Augmenting Soft Robotics with Sound

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ABSTRACT

During the past decade soft robotics has emerged as a growing field of research. In this paper we present exploratory research on sound design for soft robotics with potential applications within the human-robot interaction domain. We conducted an analysis of the sounds made by imaginary soft creatures in movies. Drawing inspiration from the analysis, we designed a soft robotic prototype that features real-time sound generation based on FM synthesis.

CCS CONCEPTS

• **Human-centered computing** → **Interaction design**; • **Applied computing** → **Media arts**; • **Computer systems organization** → *Robotics*.

KEYWORDS

soft robotics; robotic art; media art; sound design; human-robot interaction

1 INTRODUCTION

Soft robots can be defined as systems that are capable of autonomous behavior and primarily composed of materials with elastic moduli in the range of that of soft biological materials [18]. Soft robots are claimed to offer inherently safer interactions with humans [1, 15], yet only a few publications have addressed how humans experience soft robots and how intuitive and engaging human interaction with them might be designed [2, 12, 16, 20–22]. Soft robotics technology has recently made its way into art, design, and architecture projects [11, 13]. Yet adding sound to soft robots has not previously been explored, despite the fact that sound is argued to be a vital element of human communication and interaction, which should be supported in human-robot interaction (HRI) [8]. This exploratory arts-led research project departs from the speculative question *What does a soft robot sound like?* It explores how incorporating sound into a soft robot can add to its qualities. As research shows people to have a better impression and understanding of products and designs where two or more sensuous modalities are coupled [14], we chose to focus on how sound might augment soft robotic movement in the first phase of the project. This *Late-Breaking Report* presents initial research outcomes and the prototype *SONŌ*.

2 RELATED WORK

2.1 Sound in product design

A sound's identity - its spectro-temporal characteristics such as pitch, timbre, duration, and level - and the location of its source allows people and animals to extract relevant information from audio [4]. Auditory perception relies on information derived from these features that is recombined in the brain into useful and decodable signals [4]. Every sound and acoustic event - unwanted or wanted - can be understood as a decodable sign carrier that communicates information about the world [9]. For living creatures, a distinction can be made between *internal* and *external auditory cues* [5]. Internal auditory cues are sounds entirely generated by the creature's own body such as breathing, snoring or sighing, and external auditory cues are produced by its physical interaction with the environment. Echoing this distinction, commercial sound designers also differen-tiate between *consequential sounds* and *intentional sounds* [14]. Consequential sounds occur due to the mechanical functioning of a product's parts, intentional sounds are auditory instances meant to be triggered when products interact with their surroundings [14]. Where consequential sounds are often regarded as noisy and are restricted by the physical design and properties of the product, intentional sounds are composed and designed.

2.2 Sound design for robots

A number of HRI studies have called for more focus on sound, yet robot sound design is still a nascent field of research. Adding sound has been argued to potentially improve human communication with a robot and to allow for more complex and meaningful interactions [5, 6, 10]. Sound signals may also be more effective than visual cues for conveying emotional states in social robotics [7] and in HRI sound is used to engage, inform, convey narratives, create affect, and generate attention [19]. Explorations of robot sound design have taken many different forms including the voice-based teacher robot, *Silbot* [8], interactive sound generation with the humanoid *Robot Daryl* [19], Breazeal's sociable infant robot *Kismet* with childlike sounds [3], as well as investigations of people's aural impressions of servo motors [17]. While many research efforts have centered on recreating human or animal sounds and human speech artificially [6], recent research also exists that challenges this approach. It has been argued, for instance, that mimicking human or animal sounds could raise false expectations about a robot's abilities [19].

3 RESULTS

3.1 Analysis of Soft Creature Sounds in Movies

As we did not want our sound design to directly mimic animal and human sounds, we started by analyzing sounds made by imaginary soft creatures portrayed in movies. This existing pop-cultural frame of reference was studied, to gain an understanding of what soft entities have been imagined to sound like and how these sounds may have been generated. This would provide inspiration and guidelines for our sound design. Ten movies (including *The Blob* (1958), *Flubber* (1997) and *Venom* (2018)) that feature characters with bodies made from pliable or change-shifting soft matter were selected. In the comparative qualitative analysis, we focused on deriving shared defining features of the characters' sounds as well as contrasts between the different examples that could be considered vectors spanning the sound design space. It goes beyond the scope of this LBR to summarize the full analysis, but we note here the following main observations that have influenced our sound design:

- Sound is dynamic (rapid changes in the sound)
- Two strategies for generating sound are prevalent: 1. Recorded sounds from animals are layered, 2. Layered sounds from synthesizers are used
- Sounds are often manipulated by raising or lowering pitch or using filters. This creates "wet" or "slippery" sounds, that morph in accordance with the characters' movements.
- Internal auditory cues convey the character's state of mind and mood. External auditory cues provide information concerning the creature's movements or physical interactions with the environment.

3.2 SONŌ - A Sound Augmented Soft Robotic Prototype

After conducting our initial analysis of movie character sounds, we designed *SONŌ*, a soft robotic prototype.[1]

3.2.1 Technical implementation. The morphology was cast in Ecoflex 0030 silicone. We used an Arduino UNO microcontroller to control two H-bridge chips (L292D) that drive three low noise pumps (MITSUMI R-14 A213) and three solenoid valves (Uxcell Fa0520D 6V NC). Audio that matches the robot's movements is generated in real-time by a laptop running *Ableton Live*, through Cycling'74's *Max For Live Arduino-connection kit.* The microcontroller sends a signal via serial connection when a pump or valve is switched on, which triggers a note on an FM synthesizer. The FM synthesizer runs two oscillators in opposing frequency positions through an LFO, a lowpass filter, and a pitch modulating echo effect. When an air chamber inflates the frequency of the main oscillator and the cutoff of the lowpass filter increase and they decrease when an air chamber deflates. With the current setup the pitch and filter positions are controlled manually in Ableton Live and the robot switches between preprogrammed movement sequences.

3.2.2 Design considerations. In our design of the robot morphology and its sound we aimed for designs that would be perceived as organic yet unfamiliar. We used abstract rounded shapes and reddish colorations to give the robot organic connotations and chose gradually changing sounds as expressive internal auditory cues.

[1]A video showing the prototype is available at: http://bit.ly/SonoVideo2020

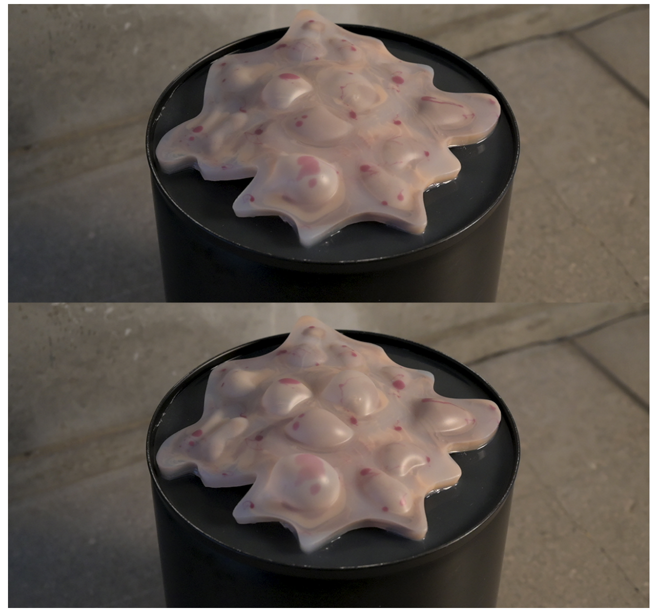

Figure 1: *SONŌ* - a sound generating soft robotic prototype. The soft morphology is approx. 25 cm in diameter and installed on a black plinth which is 40 cm high.

4 FURTHER WORK

While the current work demonstrates how to procedurally generate real-time sound to augment the expressive movements of a soft robot, further work is needed to fully comprehend sound's potential for guiding human interaction with soft robots and contributing to expressive communicative robot behaviors. With the current prototype the microcontroller triggers synthesizer notes during preprogrammed movement sequences. Yet the setup easily lends itself to modifications that will render it more interactive. As next steps we plan to:

- Implement sensing (e.g. pressure sensors to detect touch)
- Conduct user tests to investigate how people's perceptions of a soft robot are affected by different sound designs
- Design and construct different soft robot morphologies with other sound designs (e.g. by having input from the Arduino control other parameters)
- Design an art installation that showcases different sound producing soft robots that use the system

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