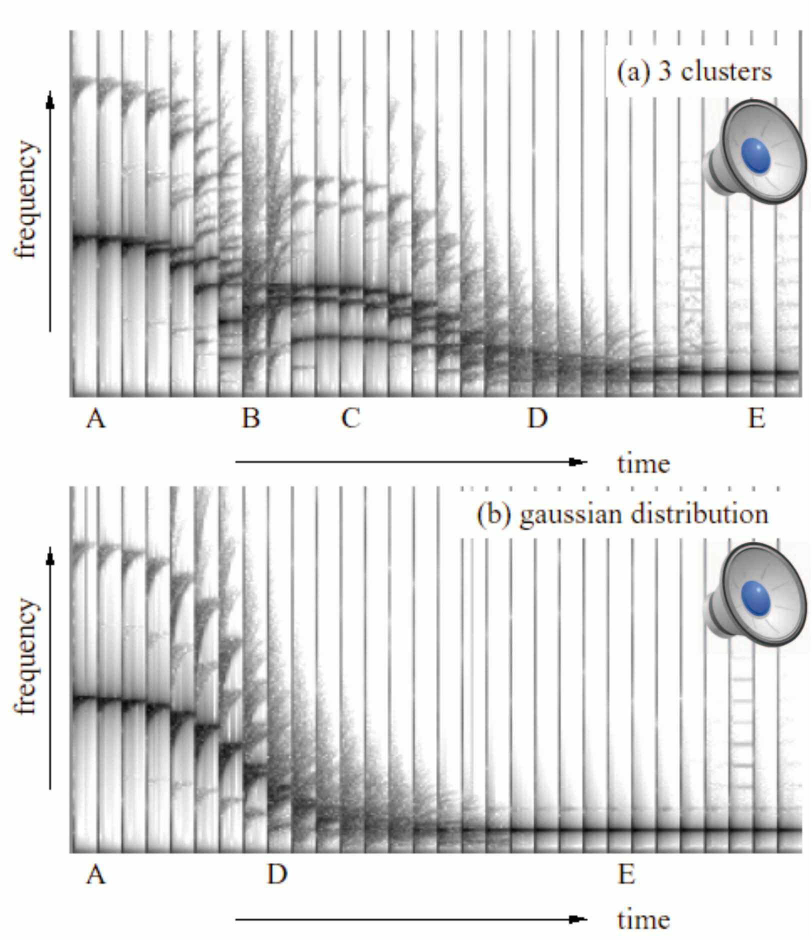




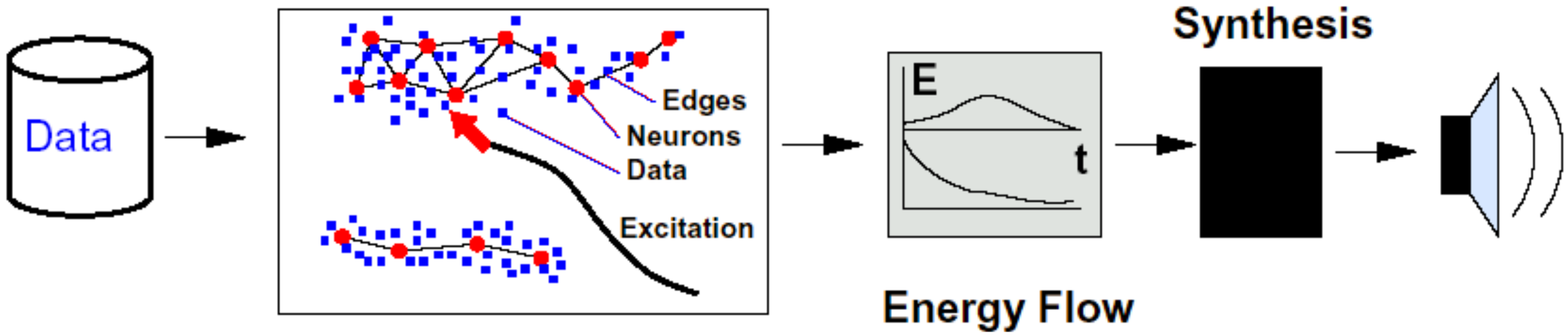
- **Typical Particle behavior:**
- **Model Parameters:**
  - Data mass m_d and particle mass m_p
  - Bandwidth σ
  - Friction constant γ
- **Sound represents V on multiple scales in time chaotic → timbral → pure harmonic → sinusoid**
- **Sound depends on clustering properties**
  - Ensemble 1 cluster: 3 clusters:

Particle Trajectory Sonification Model
σ - sweeps

- **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

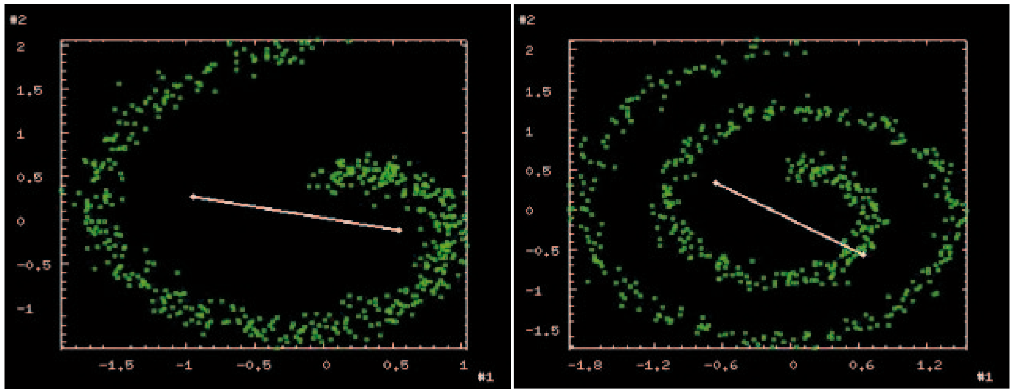


Growing Neural Gas (GNG) Sonification for Data Dimensionality Analysis



$$\frac{dE_i}{dt} = -gE(t) - \sum_{j \in I_N(i)} q(E_i(t) - E_j(t))$$

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



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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**

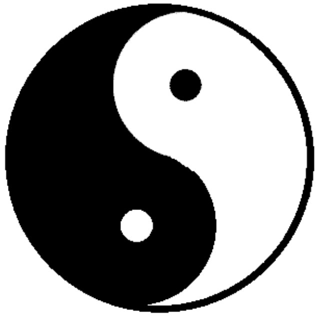
But also:

- **Designers**
- **Psychologists for Evaluation**
- **Interactional Linguistics**
- **Cultural Studies**

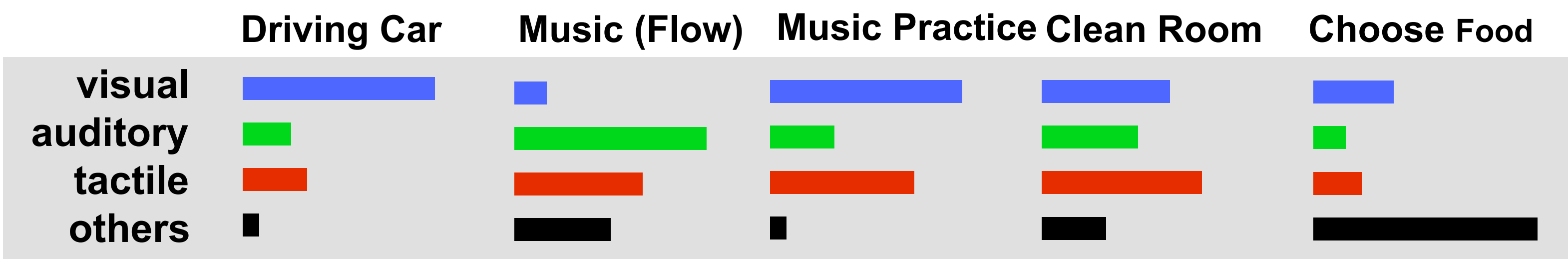
Functional Aspects

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

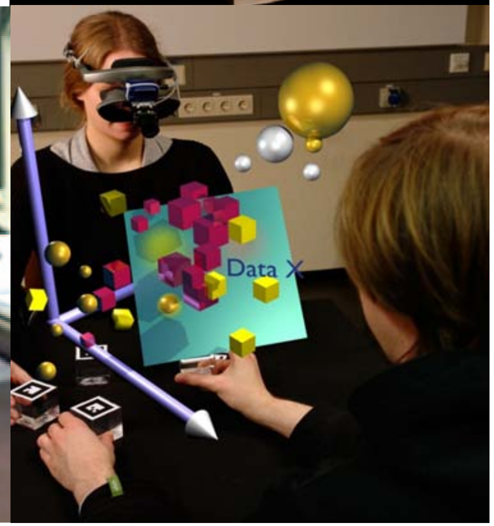
Outlook: SID & Sonification for Ambient Intelligence

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

ubiquitious multimodal context-aware
adaptive
unobtrusive calm technology personalized
anticipatory embedded

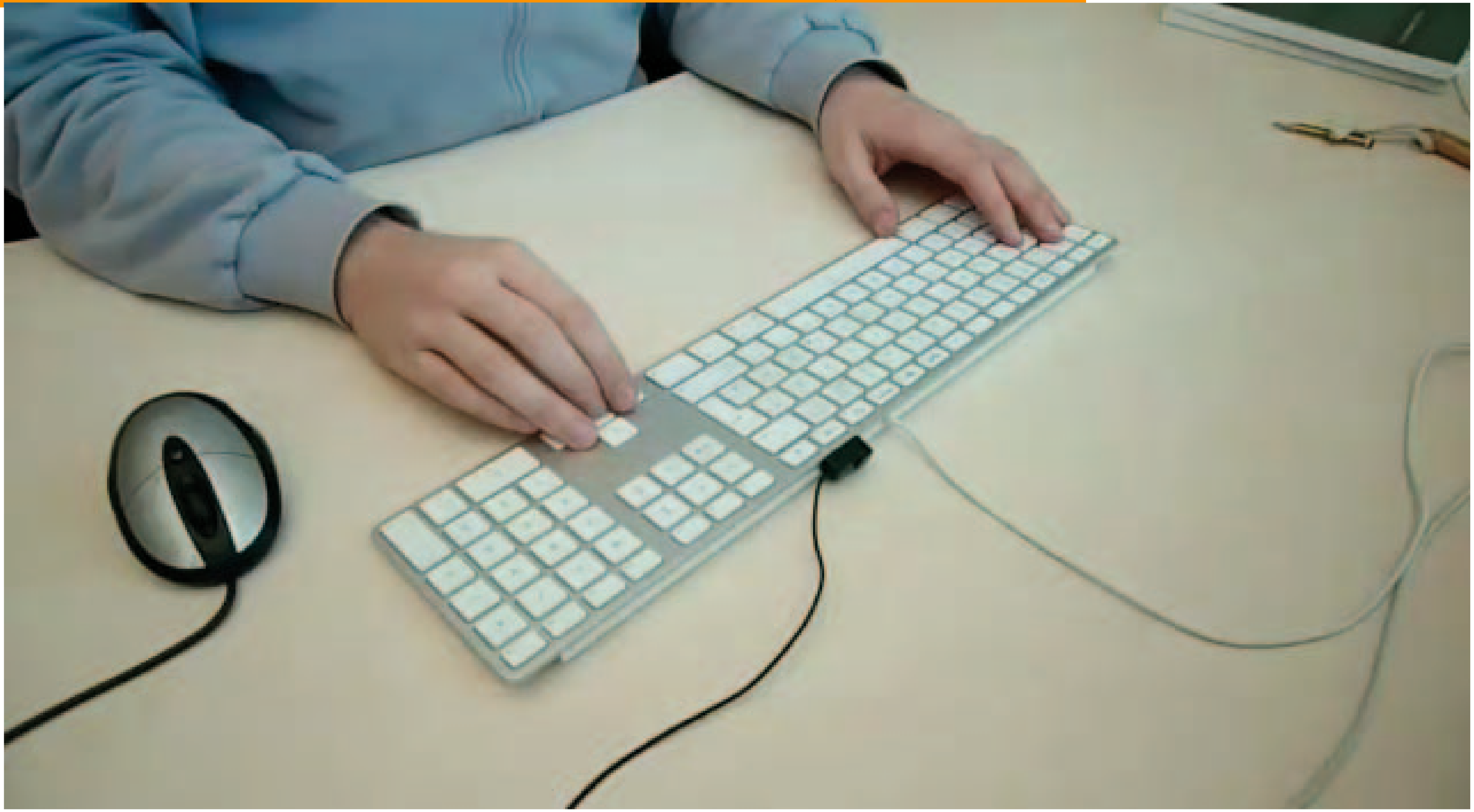
Perspectives of SID for Ambient Intelligence

- 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



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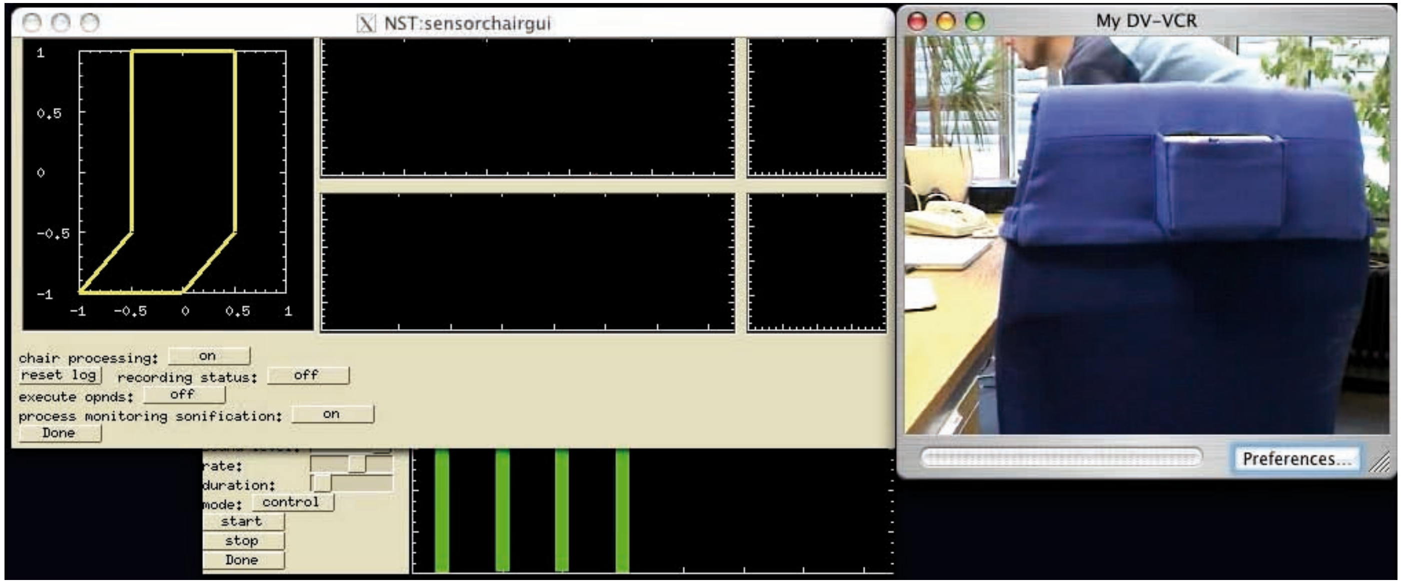
tacTiles – tactile sensitive furniture



- 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?