Plausible Auditory Augmentation of Physical Interaction

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Scope

Introducing the concept of ***plausibility*** to the topic of auditory augmentations of physical interactions

- ↳ providing an experimentation platform for investigating surface-based physical interactions
- ↳ understanding relevant acoustic cues and redefining these via auditory augmentation / blended sonification
- ↳ to empirically measure the plausibility limits of such auditory augmentations.
- ↳ Introducing a practical experimentation system together with a very first qualitative pilot study

Introduction

Our physical interactions with the world evoke specific sounds that depend on the properties of the physical object and the type of interaction.

Auditory feedback: the resulting sound of these interactions.

Auditory feedback is a major part of our acoustic environment and we use it consciously or unconsciously while pursuing daily activities.

Introduction

Augmented auditory feedback is defined as the **artificially modified** sonic reaction to physical interaction

The authors focused on the exploitability of the communication channel that augmented auditory feedback can have to sonify data.

This exploitability depends on two factors:

- *Plausibility*
- *Usability*

Introduction

To convey additional information in a physical interaction through *Augmented auditory feedback, four condition should be met:*

1. *There exists a manifold of sounds which serve as plausible auditory feedback. Its borders define the plausibility range.*
2. *There exists a manifold of sounds which serve as usable auditory feedback, i.e., the sounds are helpful to perform the specific actions. Its borders define the usability range.*
3. *The manifolds of plausible and usable sounds overlap. They define this overlap region as the manifold of alternative auditory feedbacks.*
4. *It is possible to discriminate between different alternative auditory feedbacks.*

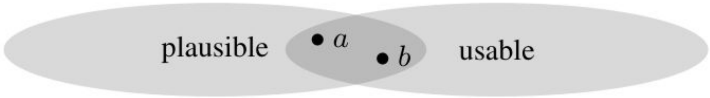


Figure 1: Sets of plausible and usable variants of auditory feedback for a specific physical interaction. Points *a* and *b* represent two discriminable but still plausible and usable sounds.

PLAUSIBLE AND USABLE AUGMENTED AUDITORY FEEDBACK

For sensory feedback to be plausible, it has to be consistent with previous experience of the interaction.

The greater the dominance of auditory feedback, the more this influences user perception, emotion, and behaviour.

Perceptual plausibility depends of the congruency of the different modalities (haptic, visual or auditory).

↳ **Hypothesis**: perceptual plausibility increases with increasing congruency (agreement) between cues (information) from different sensory modalities (information channels).

For augmented auditory feedback to be plausible, the augmentation has to be meaningful

and feasible ⟶ The illusory fiscal properties it creates make sense.

PLAUSIBLE AND USABLE AUGMENTED AUDITORY FEEDBACK

Auditory feedback is **usable** thanks to the information it carries about the performed action and the physical object it affects.

This information is divided as:

- ↳ Relevant physical properties → Influence usability → Rather leave them unchanged
- ↳ Irrelevant physical properties → Do not influence usability → Potential for augmentation

✷ The goal of usable auditory augmentation is **to preserve** the physical object affordances in the best possible way **while adding new affordances** such as exploratory data analysis through manual interaction

Related Work

- ***Auditory augmentation*** *→ Enhancing the original sonic response of an object with information on external data. T. Bovermann, R. T ̈unnermann, and T. Hermann, Auditory Augmentation, ser. Premier reference source, K. Curran, Ed.Information Science Reference, 2010.*
- ***Blended sonification*** *→ Ubiquitous audio and data components perceived as coherent audio events. R. T ̈unnermann, J. Hammerschmidt, and T. Hermann,"Blended sonification – sonification for casual information interaction," inICAD, 2013.*
- ***Embedded interactive sonifications into found objects*** *→ Creating physical media of exploration of otherwise imperceptible and abstract data. S. Barrass and T. Barrass, "Embedding sonifications inthings," inICAD, 2013.*

4. The Mondrian Table

A *experimentation platform* on top of a horizontal, rigid and stationary surface to explore plausible and usable auditory augmentation.

Two modes of operation:

1. **Unobtrusive blended soniciation** outside the focus of attention while performing daily activities that affect it. Eg. writing or positioning of other physical objects.
2. A **exploratory interface for data analysis** through manual interaction in the form of tapping, scratching, etc.

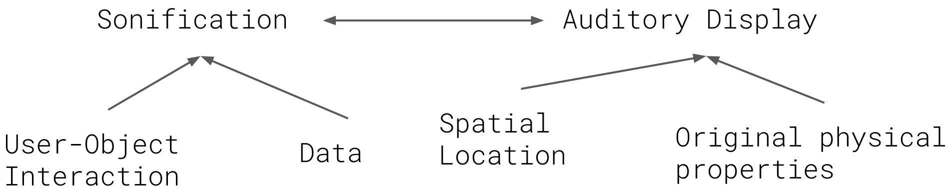
4. The Mondrian Table

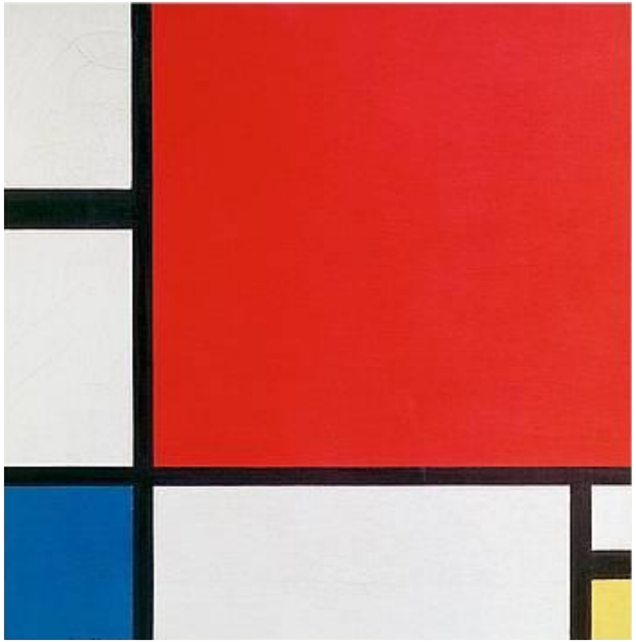
Inspired by Piet Mondrian's "Composition" series, the Mondrian Table sonfies time-invariant geometric structures as regions with different physical properties.

The data to be sonfied is mapped to the parameters of a physical model (material category, shape, etc.) that filters the original sound emerging from interaction between the user and the physical object.

Each color of the Mondrian table represents a model with specific physical properties and gain.

Black lines are interpreted as silence.





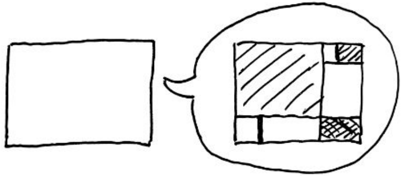


Figure 2: Concept of the Mondrian Table, inspired by Piet Mondrian's "Composition II in Red, Blue, and Yellow" (1930).

4. The Mondrian Table - Implementation

First prototyped based on a graphic table.

Advantage: The coordinates of the stylus are tracked while it hovers in the air. This helps to adjust the filter parameters before the interaction actually happens and thus reducing latency.

Spatial mapping is also take into account to favour spatial congruency and plausibility. Spatialization is only on the horizontal plane and with a stereophonic setup.

A Bela board is used to reduce latency.

In addition, two piezo mics are placed underneath the table.They are used as input for the excitation of the resonant filter model.

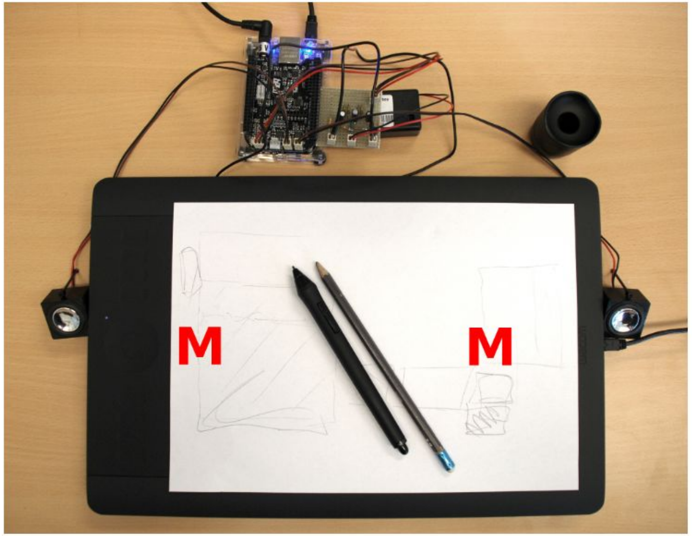
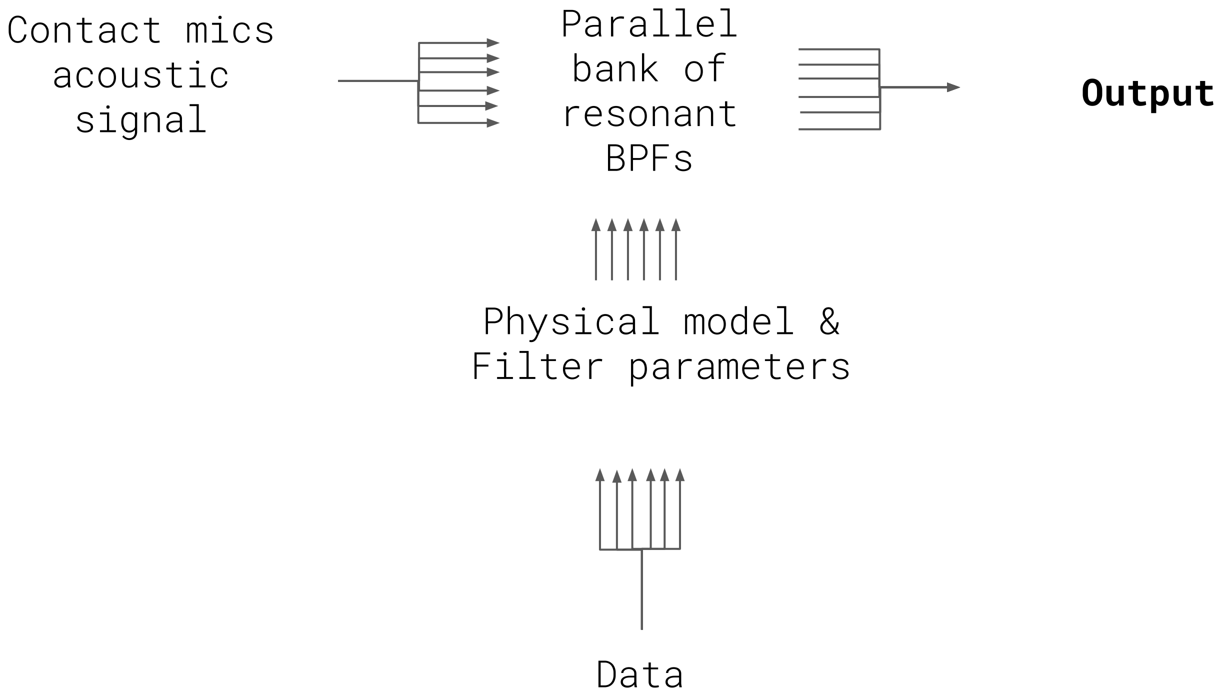


Figure 4: The Mondrian-Graphic-Tablet. The positions of the contact microphones underneath are marked through a red 'M'.

4. The Mondrian Table - Sonic path



4. The Mondrian Table - Evaluation I

A Mondrian Generator was used to generate a random Mondrian composition.

The graphic tablet was cover by a sheet of blank paper.

Users had to trace back the sonified structures with the stylus, and to draw a visual representation of the perceived structure.

Findings:

- Latency was a major factor for plausibility and successful auditory augmentation. 14ms latency was sufficient when watching another person interacting but 1.5ms latency was needed for personal interaction.
- The synthesized materials felt realistic and created the sensation of physical augmentation.
- The geometric shapes were easy to detect.

4. The Mondrian Table - Evaluation II

High quality contact microphones

The graphic table is replaced by just the sheet of paper fixed on the surface and the tracking is done by a Kinect v2 sensor.

Users did not come explicitly to a test but the feedback was gathered from a public demonstration.

Findings:

- The low resolution of the Kinect sensor made accurately detecting the Mondrian structures difficult.
- Instead, the users were asked to detect a triangle (ceramics), a rectangle (metal), and a circle (glass).
- The noisy environment made the demonstration difficult.
- The synthesized materials felt realistic and created the sensation of physical augmentation.
- The geometric shapes were easy to detect.
- 55% identified correctly the location of all three regions.
- From this 55%, 40% assigned all correct shapes and 60% hit the correct size.
- The task was very hard to accomplish, surely because of the low resolution and context.
- Four different strategies for task completion were extracted:
    1. Continuous drawing
    2. Systematic tapping
    3. Random tapping (only used by children and with quick reliable results for shape identification)
    4. Continuous scanning and marking material changes

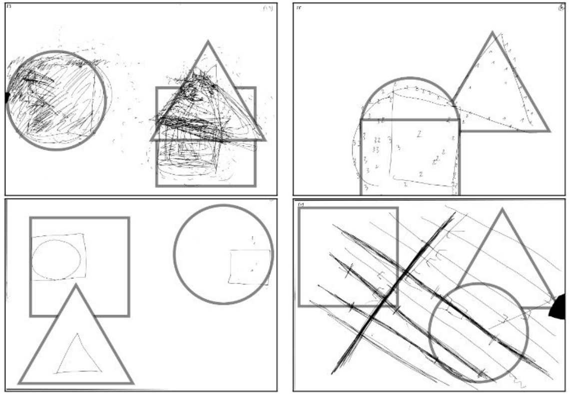


Figure 7: Drawings from participants 3 (top left), 5 (top right), 8 (bottom left), and 19 (bottom right), overlain by the corresponding "correct answer", respectively.

5. Conclusion

- The paper introduces the question of plausibility of auditory augmentations for physical interaction.
- The scope is the available bandwidth of discriminable alternative auditory feedbacks, so that the sound is still plausible and useful.
- Time-varying auditory augmentations may work well for real-time sonification but at the cost of plausibility.