PerForm: Deformable Interface for the Exploration of Sound through Shapes

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Abstract
UPDATED—22 February 2018. In this paper, we describe a novel electronic musical interface, consisting of a strand-like object that can be physically transformed by bending to create various shapes and signifiers. Users are encouraged to explore a visual language in a musical context, as each new shape portrays a different musical instrument with unique sonic behavior. We apply concepts from research in the area of cross-modal perception as guidance for mapping shapes and signifiers to corresponding sounds.

Author Keywords
Tangible interface; flexible sensors; deformable instrument; musical expression; sonic interaction; sound-shape association; MIDI; sound production and synthesis.

ACM Classification Keywords
Hardware ~ Sensor applications and deployments, Sensor devices and platforms, Human-centered computing ~ Sound-based input / output

Introduction

"*Music is not limited to the world of sound. There exists a music of the visual world***."**
- Oskar Fischinger, 1951

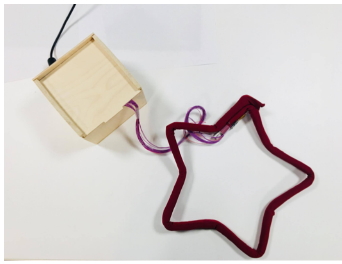

Figure 1: Current working prototype of PerForm, showing a deformable strand-like instrument connected to a system that converts sensor signals to MIDI messages.

Half a century ago, when the German-American animator and film-maker Oskar Fischinger created musically inspired animations and works of art, he touched on perception matters that were fascinating to his contemporary researchers, but not completely understood or put to practice. Even today, with the advancements in perception and neuroscience research, we still have not entirely figured out how the brain makes associations between all the different sensory stimuli it receives.

Some principles of the psychology of perception are widely discussed in the context of vision, but not so much in the realm of the sound. There is evidence, though, that our brains create relationships between shapes and sounds, even in the context of language [1]. Motivated by these concepts, PerForm explores the relationship between visual, tactile and auditory perception. It is a deformable and conformable physical interface, responsive to touch and gesture, which enables users to explore the associative meaning of shapes in a musical context (Figure 1).

Concept

The interface consists of a bendable strand-like object with rigid segments connected by flexible joints. The choice of form factor was due to the affordances of a strand or line-like object: while it allows the user to easily outline iconic instruments, geometric shapes or other objects, it offers the physicality of a material object, making it possible to manipulate it in space.

This functionality enables the exploration of the intuitive relationship between signifier and signified, in a manner similar to that envisioned by Ken Perlin's ChalkTalk [2]. Therefore, it is exploratory in nature and instigates the development of a personal visual language in the context of sound.

The interface allows users from different levels of musical familiarity to interact, discover the sounds, and create music using intuitive gestures. Geometric forms are mapped to percussion sounds, while the shape of iconic instruments - such as a piano or harp - enables a new mode of interaction through non-contact gestures for modulation of pitch.

Related Work

PerForm builds upon the work of many researchers who have explored gestural and deformable interfaces, as well as the use of sensors for musical controllers.

Deformable interfaces have been explored as tools to expressively generate and modulate sound and effects [3]. One such example is SoundFORM, which allows composers to interact with electronically generated waveforms of their music [4] through the use of a shape-shifting display. Other examples are Sonic Banana and FabricKeyboard. The first one makes use of bend sensors to modulate sound according to the manipulation of the object, and the second explores physical and non-contact gestures to produce music through a fabric-based interface [5,6].

ShapeTape uses a flexible strip sensitive to bend and twist as the input for manipulating curves and surfaces in computer graphics [7]. lineFORM, on the other hand, uses the power of figure abstraction and the affordances of the line for definition of contour to develop possibilities of interaction, evoking the imagination of the user [8]. While those projects

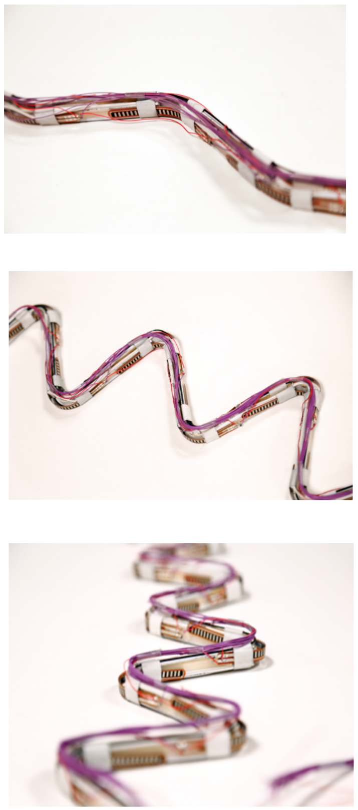

Figure 3: The bendable interface without the fabric cover. Images display the bend sensors on segments of styrene connected through thin wires.

explore physical interactions, ChalkTalk focuses on visual language for augmented reality [2].

Based on these prior efforts, PerForm allows users to associate shapes to the sounds generated. It appeals to the intuitive visual language and adds the element of discovery to the experience.

Structural design

The current working prototype consists of an array of short styrene segments on each side of the object, which provide structural support for twenty flex sensors and their wirings (Figure 2).

A long brass strip between these layers helps retain the shape after a hinge is bent. At the two ends of the strip, in a final segment which also functions as a handle, an accelerometer and proximity sensor are attached and connected to the microcontroller.

Between every two rigid segments, flexible joints enable the affordance of bending. Flex sensors are positioned on each hinge, allowing for the detection of curvature or approximate angle and the resulting shape. Gestural taps and shakes are detected with the use of an accelerometer. Magnets facilitate snapping the two ends of the strand to complete the 2D shape and make it easier to hold. Figure 3 shows the skeleton of PerForm, without the fabric cover.

Technical Overview

As illustrated in Figure 4, Arduino DUE was used as the microcontroller that processes the flex sensors (SEN-08606) analog data to digital format and communicates with the proximity sensor (VL53L0X) and accelerometer (MPU9150) through the I2C protocol. The digital data is then converted into MIDI messages before being sent to a digital audio workstation (Ableton Live 9) through a serial bridge (Hairless MIDI) running at 115200 bps.

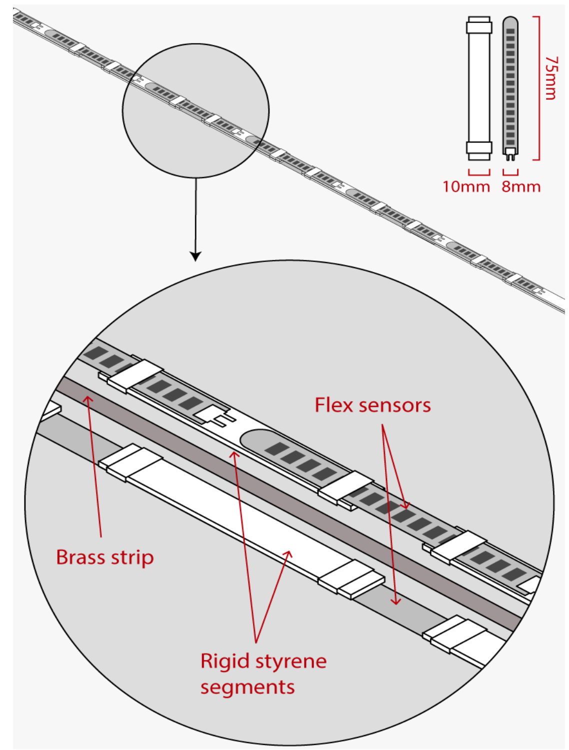

Figure 2: Isometric view of the structure of the prototype, showing the arrays of rigid styrene segments giving support to the flex sensors

Because a large number of flex sensors were used, two multiplexers (CD74HC4067) were implemented in order to expand the number of analog channels provided by the microcontroller. Each of the two arrays of flex sensors is connected to one the multiplexers. The

Figure 6: Possible shapes for percussion instruments.

microcontroller addresses the input pin of both multiplexers simultaneously and reads them through two ADC pins.

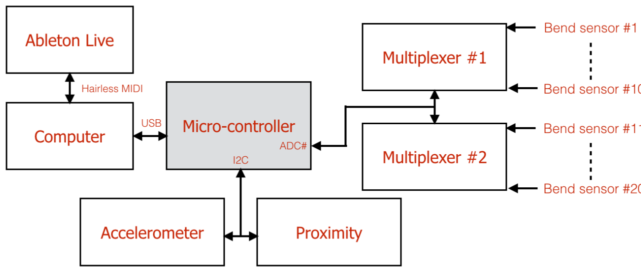

Figure 4: Schematic of the PerForm system

The flex sensor signals obtained from the physical manipulation of the controller are continuously read. Read values are matched to the specification of a MIDI protocol and a message is then populated with status, channel (the instrument ID), note on/off, amplitude, and expression value. When the shape that was detected enables the gestural mode of play, a threshold value received from the proximity sensor triggers the modulation of pitch through non-contact gestures.

When the detected shape is mapped to a percussion instrument, the vibration mode is activated. Values from the accelerometer, classified as light (tap) or strong (shake), modify the amplitude of sound output. The MIDI message is sent from the microcontroller and received by an audio sequencer framework such as Ableton Live or GarageBand (in this project, we used Ableton Live 9). The audio software will then process each MIDI message and play sounds based on the user gestures and settings (Figure 5).

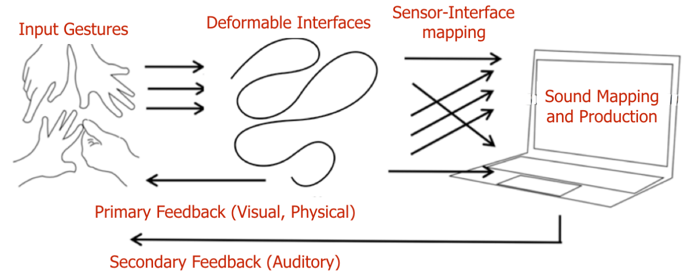

Figure 5: Sensor-computer interfacing

Sound-shape Correspondence

The mapping of shapes into different sounds or instruments (Figure 6) takes inspiration from a number of articles and research experiments, which suggest that the way how we connect auditory and visual-tactile perception is not entirely arbitrary.

In the "Kiki-Bouba" experiment, conducted for the first time by Kohler in 1929, people were asked to match a spiky, angular shape and a round, smooth shape to the nonsense words "kiki" and "bouba" [1,9]. There was a strong preference to associate "bouba" to the round, smooth shape, and "kiki" to the angular shape, independent of the language spoken by the individual. In a replication of this experiment conducted in 2001 by Ramachandran and Hubbard, this preference accounted for at least 95% of the subjects [10].

In an article published by Nature in 2016, Chen *et al.* investigate how this correspondence manifests across languages and contexts, and analyze the association of frequency or amplitude to shapes [11].

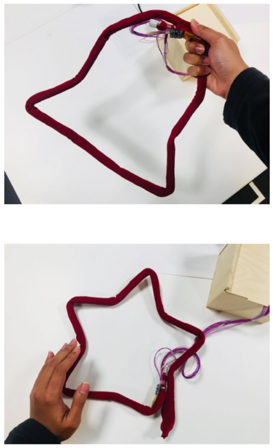

Figure 7: Shaking a bell and tapping a star-shaped instrument.

PerForm extrapolates on the idea of visual-auditory correspondence present in these studies, applying the concept to a direct connection between the general appearance, the acute or open angles in figures, and the perception of sounds generated by specific instruments.

Interaction

The rope-like form makes the object work as a drawing tool and has the affordance of being deformed and manipulated by hand. The materials, rigid at some parts and flexible at others, intuitively indicate locations where the object affords to be bent.

While manipulating the object to the desired shapes, the user may shake it or tap it and hear which sound was generated. This allows the user to naturally explore the possibilities of instruments by transforming the object's shape. A round shape may be mapped to a drum, a bell figure to a cowbell and a star to a high-frequency bongo, for example (Figure 7). Once the desired shape is achieved, the user may play it intuitively as a tambourine or other percussion instrument.

As a separate mode of interaction, the shape of iconic instruments enables a special mode of play. In this mode, touching or strumming the area inside of a 2D shape (Figure 8) allows the player to simulate the use of a harp or a piano.

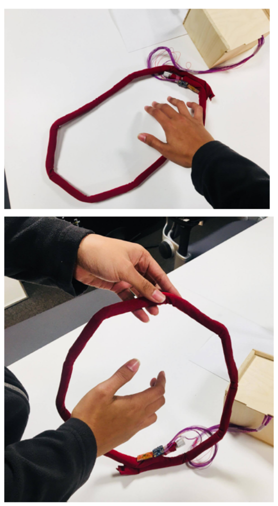

Figure 8: Playing a keyboard and strumming a string instrument.

Applications

PerForm offers new possibilities of interaction and discovery for the musical experience. Its intuitive and explorative affordances can be used as a learning tool for beginners in the study of music. Moreover, such a tool offers creative possibilities for performers interested in exploring the materiality of sound and the intersection of the sensory stimulus in artistic contexts.

This deformable strand-like interface can also be used as an independent musical interface or as a secondary tool for shaping or modulating sound, complementing the main instrument. One possible application is for a single user to perform a "one man's band", by building many different instruments with a single transformable object and superimposing sound layers in digital audio software to achieve a full musical performance.

The MIDI protocol implemented in PerForm enables easy "plug and play" connection to any audio workstation, allowing musicians, sound artists and interaction designers to explore the sonic experience given by this instrument and express themselves by experimenting with different sound metaphors.

Furthermore, the exterior simplicity of this instrument could also motivate children to play and learn more about the perception and physics of sound through direct manipulation of shapes.

Future Work and Improvements

The current implementation of PerForm has limitations, which we intend to address in the future. First of all, the weight and feel of the final object will be improved by redesigning it with lighter, more flexible materials. The implementation of additional joints and segments would allow for more variety of shapes (Figure 9), while the integration of other sensors could expand the functionality of this interface.

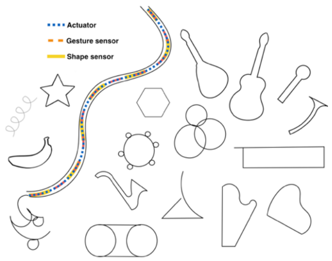

Figure 9: Future possibilities of more complex shapes, with more joints and segments added to prototype.

We will also work on making the instrument wireless, enabling the user to fully explore the relationship between sound and shape without spatial constraints.

Another possibility we would like to explore is the actuation of the joints using the shape-memory properties of nitinol. The alloy, allied to software built to analyze shapes, would assist users in achieving the desired form. Also, an in-depth user study on how people from various levels of musical background learn to play and interact with this object would give us deeper insight into their cognitive experience.

Finally, we look forward to collaborating with musicians and sound artists to explore and demonstrate the capabilities of this interface for musical performance.

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