Rumbler: A Reverb-Based Feedback Instrument

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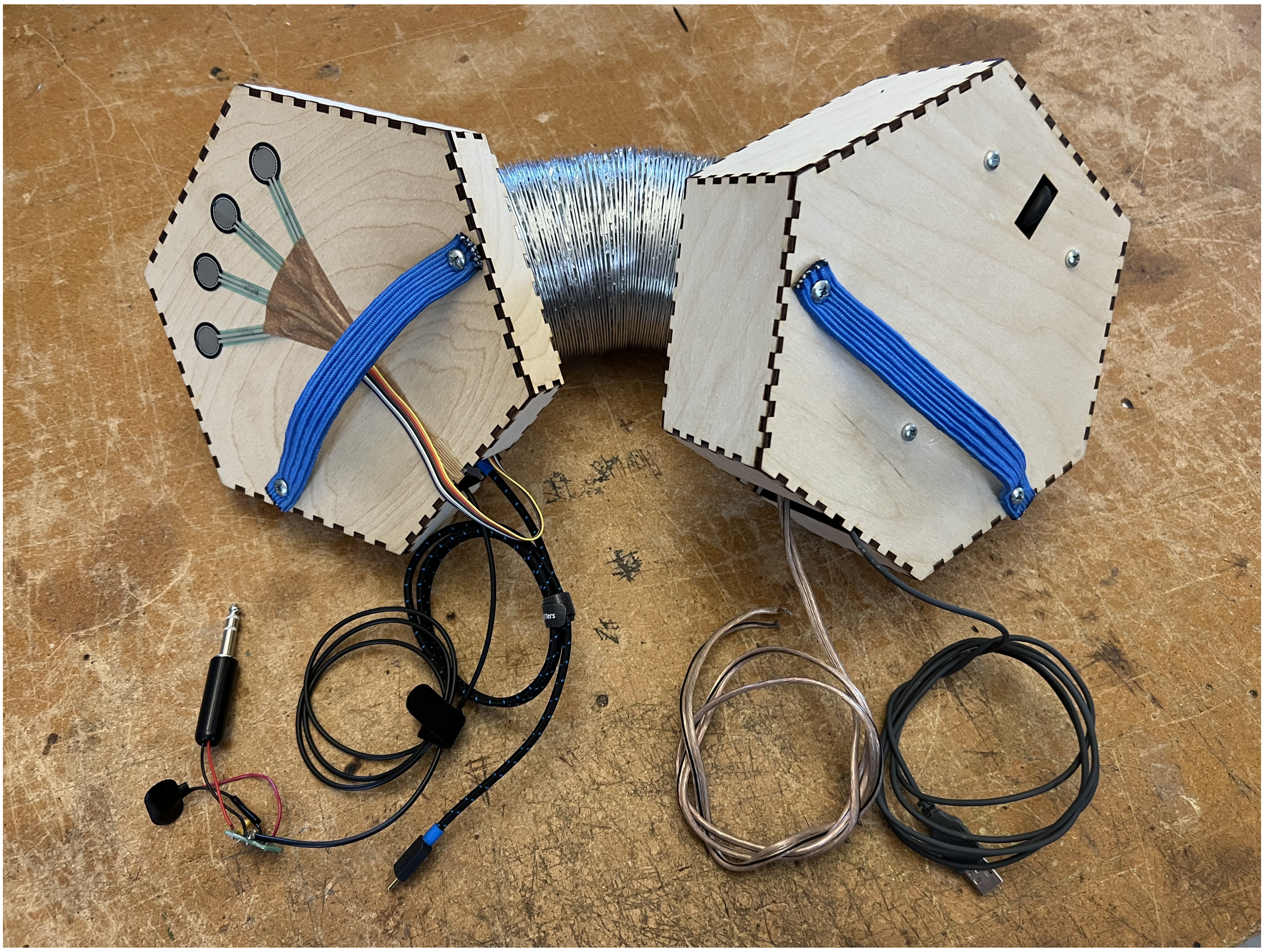

Figure 1: The *Rumbler*.

Abstract

We present the *Rumbler*, a feedback instrument that harnesses acoustic reverberation to generate complex, unpredictable sounds. A microphone and speaker are mounted to opposite ends of a tube. As the tube is stretched and compressed, the acoustic space within it changes, amplifying different resonant frequencies and altering the resulting pitch. The *Rumbler* also features four force-sensing resistors, a mouse scroll wheel, and a 9DOF sensor, which can be mapped to various audio filters. These controls modify the audio feedback, enhancing the instrument's expressiveness and sonic complexity.

We discuss strategies and considerations for mapping filters for the *Rumbler* and detail two particular mappings that were used for live performance. We share our reflections on the success and limitations of these mappings. Finally, given that the *Rumbler* can sustain sound without any audio input, we explore the connection between the *Rumbler* and no-input mixing and its implication for future practice and performance.

Keywords

Feedback, Reverberation, No-input, NIME

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1 Introduction

Since the mid-20th century, feedback has been harnessed by musicians as a compositional and performative technique, implemented in musical performances, installations, and instruments [5]. In recent years, this has been more thoroughly explored through the Feedback Musician Network [8]. Feedback instruments exhibit emergent, unpredictable behavior, requiring negotiation rather than full control. Musicians frequently describe relinquishing control in favor of heightened listening and responsiveness to the instrument's evolving state [5].

Feedback can augment the sonic richness of existing instruments, as in Úlfarsson's Halldorophone [10], or to coax sonic complexity from simple systems, as in Bovermann's Half-closed Loop [1]. Most feedback instruments control resonance by exciting physical materials (e.g., strings, metal) or the air of a wind instrument; the positions of the microphone (pick-up) and speaker (actuator) that create the feedback loop are fixed in place. Cybulski's Feedback Synth [3] precomputes mappings between mic-speaker configurations and their corresponding resonant frequencies inside an enclosed system, which are then accessed via a keyboard.

One of the most famous examples of the use of feedback is Alvin Lucier's sound art piece *I am sitting in a room* [4]. In the piece, Lucier records himself speaking, then plays it back while re-recording it. The resulting audio, after many iterations of recording and playback, is a hum of the resonant frequencies characteristic to the room, microphone, and speaker. What does a room sound like? While the technical answer is "the impulse response of the reverb," Lucier's piece suggests a more musical answer might be found through feedback.

What if we could dynamically change the shape of the room and consequently, the resonant frequencies? The *Rumbler* harnesses this purest form of feedback: a speaker, microphone, and the space between them to explore the possibilities of a dynamically changing acoustic space. Filters are added within the signal chain to further shape the sonic possibilities.

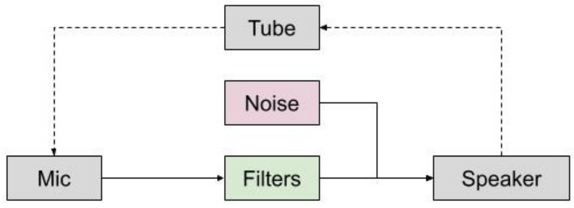

Figure 2: Simplified signal diagram of the *Rumbler*.

2 *Rumbler*

2.1 Software

The signal processing chain was implemented in ChucK (Figure 2). Multiple filter mappings were used for practice and performance; see Section 3.

2.2 Hardware

The frame consists of two laser-cut wooden hexagonal prisms. Elastic straps on the prisms allow them to be held up by the wrists like an accordion. A 4-inch dryer vent tube is connected to the centers of the prismal handles by Velcro for portability.

Each handle has a variety of sensors that can be mapped to different filters. The handle with the microphone has four FSR sensors, a 9DOF sensor, and an Arduino that outputs the sensor readings by USB-C connection through MIDI CC. The microphone connects to an audio interface, which is connected to the laptop. The other handle with the speaker has a scroll wheel obtained from a recycled mouse. The scroll wheel connects to the laptop with USB-A, and the speaker connects to a small amp, which connects to the audio interface. Most of the controls are placed on the "microphone handle" because it is lighter and easier to maneuver than the "speaker handle" due to the weight of the speaker.

Whereas feedback instruments such as Jeff Snyder's Feedback Trombone and Stelios Manousakis's Feedback-augmented Alto Clarinet [6, 9] feature one-dimensional control over the acoustic space (via elongation or valve actuation), the tube of the *Rumbler* can lengthen, bend, and twist, potentially resulting in more indirect acoustics reflections. Thus, the physical design of the *Rumbler* enables more sophisticated manipulation of acoustic space compared to previous feedback instruments.

3 Mappings

3.1 Strategies and Considerations

Without any filters applied, each configuration of the tube has set of resonant frequencies that typically form a harmonic tone. The fundamental frequency decreases as the tube lengthens. When the tube configuration changes (e.g., the tube twists or lengthens), the instrument switches to the new resonant frequency. This transient phase often carries interesting timbres as it mixes the sounds of the neighboring resonant pitches.

Using filter mappings, we can increase the complexity of the instrument's timbre by either lengthening the duration of the transient phase or making the sounds of the stable resonant pitches more complex. Ideally, the performer can steer the instrument's sound between the simple harmonic tones and the complex rumbly, gnarly chaos using controls that are simple, intuitive, and learnable.

Ultimately, however, feedback instruments share a certain amount of uncertainty and unpredictability, which must be tamed through practice [5]. We design the filters and mappings to augment the strengths of the *Rumbler* instead of trying to constrain the system to mimic the sounds of an existing instrument or conform to traditional music theory.

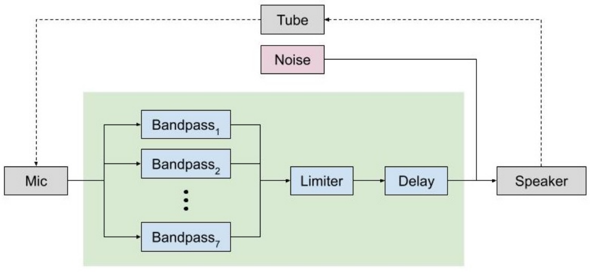

Figure 3: Signal diagram with filters mappings in performance 1.

3.2 Mappings for Performance 1

One mapping that was performed[1] in front of a live audience is shown in Figure 3. The scroll wheel is mapped to the delay duration of a delay line, and the four FSRs control the gains of bandpass filters. The delay line can be used to length the duration

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[1] Performance 1 video: https://vimeo.com/1164588862

of the transient phase and create rhythmic textures, while the bandpass filters allow the performer fine control over low, mid, and high frequency spectrum. Because a delay of t seconds (where $t \ll 1$) amplifies frequencies at integer multiples of $1/t$ Hz and alters the resulting tone, the performance used delays longer than 100 ms to instead produce a rhythmic looping effect and keep the same resonant frequencies.

The gains of bandpass filters 1, 3, 5, and 7 are mapped proportionally to the four FSR sensor readings, while the gains of filters 2, 4, and 6 are mapped to the average of adjacent FSRs. The center frequencies are

$$[50,\ 103,\ 215,\ 447,\ 928,\ 1926,\ 4000]\ \text{Hz},$$

with corresponding maximum gains

$$[21,\ 6,\ 2,\ 2,\ 3,\ 7,\ 17].$$

These values were refined iteratively through extended playing sessions so that each bandpass filter felt perceptually responsive to touch while remaining balanced in the overall feedback system.

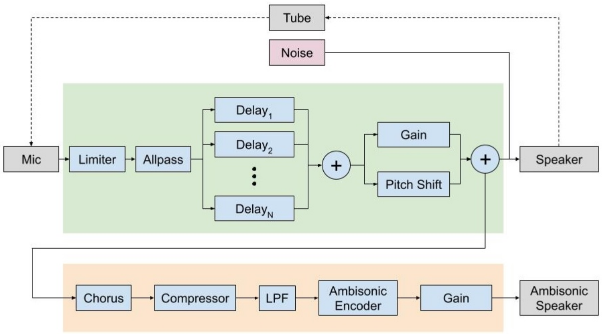

Figure 4: Signal diagram with filters mappings in performance 2.

3.3 Mappings for Performance 2

Another mapping that was performed[2] is shown in Figure 4. It features a pitch shift, several gain controls, and an array of delay lines. The pitch shift is turned on and off by an FSR and the shift amount is controlled by the pitch (i.e., tilt) of the 9DOF sensor. The gain of the limiter is controlled by the scroll wheel; the gain parallel to the pitch shift is controlled by a second FSR. This two-step gain control helps with musicality—the scroll wheel controls the maximum volume through the filter so that the audio doesn't peak, and the FSR-controlled secondary gain can be used to control the mix between the dry and wet pitch-shifted audio.

The array of $N = 18$ delay lines slows the decay of non-resonant frequencies between changes in the tube configuration, which helps expose the complex timbres found in the sonic transitions between different frequency responses. The delay durations range between 10 and 350 ms and were manually tweaked as to minimize the perceptual impact of the delays on the resonant frequency. An all-pass filter was inserted before the delay lines after experimentation revealed that the instrument sounds better and controls more predictably with the all-pass filter. After experimentation, we discovered that an all-pass filter inserted before the delay lines increases the control and predictability of the longer transcient phase produced by the delay lines.

Additionally, the performance venue had ambisonic speakers, so a third FSR controls the gain to the ambisonic speakers in which the azimuth of the sound source is controlled by the yaw of the 9DOF sensor. The chorus subtly alters timbre, which helps distinguish sounds from the *Rumbler*'s built-in speakers from the ambisonic speakers. Finally, the compressor and low-pass filter help protect the ambisonic speakers.

4 No-Input Option

No-input mixing is a technique in which a sound mixer is fed back into itself. Through feedback, the mixer is transformed into a complex instrument whose unstable and unpredictable behavior must be learned and practiced by its users [7].

The *Rumbler* similarly does not require constant noise input to sustain a sound—the ambient noise in the environment or a gentle tap on the microphone is enough to trigger and sustain feedback. However, the no-input setup makes the instrument's sounds more unpredictable, making practice and performance more difficult: without the constant noise input, the feedback audio tends to stay at the same pitch or disappear completely if the resonant frequency of the tube is too far from the current feedback frequency. While we are currently exploring the sonic possibilities of the no-input setup, we have not performed with it because of its unpredictability.

Figure 5: The performer stretches the *Rumbler* vertically as he closely listens to the sounds that emerge from feedback.

5 Reflections

5.1 Experimentation and Practice

After the *Rumbler* was built, the signal processing chain was developed through iterative prototyping and embodied evaluation to find filter mappings that were sonically compelling and performable. While some iterations were evaluated within minutes, others required days of practice before their affordances became clear.

Early experiments[3] combined feedback with low-pass and high-pass filters, pitch shifting, reverb, and variable delays. While these configurations produced dense, evolving textures, they also made the instrument difficult to control. The filters interacted in nonlinear, time-dependent ways, and small parameter changes caused drastic sonic shifts. Consequently, the system behaved inconsistently: configurations that produced compelling sounds in one session could feel unstable or unresponsive in another.

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[2] Performance 2 video: https://vimeo.com/1164539498

[3] Practice video: https://vimeo.com/1164546210

This tension between richness and controllability led us to simplify the signal chain. We prioritized mappings that expanded the sonic range while remaining learnable. Through this process, several design insights emerged.

First, simple filters can become complex through feedback and interaction. A bandpass filter or delay may sound uninteresting, but within a feedback loop, their interaction can produce evolving resonant structures. Previous feedback instruments [9, 10] have successfully utilized minimal signal chains (e.g., a single bandpass filter or gain control) to generate complex timbres and user interaction.

Second, parameter sensitivity should be matched to gesture scale. Parameters capable of dramatic sonic shifts (e.g., delays and pitch shifts) are mapped to larger, more stable gestures (e.g., the 9DOF sensor or scroll wheel). Parameters intended for moment-to-moment shaping are mapped to the FSR sensors. Because independent finger control is challenging, we avoided assigning strongly coupled or highly nonlinear parameters across the FSRs. Our mapping philosophy mirrors that of gestural instrument musicians who construct “simple, robust metaphors” [2] that enhance musician and audience engagement through clear visual correspondence and theatrical expressivity.

Third, tuning parameter ranges is as important as selecting the signal processing chain. The center frequencies and maximum gains of the bandpass filters (Section 3.2) and delay durations in the second mapping (Section 3.3) were calibrated through iterations of playing and adjustment. Small changes to these ranges significantly altered how the instrument responded to gesture, affecting stability and perceived expressivity. Thus, responsiveness is not inherent to the filters, but emerges from careful alignment of parameter scaling, feedback dynamics, and embodied control.

5.2 Performance

When preparing for performance, we “freeze” the signal chain to stabilize the instrument behavior. This constraint allows internalization of mapping responses and development of strategies for recreating interesting textures.

However, the *Rumbler* resists strict reproducibility, and performance becomes a practice of attentive listening and navigation—recognizing when interesting states arise and learning how to sustain or gently steer them.

These experiences align with themes of agency, discovery, and (un)control reported by other feedback musicians [5]. The *Rumbler* operates as a partially autonomous partner with its own tendencies. The performer shapes boundary conditions and responds to emergent behavior rather than shaping exact outcomes.

6 Future Work

Future work broadly spans three dimension of hardware, software, and performance. First, we may experiment lining the inside of the tube with different materials; more sound absorbant materials may minimize indirect reflections and produce purer sounds whereas more reflective materials may produce more complex sounds via indirect reflections. Second, while whereas mapping design was primarily driven by iterative experimentation and perceptual evaluation, a careful frequency response analysis of the acoustics of the tube in different configurations may provide ways to simulate and test different signal chains more consistently. Finally, we want to explore alternate inputs: no-input, fixed media, pitches tuned to a scale, or sounds of another musician.

7 Ethical Standards

The authors are aware of no potential conflicts of interest.

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