Sonic Touch: A Haptic Toolkit for Fast Vibrotactile Prototyping

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ABSTRACT

In the realm of Digital Musical Instruments (DMIs), tactile feedback typically inherent in acoustic instruments is notably absent, creating a gap in the sensory experience of musicians. Previous works typically aimed at bridging this gap by designing haptic effects using trial-and-error strategies. This paper introduces Sonic Touch, a toolkit developed in Max/MSP that facilitates the rapid prototyping of audio-driven vibrotactile haptic effects. The toolkit allows users to design a variety of haptic effects by manipulating parameters like wave type, vibration duration, frequency, repetition, and envelope, then store and manage them in buffers for output. The toolkit's architecture is grounded in a modular, building-block approach, accessible through a simple graphical user interface. Practical use of this toolkit is demonstrated through two examples, first designing a haptic tremolo effect, and second augmenting a Touché controller with vibrotactile feedback.

CCS Concepts

•Human-centered computing → User interface toolkits; •Applied computing → *Sound and music computing;*

1. INTRODUCTION

Acoustic instruments provide musicians with a tight coupling between auditory and haptic sensations, from the string vibration on a guitar to the resonating body of an instrument. DMIs lack this physical coupling, and whilst attention given to input gesture to audio synthesis output layer, haptic output is often seen as a secondary function or overlooked entirely. "Haptic" and "tactile" feedback in this context of this paper is referred to as vibrotactile stimulation, a distinction from force-feedback devices [1].

Bringing haptic feedback to the forefront of a DMI experience starts first with the design of the haptic effects themselves. The haptic feedback of a DMI can greatly impact the feel of the instrument [2], therefore rapid experimentation is key in defining what haptic effect 'feels right'.

This need for rapid experimentation led to the development of the Sonic Touch haptic toolkit in Max/MSP[1]. This toolkit addresses both considerations above, allowing for both the rapid design of haptic effects with simple control parameters, and the easy mapping between control data input and haptic output within the same patch.

The decision to use Max/MSP as the development platform was twofold: firstly, for its widespread use amongst DMI designers, allowing them to integrate haptic feedback into their projects easily, and secondly, to provide a reliable, future-proof solution to the ongoing problem of technology depreciation. The toolkit was built using only vanilla objects with the belief that the toolkit would benefit from Max/MSP's continued updates and support, keeping it relevant and functional as software and hardware advance.

To showcase the toolkit's potential, a project was conceived to enhance an existing DMI with vibrotactile feedback. The Touché Controller by Expressive E was chosen with the intention of adding a haptic dimension to its already rich gestural input design.

2. RELATED WORK

The role of tactile feedback is significant in both the acoustic and digital instrument-playing experience. Early research found that tactile feedback in the fingertips of a Cellist's hand was used to perceive time and length of articulations through amplitude and spectral content of the vibrations [3]. These findings were applied to a brass physical model, HosePlayer, using a voice coil to provide tactile feedback for the model's lip tension parameter.

The designers of the Viblotar DMI [4] took a similar approach, using vibrotactile feedback to replicate the resonating body of an acoustic instrument. Performers of the instrument stated a higher degree of enjoyment and attention with vibrotactile feedback.

Further research investigated the role of vibrotactile feedback in the perceived quality of the device and playing experience [5]. Facilitated through the force-sensitive multitouch HSoundplane interface, vibrotactile feedback increased the perceived expressiveness of the interface and the enjoyment of playing.

The TECHTILE toolkit [6] provides a notable example of how tactile feedback can be employed for educational and creative purposes. Although the toolkit is primarily aimed at non-musical applications, the easy-to-use design philosophy underlying the TECHTILE toolkit parallels our own toolkit design.

Research on wearable haptic device, such as the VR/TX system for open-air controllers [1], details the perceptual significance of haptic effect design. In a similar focus, the Vibropixels project [7] provided users with the ability to set the envelope and the oscillator parameters of individu-

[1]https://cycling74.com/products/max

NIME'24, 4–6 September, Utrecht, The Netherlands.

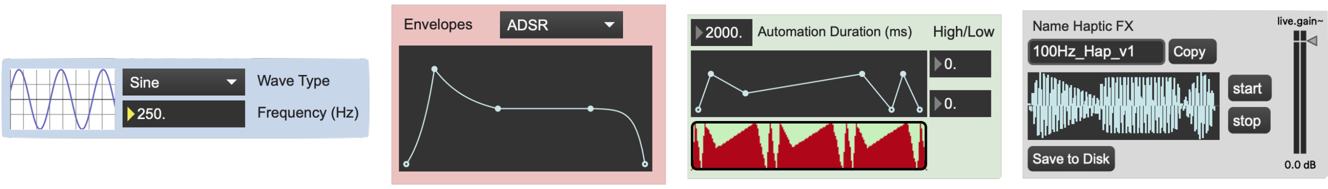

Figure 1: Audio-driven vibrotactile modules. Left to right: Oscillator, Envelope, Automation, Buffer

ally controllable vibrotactile actuator devices embedded in a garment.

Haptic feedback was further being utilised to overcome barriers for visually and hearing impaired people in applications ranging from peak metering to parameter type differentiation [8]. Moreover, actuators placed in audience's seating and footrests have improved the live music experience and stream separation for people with hearing loss devices [9].

In the VR community, the Stereohaptics toolkit introduced a VR-focused haptic framework that uses off-the-shelf audio-based tools to create haptic media [10]. In another study, the developers of the "Haptic Palette" controller proposed a system allowing users to dynamically reconfigure the haptic feedback of virtual objects based on their material properties [11].

3. SONIC TOUCH TOOLKIT

While the field has seen considerable advancements in the application of tactile feedback within specific DMI designs and broader interactive systems, the Sonic Touch toolkit diverges by emphasizing the design of the feedback effects themselves. The toolkit is designed to provide a versatile framework that can be adapted to a wide range of DMIs for designers and researchers to experiment with and prototype vibrotactile effects rapidly.

3.1 Functionality & Features

The toolkit is built around a modular architecture, offering a set of building blocks for free experimentation. The following four modules (Figure 1) are pre-defined for the easy design and capture of the haptic effect:

- **Oscillator:** The oscillator module generates basic waveforms that form the foundation of the haptic signal. Users can select the type of waveform and adjust the frequency. These wave types can be used to create different haptic textures [1]. These modules can be chained to create more complex haptic waveforms.

- **Envelope:** The envelope module includes a number of pre-defined envelopes such as ADSR, ASR, exponential decay, and also the ability to draw a custom envelope. The defined envelope is multiplied by the incoming signal on the trigger event.

- **Automation:** The automation module offers the ability to create dynamic variations in the haptic feedback. It allows for the programming of changes over a set duration, modulating parameters such as amplitude or frequency.

- **Buffer:** A critical component of the toolkit is the buffer module, allowing users to copy the contents of the editing buffer for easy re-use, event triggering, as well as the ability to save the haptic effect to disk.

Each haptic effect is defined by a number of modifiable parameters, including event length, amplitude, number of repetitions, and delay between repetitions. The "Trigger Record" button captures the haptic waveform into the editing buffer for a user-defined duration in milliseconds. As the record∼ object captures the signal, the editing buffer visually updates to display the waveform, providing a real-time representation of the haptic effect being created.

Once recorded to a buffer, these haptic effects can be outputted through to a specified audio-out channel, typically connecting to a voice coil or similar actuator to create the physical sensation of vibration [12, 13].

4. APPLICATIONS

The section details two use cases of the haptic toolkit, first in the implementation of auditory effects such as tremolo, and second in enriching the interaction with the existing Touché controller.

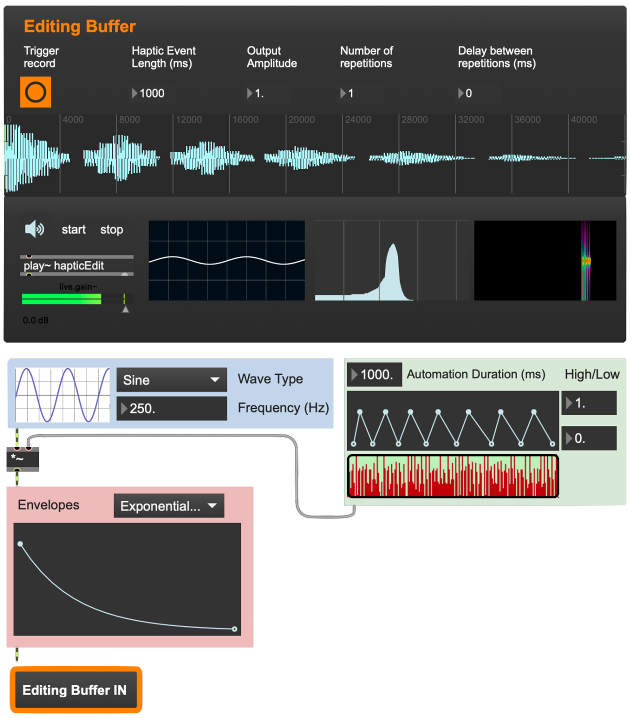

Figure 2: Tactile tremolo created with the haptic toolkit.

4.1 Tremolo Effect

Whilst the vibrotactile system is not as sensitive to amplitude modulation as the auditory system [14], it is suggested that the tactile equivalent of tremolo can be achieved by modulating the amplitude of the vibrotactile signal [15].

A tactile tremolo effect is created simply using the haptic toolkit as seen in Figure 2. A 250Hz sine wave [16] is passed through an exponential decay envelope. The amplitude of the signal is modulated using the automation object over a one-second period between values 0 and 1. The resulting signal is displayed in the editing buffer for immediate output through the connected vibrotactile device.

4.2 Haptically Augmented Touché Controller

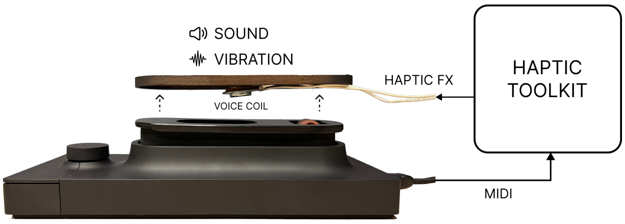

Figure 3: Touché controller retrofitted with voice coil attached to underside of faceplate.

The Touché, typically employed alongside hardware or software synthesizers, is a touch-sensitive device designed for expressive musical interaction[2]. The controller distinguishes itself from typical MIDI controllers by offering highly responsive, 2-DoF continuous positional sensitivity rather than discrete buttons or keys.

Our goal was to make the Touché controller feel like a standalone instrument through experimentation with vibrotactile feedback effects. To achieve this, a HiAX13C02 voice coil was chosen due its small footprint design and low cost (∼$5USD), and glued to the underside of the face plate (Figure 3) and connected directly into the audio jack of a laptop without the need of an amplifier. MIDI data from the Touché was handled in the Sonic Touch patch.

4.2.1 Digital Haptic Guiro

Fitted with the ability to provide haptic feedback, the next step was to define the concept and gestural mappings of the instrument. The concept of the instrument was based on a wooden frog guiro, a Latin American percussive instrument played by dragging a stick along the notches on the wooden frog's back to produce a ratchet "croaking" sound. However, unlike the haptic feedback from physical ridges, pressing down on the Touché controller does not provide tactile cues to indicate the exact position along the axis of motion, presenting an ideal opportunity for precise design of vibrotactile feedback.

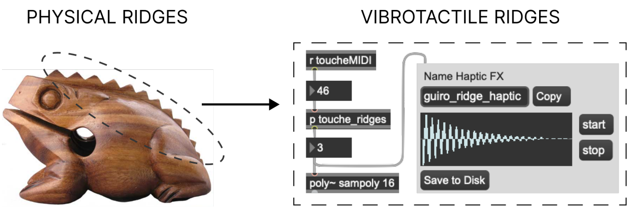

Figure 4: Spacing of ridges of a physical frog guiro mapped to MIDI values.

The haptic toolkit allows for easy design of short (100ms) haptic effects to represent the physical ridges on the guiro. These "haptic ridges" are then mapped along the MIDI value range from a users downward press of the Touché faceplate Figure 4. As the user presses deeper, the ridges are felt more closely together, simulating an increase in tactile 'resolution' that corresponds to the depth of the press. This approach mirrors the responsive dynamics of a velocity-sensitive keyboard but through the sense of touch rather than sound.

Whilst the voice coil on the underside of the Touché faceplate is primarily used for haptic effects, it can also be utilized for audio output. This is achieved within the haptic toolkit patch using a poly∼ object to trigger samples of a wooden frog guiro at the ridge points. The tactile feedback provides a physical dimension to the digital interaction, with the combined haptic and auditory result more closely resembling that of the physical acoustic instrument.

4.2.2 Ridge Detection

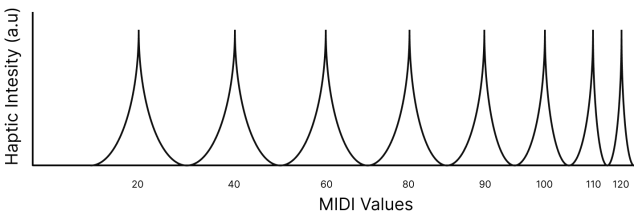

Figure 5: Peak detection with haptic amplitude modulation

Rovan & Hayward [1] suggested the effectiveness of expressing a zone-boundary crossing event by varying the amplitude of noise and a cosine envelope. Demonstrating this continuous model on the Touché controller is simple. Figure 5 illustrates a continuous haptic signal, where the amplitude of a sine wave increases as it nears a ridge, peaking at the ridge itself. A similar strategy was utilized in the implementation of a vibrotactile metronome, which aided musicians in anticipating the next beat [17]. In the Touché, this haptic effect offers a spatial awareness of the ridges' positioning, giving the user an intuitive feel for the landscape of the controller's surface as they interact with it.

5. DISCUSSION

One limitation of the haptic toolkit is the need for a user to trigger the recording of the haptic effect into a static buffer. However, this can be addressed by bypassing the editing buffer and routing a continuous signal directly to the DAC, enabling dynamic control over the haptic effect. For example, musicians could control the tremolo speed in real-time using a MIDI controller's modulation wheel or an OSC-enabled touch surface. This opens up possibilities for real-time tactile expression, aligning the toolkit closer to the tactical nature of acoustic instruments.

Furthermore, development is underway to create a fully editable library of vibrotactile effects, allowing users to integrate haptic feedback into their DMIs without extensive configuration. Categories might include haptics based on types of instruments (e.g., plucked string, percussive hit), or specific tactile textures (e.g., smooth, rough).

Whilst a formal user evaluation of the toolkit has not yet been performed, informal feedback from instrument designers and musicians has been positive. Feedback highlighted its simple and intuitive UI, and useful capability to store multiple haptic effects for experimentation. When vibrotactile feedback was added to the Touché, users became much more engaged with the simple instrument, taking time "feel" the individual haptic ridges of the digital guiro.

[2]https://www.expressivee.com/1-touche

6. CONCLUSION

This paper presented a toolkit for the easy creation of audio-driven vibrotactile effects, addressing the often overlooked aspect of haptic feedback in DMI design. The toolkit's user-friendly, modular design within Max/MSP makes it accessible to those without haptic design experience. Its versatility is demonstrated through two use cases: the tactile tremolo effect and guiro-inspired implementation with the Touché controller. These examples hopefully encourage DMI designers to experiment with vibrotactile feedback in their own projects. A video demonstration of the Sonic Touch toolkit can be found at the link `https://vimeo.com/910935568`, and can be downloaded from its github repository at https://github.com/IDMIL/Haptic-Toolkit.

7. ETHICAL STATEMENT

The authors affirm that this research was conducted without any conflicts of interest. Informal feedback was collected from volunteer participants to enhance toolkit usability. No formal human subjects research was conducted.

8. ACKNOWLEDGEMENTS

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