Embedded Digital Shakers: Handheld Physical Modeling Synthesizers

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ABSTRACT

We present a flexible, compact, and affordable embedded physical modeling synthesizer which functions as a digital shaker. The instrument is self-contained, battery-powered, wireless, and synthesizes various shakers, rattles, and other handheld shaken percussion. Beyond modeling existing shakers, the instrument affords new sonic interactions including hand mutes on its loudspeakers and self-sustaining feedback. Both low-cost and high-performance versions of the instrument are discussed.

Author Keywords

Shaker, percussion, PhISEM

CCS Concepts

•Applied computing → Sound and music computing; •Computer systems organization → Embedded systems;

1. INTRODUCTION

Shakers are an ancient and ubiquitous class of musical instruments, encompassing a great diversity of timbres, materials, and designs. Gesturally speaking, they are deceptively simple to interact with, and often require practice to attain truly musical control. Indeed, the continuous nature of the playing gestures involved very much defies a MIDI-like "note-on, note-off" paradigm when reasoning about playability.

In [3], Cook describes a generic algorithm for synthesizing the sound of various shakers and rattles known as physically-informed stochastic event modeling (PhISEM). It is a form of stochastic granular synthesis rather than explicit physical modeling; simulating the collisions of dozens if not hundreds of "beans" is far too computationally expensive to execute in realtime at audio sampling rates, so the PhISEM technique resorts to the statistical properties of shaker physics, which can be conveniently emulated using exponentially-decaying envelopes. In brief, when there is more energy in the system the collisions within the shaker will be more intense, and thus contribute more sound energy. This system energy decays exponentially, and a Poisson process is used to, at random intervals, add this energy to another decaying envelope which is applied to a noise signal. The effect is one of many overlapping small envelopes, and this excitation signal is then run through one or more filters which approximate the resonant properties of a given shaker.

In [2], Cook describes the design of controllers which can be used to interact with PhISEM models; early controllers simply generated MIDI data from their sensors, but the *Haptic Maraca* was designed with a built-in haptic actuator so gestural control and sound production could be co-located. The *bEADS Extended Actuated Digital Shaker* [4] builds upon these concepts by incorporating both a loudspeaker and haptic actuator into the body of the instrument. These instruments, however, still depend on a laptop for sound synthesis.

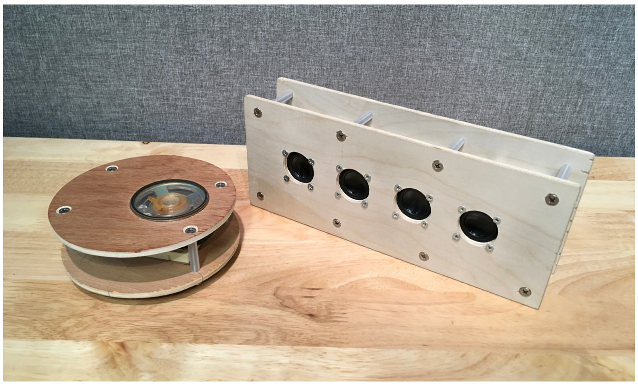

Figure 1: The eShaker (left) and eChocalho (right).

2. DESIGN

The instrument's body is made of plywood plates fastened together with standoff screws, facilitating quick construction. No attempt was made to design the enclosure as a conventional (i.e. sealed or ported) loudspeaker cabinet, nor to make the body resemble any existing shaker. Though future refinements may occur in this area, we feel that the current enclosure design does not adversely impact playability; instead, the unusual sound radiation pattern and body shape can offer new, unexpected musical interactions.

Power is provided by a lithium polymer battery, with onboard charging managed by an Adafruit Micro Lipo module. Motion is sensed by a Sparkfun ADXL337 analog accelerometer, and amplification is provided by a PAM8403 stereo 3-watt class D amplifier. These modules are all mounted to a small printed circuit board containing all necessary supporting components, voltage regulation, and connectors (Figure 2). The Mozzi sound synthesis library [1] is used for sensor input and audio rendering.

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2.1 eShaker

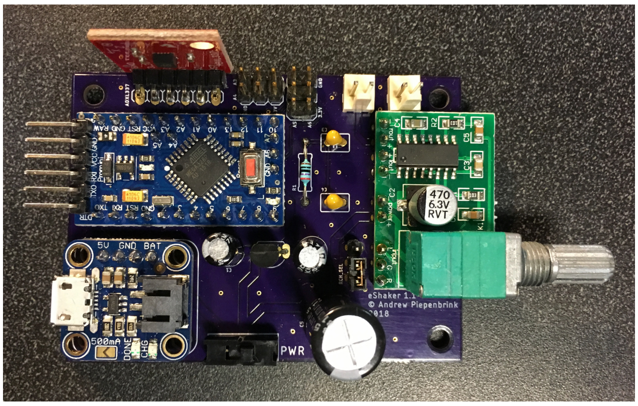

Figure 2: eShaker PCB with (clockwise from right) PAM8403 amplifier, lithium battery charger, Arduino Pro Mini, and analog accelerometer.

One of the goals of this project was to optimize for cost; to this end, we turned to the ATMega328, the microcontroller found in the Arduino. The ubiquity of the Arduino platform means the ATMega328 is well-understood and broadly supported; we believe the choice of this chip makes our work more accessible to the NIME community and beyond. Unfortunately this platform has very limited processing power, necessitating the use of fixed-point arithmetic in the synthesis algorithm.

2.2 eChocalho

We have developed a second variant of the instrument using the Teensy 3.6, a much more powerful microcontroller than the ATMega328. The processor is a 32-bit ARM Cortex M4F, running at 180 MHz with support for hardware floating point instructions. This increased processing power enables the execution of more sophisticated instrument models like tambourines and sleighbells, which require a larger number of filters which must be detuned in real time. We have dubbed this variant the eChocalho, after the Brazilian tambourine-jingle rack used in samba.

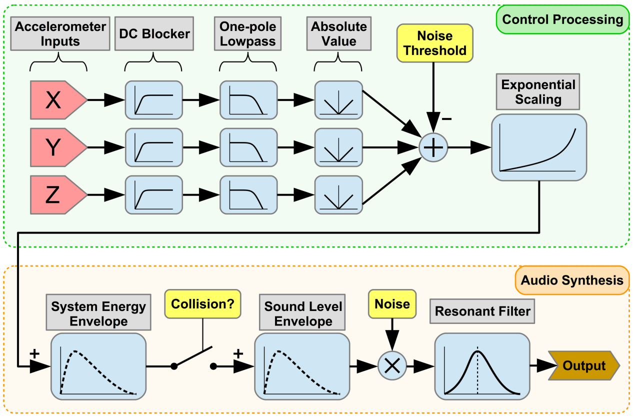

Figure 3: System architecture.

3. RESULTS

It was a conscious decision to avoid the inclusion of sound-modifying controls as part of the interface; acoustic shakers do not have these, and we felt that providing such controls could be distracting, particularly in early stages of development. With the accelerometer as the only sensor, careful attention was given to conditioning its signals (Figure 3), which are each sent through a DC-blocking filter to remove the constant acceleration due to gravity, then a low-pass filter to reduce noise. The absolute values of each axis's motion are summed, thresholded for noise, and slightly exponentiated to enhance dynamic range for accented gestures. Without this thresholding and filtering, not only was the instrument more difficult to play, but outside observers noted that the correspondence between gesture and sound became much less convincing.

The constrained playing affordances of the instrument led to the discovery of some unusual performance techniques. The loudspeaker is mostly unidirectional, but the open enclosure radiates some sound from its sides as well; twisting and sweeping gestures can thus be used for timbral effects. The larger speaker in the eShaker can be muffled or cupped with the hand, further expanding the range of sounds available. Self-sustaining feedback also emerged as an effect, wherein high levels of low-frequency content would perturb the accelerometer enough to continue exciting the synthesis model. The phenomenon was initially regarded as a flaw and corrected with a high-pass filter, but we later recognized that it could be exploited for musical purposes.

4. CONCLUSION AND FUTURE WORK

We have demonstrated an embedded physical modeling instrument for synthesizing the sounds of shakers. Both low-cost and high-performance versions have been built, each with their own strengths, weaknesses, and implications.

A non-exhaustive list of future developments includes wireless connectivity, onboard datalogging, more powerful amplification, and miniaturization. As the system's design matures and stabilizes, digital fabrication will be employed to ease production of the instrument in quantity. It is our hope that when it can be deployed in larger user studies, the instrument may serve as a research tool for better understanding how musicians interact with shakers.

5. REFERENCES

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