The Sound of Touch

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Abstract

In this paper we describe the Sound of Touch, a new instrument for real-time capture and sensitive physical stimulation of sound samples using digital convolution. Our hand-held wand can be used to (1) record sound, then (2) playback the recording by brushing, scraping, striking or otherwise physically manipulating the wand against physical objects. During playback, the recorded sound is continuously filtered by the acoustic interaction of the wand and the material being touched. Our texture kit allows for convenient acoustic exploration of a range of materials.

An acoustic instrument's resonance is typically determined by the materials from which it is built. With the Sound of Touch, resonant materials can be chosen during the performance itself, allowing performers to shape the acoustics of digital sounds by leveraging their intuitions for the acoustics of physical objects. The Sound of Touch permits real-time exploitation of the sonic properties of a physical environment, to achieve a rich and expressive control of digital sound that is not typically possible in electronic sound synthesis and control systems.

Keywords

Digital sound manipulation, tangible user interface, electronic music controller, sensing, digital convolution.

ACM Classification Keywords

[H5.2 User Interfaces] Interaction Styles.

Introduction

Sound exploration and musical performance have been common activities of humankind for thousands of years. Our desire to expressively create sound in real-time has led us to explore a wide range of available materials and technologies. Striking together, grinding or breaking objects found in nature is perhaps the simplest way to generate sound deliberately, and was likely the original manner in which materials were leveraged by people to sculpt sounds. However, evidence of specially-built musical instruments have been discovered dating as far back as 9000 years [4], suggesting that people have long been interested in ways to control musical sound in more articulate ways, by blowing, bowing, striking, picking, plucking and fretting their instruments. The wide range of acoustic instruments that musicians use today, from horns to strings to percussion and more, demonstrates the intellectual energy that has been expended throughout the years to craft better ways to explore and control sounds.

People have a lot of experience hearing the sounds produced when they touch and manipulate different materials. We know even without doing the action what it will sound like to bang our fist against a wooden door, or to crumple a piece of newspaper. We can imagine what a coffee mug will sound like if it is dropped onto a concrete floor. These intuitions are useful when we want to create a particular sound with objects in our environment, and they can guide exploration if we just want to play and experiment with new sounds.

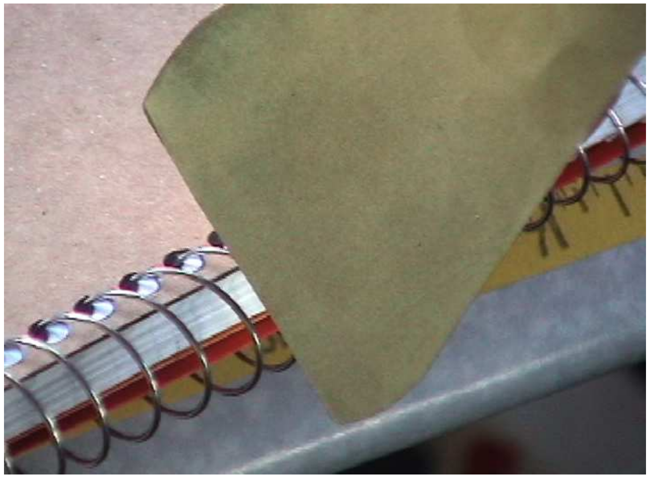

Figure 1: Scraping the wand across the spiral binding of a notebook. The contact between the wand and the notebook causes a continuous acoustic stimulation of the recorded sample.

Electronic Music and Digital Sound

In the last 100 years the growth of analog electronics and more recent digital techniques has opened up many new possibilities for creating and manipulating sounds. Arbitrary waveforms can be synthesized electronically, making it now possible to artificially generate a sound that mimics an acoustic instrument, or that sounds like no acoustic instrument that ever existed.

Decoupling Input from Output

With found objects and acoustic instruments, the control interface and the sound production mechanism are one and the same – they are the object itself. A drum head vibrates when struck, and a violin string vibrates when bowed. The relationship between a player’s gesture and the resulting sound in an acoustic device is fixed by the physics of the resonant element, whether it is a string, a membrane or a column of air. An electronic instrument however, can be built to implement an arbitrary ‘mapping’ between gesture and sound, a revolutionary decoupling that had never before been possible. Moreover, the sound produced by an electronic musical instrument need not (and typically does not) correspond at all to the physical materials from which the instrument is built.

This decoupling of control affordances from the synthesis mechanism and thus from the resulting sonic output is a turning point in musical technology, because musical sounds are now limited only by the skill and imagination of the instrument designer, musician or sound engineer, rather than by the physical properties of materials. The most popular and widespread example of this decoupling is the MIDI digital communication standard, which allows many different input controllers and sound synthesizers to be used together interchangeably.

Problem Statement

Modern electronic instruments afford musicians new and compelling modes of sound synthesis and control. However these tools have been received less enthusiastically in performance contexts. While the explosion of sampler/sequencers and digital audio production software has allowed musicians to easily compose music by arranging pre-recorded or synthesized sounds for later playback, the expressive performative affordances of electronic instruments have been criticized. Some musicians report that electronic synthesizers sound sterile or cheap, and that digital communication standards like MIDI interfere with expression, lacking the continuous and organic feel that is found in acoustic instruments.

Hypothesis

We believe that musicians’ dissatisfaction with electronic music instruments stems at least in part by the fact that electronic instruments lack the subtle affordances featured by acoustic instruments. The decoupling of performer gesture and output sound inherent in electronic instruments comes at a cost: *most musical affordances must be deliberately created by the instrument designer*. For a device to respond to pressure on its body, a pressure sensor in the appropriate location must be incorporated. If it is to respond to bending, or blowing, or changes in tilt or temperature, each of these affordances must be engineered with sensing elements and the data mapped to synthesis parameters. Furthermore, the most straightforward configuration for an electronic music instrument makes the sensing parameters independent, each capable of being actuated separately by a performer without affecting the others. If the control parameters are to feature inter-connected behavior, this too must be an explicitly designed feature.

This requirement for explicit design of the device’s operation stands in contrast to acoustic instruments, which feature many “accidental” or serendipitous affordances that need not have been foreseen by the instrument’s designer. These ways to play fall out of the materials an instrument is built with, and its mechanical construction. For instance, plucked notes on an acoustic guitar can be detuned by physically pushing on the guitar neck, causing it to bend and change the distance between the endpoints of the string. Additional affordances like this are learned partially through experience with the specific instrument, but are also informed by our life experience manipulating physical materials. Since most people have handled and bent wooden objects before, the fact that a guitar neck is bendable can be intuited directly by looking at the instrument.

Wanderley et al. investigated the design question of cross-coupled versus independent parameter control in a musical interface, finding a preference for cross-coupled parameters [2]. This preference for a more inter-connected mapping is useful for musical instrument design because it suggests that electronic music instruments might benefit from the kind of cross-coupling that acoustic instruments naturally feature. Moreover, it signals a general appreciation for the continuous and subtle properties of our interactions with physical objects.

Approach

A primary design goal with the Sound of Touch has been to build an interactive system for sound manipulation that will allow people to once again utilize their intuitions about how striking, scraping, or other gestures manipulating our surroundings can create sound. Our wealth of experience handling physical materials does not typically produce much intuition for operating a new electronic instrument, given the inherently arbitrary mapping from gesture to sound. Our experiments address how people can leverage this intuition during musical performance.

The Sound of Touch System

We have created a wand interface and texture kit that extend Aimi's methods [1] for realtime percussion instruments. Aimi's system allows a stored digital sound sample to be 'stimulated' continuously by the signal from a piezoelectric sensor attached to a drum brush. The underlying mechanism of this stimulation is an always-running digital convolution of the stored sound sample and the (digitized) incoming signal from the piezoelectric element. The resulting interaction features a directness and sense of physicality that sets it apart from the gesture-sensing, arbitrary mapping and synthesis of electronic music instruments.

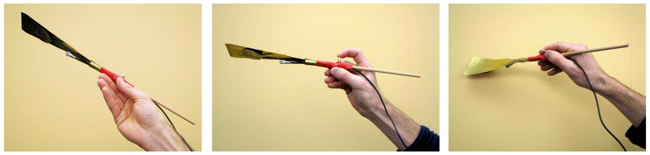

Figure 2: Holding the wand, pressing the record button to capture a sound sample, and scraping the wand against a wall to stimulate the sample.

Digital convolution is an algorithm that is fundamental to much of digital signal processing [3]. It is the primary technique by which digital filters are implemented in software or on digital signal processing (DSP) microchips to shape the frequency spectrum of a sampled signal. The basic principle of digital convolution is that two sampled signals are applied to each other in multiplicative manner, and the resulting signal has a frequency spectrum that is a product of the individual frequency content of the two original signals. Sonically, this means that if a presidential campaign speech is convolved (the act of convolution) with a sample of a church bell being struck, the resulting audio sounds like a mixture of the two, as if the speech were being played *through the church bell* or vice versa.

Aimi's work develops a number of "semi-acoustic" percussion instruments that utilize his technique with pre-recorded samples and the live signal from piezoelectric sensors manipulated in real-time. They provide greater realism and intuitiveness, as well as low latency response to digital percussion.

The Wand

Our wand incorporates both a microphone for recording samples and the piezoelectric sensor for stimulating the newly-recorded sounds. To activate recording, a user presses a button on the wand. As soon as the button is released, the sample is stored and the piezoelectric sensor stimulation becomes active. The wand can then be brushed, tapped, scratched, or otherwise manipulated against physical objects. The wand makes acquisition of new samples rapid, lowering the effort required for experimentation with different sounds. The wand's flat shape allows it to be used as a probe to touch, strike, or scrape objects the world, or it can be held against another object which is itself manipulated. The wand locates all of the relevant components for this activity in a single instrument. This interaction technique of co-located media capture and manipulation has been shown to be intuitive in visual composition [4], and our preliminary experiments indicate that it maps well to the auditory domain.

The Texture Kit

Aimi's method allows sampled sounds to be acoustically filtered by stimulating them with materials that have specific textural or resonant qualities. A recording of a bell will sound sharp when stimulated by contact with a piece of steel, but soft and muffled against soft felt. We elaborate on this idea by our creation of a "texture kit" comprised of a number of different physical objects with varying shapes and textures. The purpose of the kit is to enable convenient experimentation stimulating a stored sample with a wide range of physical textures. The kit includes a soft paintbrush, stiff wicker bristles, fabric, plastic, velcro, and a number of other unusual objects. It is a palette of textures that were selected for their diversity in stiffness and surface features, making them a useful basis for experimenting with sound. In contrast to traditional electronic instruments, the Texture Kit introduces acoustic affordances to the system without requiring they be integrated into the electronic instrument itself.

Figure 3: The texture kit, with elements selected to represent a range of physical structure and acoustic resonance.

Our wand and texture kit facilitate sonic exploration of recorded samples against a wide range of surfaces. Playing with sound in this way heightens our interactions with physical objects, allowing us to explore and exploit their features in a way that leverages our intuitions about them, providing a new way to intuitively sculpt digital sound samples.

Conclusions and Future Directions

In this paper we have described the Sound of Touch, a tangible wand, software system and texture kit for real-time sound recording and exploratory stimulation of recorded samples. The Sound of Touch enables a flexible capture and manipulation of audio that is characteristic of digital tools, but in a direct and physical manner that approaches the continuous experience of manipulating acoustic musical instruments and found objects. Importantly, the Sound of Touch allows people to leverage their existing intuitions about how different objects will sound when these objects are touched, struck, or otherwise physically manipulated – another feature shared by acoustic instruments and objects from our everyday lives. The Sound of Touch is thus a sonic exploration tool that borrows properties from both acoustic and electronic sound creation, bringing them together in a way that leverages advantages of each.

Figure 4: Recording a vocal melody into the system using the wand, and stimulating the piezoelectric sensor directly with soft paintbrush bristles.

In the future we plan to make the Sound of Touch system more mobile, making use of a portable computer, PDA or phone. Sounds and textures from anywhere in a person's physical environment could be captured and stimulated, enabling roving musique concrète[1] experiences or impromptu performances. Additionally, the implementation of a palette for sound samples that could be captured on-the-fly, stored, then easily selected for stimulation would make the wand a fully capable musical instrument. We look forward to developing performance experience with this system.

Acknowledgements
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[1] The practice of making music out of sounds recorded in the "real world" by first experimenting with them, then abstracting them into musical compositions.