Mechanoise: Mechatronic Sound and Interaction in Embedded Acoustic Instruments

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ABSTRACT

The use of mechatronic components (e.g. DC motors and solenoids) as both electronic sound source and locus of interaction is explored in a form of *embedded acoustic instruments* called *mechanoise* instruments. Micro-controllers and embedded computing devices provide a platform for live control of motor speeds and additional sound processing by a human performer. Digital fabrication and use of salvaged and found materials are emphasized.

Author Keywords

Mechatronic, Embedded Acoustic Instruments, Digital Fabrication

CCS Concepts

•Applied computing → Performing arts; Sound and music computing;

1. INTRODUCTION

The implementation of actuators and mechatronics as a means to enhance musical instruments has seen extensive research and development in the past several years. Electromagnetic actuators have been added to acoustic instruments to induce computer-controlled resonances meant to coexist with gestures by a human performer [5]. The field of robotic musicianship frequently employs mechatronics to replace or augment human performance on acoustic instruments [4]. Mechatronics have also been used to execute gestures transmitted from one or more remote locations[1] or distribute gestures among multiple performers and instruments [6].

The origins for the notion of mechanical noise itself as a sound source for musical purposes can be traced far back to Luigi Russolo's seminal 1913 Futurist Manifesto "The Art of Noises" and the related *Intonarumori* instruments. More recently, works like Zareei et al's *Rasper* [8] and *Mutor* [7] projects utilize the acoustic sonic output of mechatronics (DC motors and attached apparatuses) as sound sources for sound art performance and installation pieces. Similarly, the *mechanoise* instruments presented in this paper also feature mechatronic components as sound sources unto themselves, rather than a means to excite acoustic instruments. However, the *mechanoise* approach relies on amplification and processing of the fluctuating electromagnetic fields produced by the motors and solenoids through magnetic pickups. Additionally, direct live control and physical co-location of the mechatronic components to the performer promotes further exploration of nuanced manual manipulations.

[1]Paul Stapleton and Tom Davis' "Ambiguous Devices" `http://www.paulstapleton.net/portfolio/tomdavis`

2. OBJECTIVES

The objectives of *mechanoise* instrument design draw on multiple established areas in NIME research:

Foster direct human-mechatronic interaction. The interest in creating a shared interaction between mechatronic elements and human performers was partially inspired by Gurevich's *Stringtrees* [3]. Like *Stringtrees*, *mechanoise* instruments provide human performers with real-time control over the speed of mechatronic actuations. While the strings in *Stringtrees* act as an acoustic intermediary between the mechatronics and the human performers, providing a shared locus for their actions, this auxiliary acoustic element is removed from *mechanoise* instruments.

Realize infra-instrument aesthetic in embedded form. It was presumed from the outset that, even with continuous control, the sonic output of motors and solenoids would be somewhat one-dimensional and "incomplete" as the foundation for an expressive musical instrument. Bowers and Archer suggest that such limited means for interactive and sonic potential can serve as an ideal platform for further digital processing and enhancement in their work with *infra-instruments* [2]. Berdahl's *embedded acoustic instruments* provide an ideal framework around which to build standalone self-contained instruments with built-in micro-controllers, audio processing, and amplification [1].

Promote non-autonomous mechatronics. Whereas the rich and varied field of robotic musicianship centers on systems with innate or automatic behaviors often carried out through mechatronics [4], *mechanoise* instruments deliberately feature no such pre-programmed actions.

3. DESIGN

Explorations of *mechanoise* concepts were initially performed on a single DC motor prototype instrument (see Figure

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3). A second iteration named Mechanoiser Sr. was subsequently built around four different mechatronic components - three different DC motors and one solenoid. This section will focus on the second device.

Mechanoiser Sr. was designed and built with a combination of a lasercut enclosure construction, 3D-printed actuator mounts, and salvaged DC motors and solenoids (see Figure 2(a)). Using digital fabrication techniques ensured fast prototyping and proper fit for found and salvaged materials, which included surplus motors from previous projects or removed from old thrift-store VCRs. Embedded amplification and speakers installed in an audience-facing orientation enable performances without supplemental sound reinforcement.

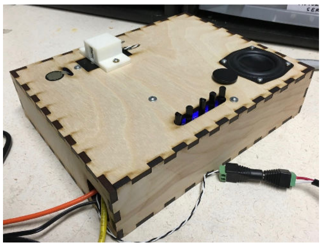
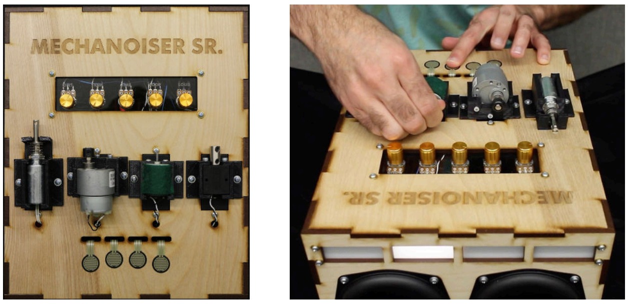


Figure 1: Mechanoiser Jr. prototype

Motor speed is controlled by the performer via a set of four force-sensing resistors (FSRs) which are connected to an Arduino Nano. The Arduino outputs PWM signals proportional to the pressure exerted by the performer, which are sent to a simple custom motor driver circuit. Each actuator is mounted directly over an inexpensive magnetic bass guitar pickup. The pickups amplify not only the rotational oscillations of the motors and percussive actions of the solenoid, but also electrical noises induced by the fluctuations of the PWM signals from the Arduino. The outputs of all four pickups are summed to a mono signal and processed through a custom Pure Data patch on a Raspberry Pi 2 running Satellite CCRMA[2]. Though audio processing is limited to simple effects - distortion, amplitude modulation, and delay - they add considerable depth to the expressive capabilities of Mechanoiser Sr.



(a) Top view (b) In use

Figure 2: Mechanoiser Sr.

4. OBSERVATIONS

Both Mechanoiser Jr. and Mechanoiser Sr. were presented at local "maker faire" exhibitions and in performance settings.

The maker faire demonstrations tended to attract younger participants. Observing children interacting with the devices was interesting as, despite encouragement, they showed limited interest in manually manipulating the actuators and were perfectly content to listen to the sustained sound of the DC motors. Several made comments about how much they enjoyed that it could sound like car engines.

In my own explorations through demonstrations, practice, and performance, I have found that while the sound of the mechatronics themselves is indeed one-dimensional, exploring the limits of each actuator through subtle pressure changes on the FSRs and manual manipulations of the actuators adds considerably to the expressive possibilities of *mechanoise* instruments (see Figure 2(b)). Finding and staying near the limits of the system (e.g. the PWM threshold at which each actuator is activated or friction required to stall each motor) usually provided the most compelling outcomes, allowing for more interesting textures or rhythmic patterns. Additionally, manual manipulations revealed that spinning the motors without applying current produced usable sounds. Changing audio processing parameters revealed still further potential (e.g. rhythmic pulses through delay and tremolo, liberal use of distortion leading to feedback, etc).

[2]`https://ccrma.stanford.edu/~eberdahl/Satellite/`

A short demo video of Mechanoiser Sr. can be found at `https://youtu.be/7YX5e65l6L0`.

5. CONCLUSIONS

Initial work with mechatronics as a direct electronic sound source shows some promise as a foundation for new musical instruments and interactions. The inherently customizable approach of conceptualizing sound design options using materials and components at hand and constructing original enclosures and mounting brackets is a rewarding process not unlike other NIME practices or a contemporary percussionist's preparatory routine. In particular, exploring the affordances and tolerances of the mechatronics and embracing and enhancing the noisy and incidental sounds that one often struggles to mitigate through design compromises (e.g. those of mechanical sounds and electrical interference) is especially productive and refreshing.

6. REFERENCES

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