

Tangible Signals - Physical Representation of Sound and Haptic Control Feedback

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ABSTRACT

This paper describes the Ph.D. research project *Tangible Signals* which is currently in its initial phase. This project investigates the dynamic physical representation and haptic feedback control of computer music and sound data using motorized and augmented objects. The research focuses on artistic and performative contributions that this approach offers. Special attention is given to the collaboration with visually impaired people, as they are very limited in the use of exclusively GUI-based interaction. On the following pages the background of the project will be described and methods, research questions and work progress will be presented.

Author Keywords

Tangible Interaction, Haptic Control Feedback, Dynamic Data Physicalization, Physical Sound Representation

CCS Concepts

•Human-centered computing → Natural language interfaces; Haptic devices; User centered design; User interface toolkits; •Hardware → Haptic devices;

INTRODUCTION

The creation and manipulation of sounds is fascinating and challenging. The availability and ease of use of microcontrollers, sensors and easily accessible programming environments supported the transition from Graphical User Interfaces (GUI) to Tangible User Interfaces (TUI) [4]. In interfaces like e.g. the *reactTable* [5], techniques were developed to control digital sound generation with the help of physical tokens. With the re-entering into the physical material, tangible interaction and haptic feedback is also embedded in numerous New Interfaces for Musical Expression (NIME). Some of them, like *Beatbearing* [1] or the *Tquencer* [6] even allow the creation of sounds and the operation of music interfaces through purely tangible interaction, without being dependent on visual feedback (e.g. no visual menus).

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But while many NIMEs and TUIs concentrate on enabling the creation and control of digital data, especially the control of musical parameters through the availability of tangible interaction, yet there are only a few interfaces and devices which are able to dynamically represent data in a physical way and at the same time offer the possibility to control or change this data representation and thus the data itself. This intermediate step between on the one hand the digital sound generation on the computer and on the other hand the playback or listening to the musical contents could be a useful and inspiring tool, especially for musical purposes. Especially when the physical representation of the data would be controllable and modifiable, enhanced by haptic feedback.

The physical representation and modification of digital sound data including haptic feedback is the core of this research work *Tangible Signals*. The audience is at first visually impaired musicians who are limited in their work with GUIs, but also sighted musicians who want to integrate a physical level into their creative process. In addition, this research may also be of interest to other disciplines that benefit from physical representation and modification of data.

BACKGROUND

Music-making on the computer is a combination between the creation and input of musical information, the processing of musical events and the output of the musical content. For the creation of sound, there exists now a large number of new musical interfaces, some of them that also provide physical interaction which is tangible or contains haptic feedback, like the SeaBoard¹. More and more studies on physical and haptic feedback processes show the potential of the implementation of haptic feedback in the musical context. For example Sile O'Modhrain and R. Brent Gillespie argue for a dynamic coupling of musical input and physical output in the book *Musical Haptics* [8]. However, the further processing of the sound, e.g. in digital audio workstations (Logic Pro, Reaper, etc.) is still mostly GUI based, supported by midi controllers, which have at most motorized sliders or knobs. In these systems there is no physical representation happening. Considering the manipulation of sound in digital audio workstations as part of the creative process, the absence of physical representation and tangible interaction is a limitation and may prevent new

¹Seabord: <https://roli.com/products/seaboard/>



Figure 1. SoundFORM - © A. Colter, P. Davivongsa et al.

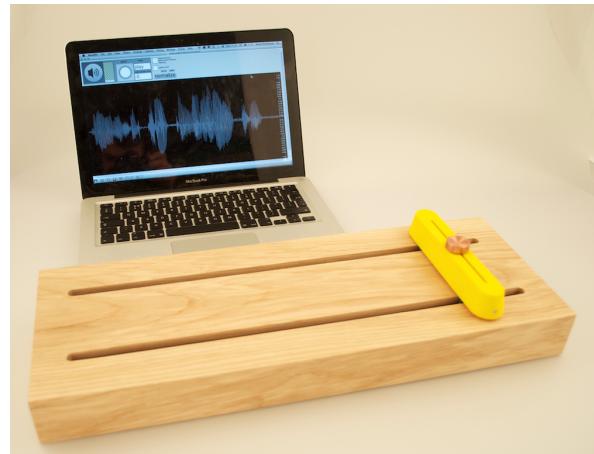


Figure 3. Haptic Wave - © A. Tanaka and A. Parkinson



Figure 2. HaptEQ - © Aaron Karp

approaches and concepts to the treatment and understanding of sound.

Physical Manipulation

There are only few interfaces that try to implement the representational manipulation of sound at this level. For example the *SoundFORM* [2] (see Fig.1), a pin-based display that follows a physical approach. It displays digital data using a grid of 24 x 24 motorized pins, a dynamic display of sound information, e.g. simple waveforms or the physical display of sound events in a sequence. There have been several previous attempts to physically represent data based on pin displays, such as Ivan Poupyrev's *LUMEN* [9], a prototype of a refreshable pin display. Another example is the *HaptEQ* [7] (see Fig.2), which allows the configuration of a digital equalizer by means of an understandable physical form. This allows to adjust the equalizer without having to use the graphical interface from the corresponding software by camera tracking of a chain-like physical object on a prepared surface. However, the object is a passive input and is not able to react to changes in the digital configuration.

An unfinished project, still, is the *Holy Braille* [3] by Sile O'Modhrain and her team, a refreshable pin display, which many blind and visually impaired people are longing for. Here already the naming shows how essential and important interfaces for the physical representation of data are especially for blind people. Which is why one of the few interfaces which is actually able to display digital sound information haptically has been developed for visually impaired people and is called the *Haptic Wave* [10] (see Fig. 3). It aims to make digital sound information, in this case the waveform, tangible. For this purpose, the interface provides a handle that can be moved on a rail, which makes it possible to scan a waveform with the help of haptic feedback and thus, for instance, find particularly loud or particularly quiet spots in the waveform. Also the development of the *Haptic Wave* has been initiated for visually impaired sound engineers and was appreciated as a valuable tool in sound production.

So far, only two of these interfaces, the *Haptic Wave* and the *SoundFORM* are able to display sound information in a dynamic-physical way. Both interfaces have their limitations, one is the focus on the waveform, the other on the low resolution. But what becomes visible in both examples is the focused interest in interactive physical representation of data, which currently still has to build up its own vocabulary and experience.

Haptic Control Feedback

While many NIMEs and TUIs concentrate on enabling the creation and control of digital data, especially the control of musical parameters through the availability of tangible input devices, there are, like mentioned above, not many examples of interfaces that are able both to physically represent sound information and to control or change the displayed sound. This union or cycle of digital representation and physical representation of sound and haptic control feedback is an obvious and promising field of research. It could extend the existing chain of transformation of digital sound, i.e. digital-to-analog conversion (D/A converter) and playback of music through loudspeaker systems.

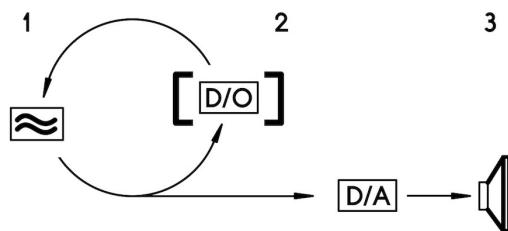


Figure 4. Digital-to-Object Conversion - 1 digital musical data processing in the computer - 2 converting to both D/A and D/O (allows for manipulation) - 3 finally playback via loudspeaker

But it is not only technical solutions (actuators, materials, digital protocols, etc.) that need to be reconsidered; new vocabulary and new approaches also have to be found on a conceptual level. In order to already make a proposal here that is metaphorically based on the D/A converter, I would like to suggest the introduction of another type of conversion: the *Digital-to-Object Conversion* (D/O converter) (see Fig.4). Here, digital characteristics of sound would not only be reproduced as sound, but as physical object-like representation, which in turn could be controlled and manipulated.

The outcomes could not only lead to a new understanding of tangible interfaces and their use in the musical context, but also to new ways of experiencing sound and sound information, also - but not only - for visually impaired musicians. The findings could even be of significance in other non-musical fields of application, for example in mathematics, physics or architecture, i.e. wherever 2D functions are to be displayed. It might also be possible to integrate resulting methods or devices into digital workflows in terms of accessibility. Another field of application could be stage-based musical live performances, in which non-visual tangible information and manipulations could also enable particularly interesting interactions.

SPECIFIC AIMS

The specific aims of this research is to theoretically, practically and artistically expand the current state of knowledge regarding the physical representation of sound and its haptic feedback control. Based on approaches from artistic research, prototypes are to be developed that embody the hitherto little-explored digital-to-object conversion. The cycle of digital sound representation, physical representation and haptic control feedback described above will be investigated in more detail and explored in practice. Apart from technical considerations, musical representation of sound will be analyzed in relation to its output as physical representation. This includes the analysis of suitable properties and images of sounds (waveform, volume, frequency spectrum, bundling of properties), possible merging of sound areas, and other states of sound that are suitable for physical representation. Thus, an essential aspect is the necessary relationship of the resolution of sound aspects in relation to the resolution of physical representation. The development of individual control software will be necessary for the practical implementation of prototypes and experimental approaches. This software will be implemented based on the programming languages SuperCollider

and Javascript. The use of other programming languages is conceivable, as required.

RESEARCH QUESTION

- How can the physical representation of sound and haptic feedback control contribute to the process of sound generation, sound processing and artistic performance?
- How does the physical representation of sound and its haptic control feedback open up new inspiration and creativity in artistic-musical expression?
- How does the interaction with the physical representation of sound and its haptic control feedback compare to GUI-based workflows?

RESEARCH METHODS

This research takes place in an artistic-musical context in the department *Tangible Music Lab* (TamLab), which is part of the Institute for Media Studies at the University of Art and Design Linz. A special focus therefore is on musical interaction, tangible interfaces and the experimental-artistic extension of existing knowledge and practical experiences. The openness and impulses that arise from an artistic research approach can also be applied to this research topic, since it will be an exploration between design, research and art that builds on one another. The work steps will take place partly simultaneously, partly one after the other.

- Iterative design process - Iterative design of multifunctional prototypes (see below)
- Qualitative analysis - Based on observation of musicians (sighted, visually impaired) using the means of physical representation and haptic feedback control, embodied in prototypes that are being developed.
- Cooperation with the Institute for the Blind in Vienna - Lectures, Workshops, Development of Braille-based music-systems
- Artistic works - Development of musical-artistic works in relation to the topic (stage-based, art installation, etc.)
- Prepared Discussions - Organized discussion (e.g. a symposium) with artists, musicians, scientists from neighbouring fields.
- Publication of research results - scientific publications at conferences (NIME, TEI, etc.) and journals

GOALS & OUTCOMES

The goal of this research project is to answer the questions raised, to extend the existing concepts and approaches concerning the physical representation of sound and haptic feedback control, to create new vocabulary, interface approaches and experiences. The technical solutions, artistic processes and side developments will be documented and will contribute to a more comprehensive view of this area. On a social and educational level, the cooperation with the School for the Blind in Vienna will open new doors for visually impaired students to engage with computer sound production.

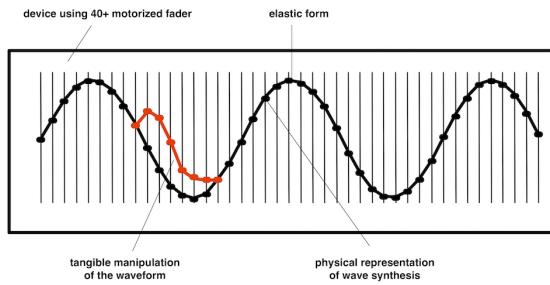


Figure 5. Tangible Wavetable Synthesis

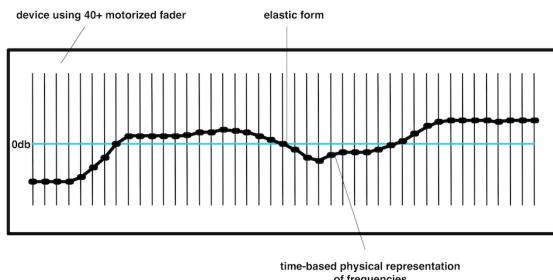


Figure 6. Tangible EQ

WORK PROGRESS

This research project started in October 2018 and thereby it is still at its very beginning. On the one hand I focus on the realization of prototypes that deal with the physical representation of sound and haptic feedback control (see below). On the other hand, a collaboration with the Institute for the Blind in Vienna started in order to slowly come into contact with visually impaired teenagers and to sensitize them to the topic of physical representation of sound and haptic feedback control. For this purpose I will develop a small mobile music system based on a Raspberry Pi (including loudspeakers), which makes it possible to use the Braille keyboard as a musical instrument and later acts as a starting point to form a Braille orchestra. Here the finished modules can also be used for the physical representation of sound and haptic feedback control in the musical performance.

Prototypes

The *Tangible EQ* (see Fig.6) is a prototype designed to explore and embody the above principles of digital-to-object conversion. It expands the ideas and concepts of the *HaptEQ*. The digital sound and its frequency characteristics are represented in a time-based manner over approx. 40 motorized faders. One of the special features of the *Tangible EQ* is the continuous elastic connection of the individual faders. The frequency curve is displayed but can be controlled to manipulate the original sound. Haptic force feedback is implemented to display the activities of the sounds in the different frequencies.

Similarly the *Tangible Wavetable Synthesizer* (see Fig.5) is a representation of a generated sine wave. It allows the representation of a sine wave (or sawtooth wave, etc.) and can not

only visualize the sound physically, but allows a manipulation that corresponds to the wavetable synthesis. The waveform can be changed manually as desired, which in turn changes the basic sound. Seth Kranzler took a similar approach in his interface Wavetable Synthesizer [18], except that he concentrated more on controlling digital synthesis and less on physical representation.

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