FingerSynth: Wearable Transducers for Exploring the Environment with Sound

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ABSTRACT

We present the FingerSynth, a wearable musical instrument made up of a bracelet and set of rings that enables its player to produce sound by touching nearly any surface in their environment. Each ring contains a small, independently controlled exciter transducer commonly used for auditory bone conduction. The rings sound loudly when they touch a hard object, and are practically silent otherwise. When a wearer touches their own (or someone else's) head, the contacted person hears the sound through bone conduction, inaudible to others. The bracelet contains a microcontroller, a set of FET transistors, an accelerometer, and a battery. The microcontroller generates a separate audio signal for each ring, switched through the FETs, and can take user input through the accelerometer in the form of taps, flicks, and other gestures. The player controls the envelope and timbre of the sound by varying the physical pressure and the angle of their finger on the surface, or by touching differently resonant surfaces. Because its sound is shaped by direct, physical contact with objects and people, the FingerSynth encourages players to experiment with the materials around them and with one another, making music with everything they touch.

Keywords

wearable, transducer, synth, glove

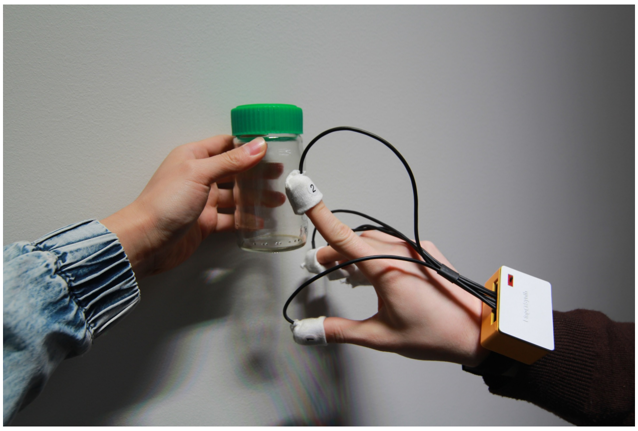

Figure 1: The FingerSynth enables its wearer to play music anywhere while exploring the resonant qualites of objects around them.

1. INTRODUCTION

Despite their widespread use in art and increasing use in consumer products, exciter transducers continue to fascinate people by seemingly magically producing sound in objects, and through bone conduction, inside our heads. In recent years, a new class of small, efficient transducers have been used in a variety of products to produce auditory and haptic feedback. In this paper we present the FingerSynth, a new musical instrument that leverages these technological developments and the magical powers of vibratory transduction to let its wearer play music on anything and anyone. The FingerSynth consists of a bracelet and a set of five independently driven transducer rings that make sound when they touch a hard surface. The bracelet generates audio signals and contains the battery and charging circuitry, as well as an accelerometer to enable gesture-based user interaction and mode switching. Each ring is tuned to a different note in a given scale, allowing the wearer to play simple melodies and harmonies by touching different objects in their environment. When not in contact with an object, the instrument is silent. If the player touches their own (or another person's) head, the sound is audible only to the contacted person, through bone conduction. The player controls the envelope and timbre of the sound by varying the physical pressure and the angle of their finger on the surface, or by touching different objects and materials. Because its sound is shaped by direct contact with objects and people, the FingerSynth encourages players to experiment with the materials around them and with one another.

1.1 Background

The idea of vibratory excitation and bone conduction in art goes back several decades; Laurie Anderson's groundbreaking 1978 installation *The Handphone Table* invited pairs of participants to sit opposite each other, elbows on a specially-equipped table and heads in their hands, and hear sound conducted through the table to their arms and inner ears [1]. Artist Wendy Jacob uses transducers at both infrasonic and audible ranges in her work with deaf students and collaborators, blurring the line between audition and tactile vibration [5].

Several individuals and companies have made instruments that use trigger sensors on the fingertips and produced sampled sound through a single speaker in the wristband; among these are two products: ThinkGeek's finger piano toy and the Piano Gloves from Brando [2]. While similar in form factor, these examples lack the connection to the environment that the FingerSynth brings through its directly physical wave shaping and audio-tactility. While not an instrument, the PianoTouch from Huang et al. [4] uses vibration motors on each finger and audible sound to accelerate piano learning; the motors indicate which fingers the wearer would use to play the sound they are hearing. Though we have not explored this possibility, we believe the vibrating transducers in the FingerSynth could be used in this capacity as well, while also allowing users to play back the patterns they have learned.

2. THE FINGERSYNTH

The FingerSynth hardware consists of five cotton finger hats wired to a wrist-worn device, with the transducers held in small pockets on each ring. Balancing size, form factor and desired loudness, we chose the Dayton Audio BCT-1 bone conducting transducers. We found the hard attachment interface of the BCT-1 to be ideal for the application, where the transducer is not well coupled to the surface and the object is hard but not necessarily resonant; most alternatives use flexible adhesive rings to attach to the surface, and are better suited to excite hollow objects or flat panels. A custom-designed enclosure contains the electronics, consisting of an 8-bit microcontroller (ATmega328) running at 20MHz, a set of switching FET transistors, an Analog Devices ADXL345 accelerometer and a lithium polymer battery with charging circuitry. The microcontroller produces waveforms that are fed to the transistors, which drive the transducers. The system can output square waves and saw tooth waves, the latter synthesized using wave tables. Analog-like output is achieved using the microcontroller's built-in high-frequency PWM outputs and the inherent low-pass filtering of the transducers. Due to clock speed limitations and the necessity for five simultaneous voices, the FingerSynth firmware outputs signals no higher than 1200Hz, corresponding to note D6. Five-voice synthesis pushes the 8-bit microcontroller close to its limit, though some processor cycles can be spared because there is no need for envelopes or sequencing.

2.1 User Interaction and Play

Using simple hand gestures captured by the onboard accelerometer, players can control the synthesizer as they play. To save processor cycles for synthesis, we use the accelerometer's internal gesture recognition to interrupt the processor; upon detection of a gesture, the processor reads the internal memory of the sensor to verify the gesture and extract more features (direction, magnitude, etc). The system detects single and double taps on the wrist to switch voices and scales, respectively, while leftward and rightward flicks of the wrist decrement and increment the output notes by predetermined intervals (5 notes in the given scale).

Envelopes and timbres for each voice are a direct result of the physical pressure and the angle of each of the player's fingers on the contacted surface. Because the filtering is mechanical, these parameters are extremely sensitive and responsive to the player's actions. The broadband energy in the sharp edges of the square and sawtooth voices also provides substantial dynamic range for expressive control. Tremolo effects can be achieved by subtly vibrating the finger. The timbre of the sound is also a function of the material qualities of the object producing it: hollow objects (boxes, musical instruments) produce a louder and fuller sound; metal objects tend to ring; glass windows carry the sound further; cups project the sound. The unique response of each object makes the FingerSynth fun to try in different environments and with others.

The player's own body serves as another exciting space for audio-tactile exploration. The chest cavity resonates deeply, while the head (through bone conduction) is inaudible to others but extraordinarily loud for the player. We have yet to fully characterize the experience of playing the instrument on the body (except to verify that it is indeed worthwhile to pursue), but for now direct readers to [3] for a thorough treatment of directed vibration and musical experience.

Figure 2: Experimenting with a different objects.

3. FUTURE WORK

The FingerSynth turns everything in the wearer's world into an interactive surface for playing music, encouraging exploration and play. Going forward, we intend to miniaturize the wristband and further develop the firmware to support wavetable FM synthesis for more complex voices. These synthesizer improvements would necessitate growing the space of input gestures to allow users to manipulate synthesis parameters directly, perhaps by adding a gyroscope. Finally, we would like to include the option of connecting the transducers to an off-board sound source, like a mobile phone. Feeding the transducers a live stream of the wearer's voice, for example, would enable users to converse in a loud place using bone conduction, holding each other's heads in a pose resembling the Vulcan mind meld.

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