INTERACTING WITH SOLENOID DRUMMERS: A QUANTITATIVE APPROACH TO COMPOSING AND PERFORMING WITH OPEN-LOOP SOLENOID-BASED ROBOTIC PERCUSSION SYSTEMS

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ABSTRACT

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1. INTRODUCTION

Among instrument families, percussion instruments are perhaps the most popular candidates for conversion to automatic and mechatronically-augmented systems. The primary reasons for the relative popularity of such instruments are largely due to the comparative simplicity of drums and other percussion objects when compared to more complex families such as string and woodwind instruments.

In spite of their apparent simplicity, mechatronic drums are not without their share of problems and challenges to the musician attempting to interact with such systems through composition and performance. In order to reliably work with existing systems, the artist needs to consciously compensate for three primary physical shortcomings in the currently available open-loop robotic percussion systems: the problem of latency between the output event and the mechatronic system's physical response, the problem of physical limitations of the speeds at which notes can be repeated by mechatronic drummers, and the problem of nonlinear output dynamics in response to a linear input value. This paper will focus on the last issue, that of the nonlinear dynamic response and how to work with existing musical robots which use open-loop solenoid-based percussion systems.

After a brief history of significant work done in the field of musical robotics and automatic musical instruments in Section 2, Section 3 will introduce the systems as tested and will more thoroughly explore the problem of nonlinear dynamic response and why composers and performers find it important to take into account during composition and performance. Section 4 attempts to quantify the dynamic response of the TrimpTron, a rotary solenoid-based drum beater. Finally, Sections 5 and 6 discuss integrating solutions proposed in prior section and overcoming the problem altogether via closed-loop approaches. Section 6 discusses such closed-loop approaches and introduces current and future work in the field of solenoid-based mechatronic percussion systems.

2. RELATED WORK

Composers and instrument builders have been fascinated by automatic musical instruments for centuries. [CITE EARLY HIST.] and [OTHER EARLY HIST] describe many of these early systems, most of which used punched or pinned rolls and barrels to store musical information. With the advent of the loudspeaker, automatic instruments faded into the background.

The later decades of the 20th Century saw a resurgence in such systems, with the emergence of several notable workers. Sound artist Trimpin, whose works are described in [TRIMPIN BOOK], has done a great amount of personal research and work on solenoid-based percussion systems, going so far as to experiment with feedback techniques and drum beaters utilizing multiple solenoid coils. In addition to Trimpin, fellow early musical roboticist Godfried-Willem Raes, founder of the kinetic arts collective Logos Foundation, has created many open-loop solenoid-based percussion instruments [RAES CMJ].

The last two decades have musical robotics arise as an academic discipline. [KAPUR 2005] describes many academic artists who conduct and share research toward artistic ends. Several current researchers have focused on mechatronic percussion systems: Eric Singer's LEMUR collective consists of an array of open-loop solenoid-based systems used in an installation context as well as tools for live performance [LEMUR]. Researcher Gil Weinberg has in recent years focused on a variety of percussive systems. Weinberg's work has revolutionized many aspects of human/computer interaction [WEINBERG].

Second author Ajay Kapur's research (exemplified in [AJAY SOLENOID] and [AJAY BOOK]) has paved the way for this paper, laying down a foundation of quantitative study of solenoid-based percussion systems. Kapur’s more recent work with collaborator Michael Darling, which provided the authors with a motivation for this paper, is described in Section 3.1.

3. SOLENOID-PERCUSSION SYSTEMS

Solenoids are mechanically simple, providing instrument builders with a straightforward means of converting electrical signals into motion. Due to this simplicity, solenoids are often used as the basis for mechatronic drum systems. The following subsections will describe the authors' solenoid-based systems as well as the challenges in creating dynamically predictable performances and compositions with such systems.

3.1. The Machine Orchestra

The Machine Orchestra, developed by second author Ajay Kapur and collaborator Michael Darling, is the performance-oriented outlet for the first two authors' musical robot compositions. Within the framework of the Machine Orchestra, new mechatronic designs are built and tested in a real-world interactive performance scenario. [TMO CMJ] details the ensemble. The necessities of performing with solenoid drummers in The Machine Orchestra provided the impetus for the work done in this paper: creating a workflow for interacting with open-loop solenoid percussion systems.

3.1.1. The KarmetiK NotomotoN: TrimpTron and KalTron

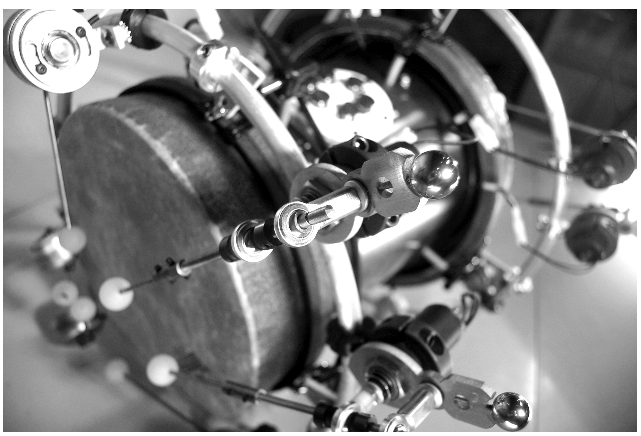

Figure 1. The KarmetiK NotomotoN, with KalTron and TrimpTron beaters visible.

The KarmetiK Notomoton, described in [NOTOMOTON], is a robotic drummer which represents the most advanced integrated solenoid-based drummer in the Machine Orchestra. There are two types of drum beaters used in the NotomotoN: the TrimpTron, which utilizes a rotary solenoid, and the more mechanically intricate KalTron, which utilizes a linear pull-type solenoid. Both designs are by Michael Darling, closely inspired by work done by Trimpin. Figures 2 and 3 illustrate the key components of both types. The NotomotoN has become a central player in the Machine Orchestra; with its integration in the orchestra, the problem of the highly nonlinear dynamic response of its beaters has become quite obvious.

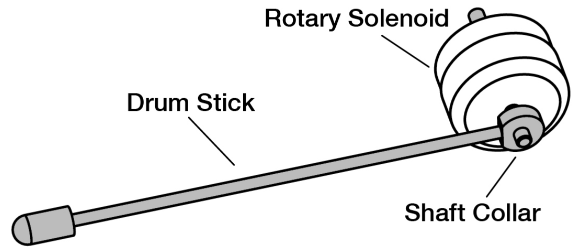

Figure 2. The components of a rotary-style solenoid percussion beater, similar to the TrimpTron beater.

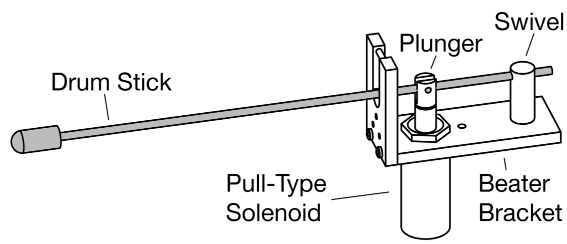

Figure 3. The components of a pull-type solenoid percussion beater, similar to the KalTron beater.

3.2. Motivation: The Problem of Dynamic Response

As mentioned in this paper's introduction, solenoid drum beaters do not produce linear output loudness in response to linear input values. This nonlinear dynamic response proves highly troublesome when corresponding with composers and performers who do not have access to the instrument: while the output dynamics are specified as MIDI CC values ranging from 0-127, the nonlinearity means that those without access to the instrument can not know how the solenoids will behave in real-world performance scenarios.

As an example, visiting composers have found that pre-sequenced compositions behave unpredictably when played on the NotomotoN's TrimpTron beaters. A perceived need to more closely quantify the actual behaviour of the beaters on the NotomotoN has led to the work undertaken in the following sections. It is the authors' hope that this paper can provide background and reference to future collaborators and guest composers when preparing to work with the myriad of open-loop solenoid drum systems of the Machine Orchestra.

4. EXPERIMENTS

4.1. Experimental Setup

The remainder of the work shown in this paper will concentrate on our attempts to understand the nonlinear dynamic response of the TrimpTron rotary solenoid beater. To determine the degree to which the TrimpTron is nonlinear, experiments were undertaken to compare the input values with actual output values.

4.1.1. Hardware

The hardware used in the dynamic range tests is divided into two sections: the solenoid driver hardware and the datalogging hardware.

The solenoid driving hardware is similar to that used by the Machine Orchestra. It consists of a microcontroller using the HIDUINO firmware suite [HIDUINO] to convert MIDI HID values to logic-level control voltages. The logic level signals are then amplified using power MOSFET chips capable of driving the 24V DC solenoids. Dynamics are controlled using a standard chopper drive method of solenoid control.

The datalogging section consists of hardware which records the output power created by the drumstick striking a surface. To test the dynamic response of the TrimpTron rotary solenoid beater, a piezoelectric pickup was used. The piezoelectric pickup output data to an Alesis D4 16 bit drum module. The D4 drum module converted the piezo's pickup to MIDI CC values, which were transmitted to datalogging software on a PC.

4.1.2. Software

To properly analyse the values picked up by the Alesis D4 drum module, the D4's output range had to correspond with the maximum value output by the TrimpTron: to normalize the MIDI values output by the D4 against the velocity commands input to the TrimpTron, correlation software was written using the ChucK programming language [CHUCK]. The correlation software sent a series of values to the TrimpTron and compared those with the values returned by the D4.

To gather dynamic response data, a linear series of output values were transmitted to a HIDUINO-equipped AVR microcontroller. For each of the linearly increasing output messages sent to the solenoid via the microcontroller, the corresponding value received by the piezo pickup was recorded. The following subsection discusses the results obtained by the tests.

4.2. Results

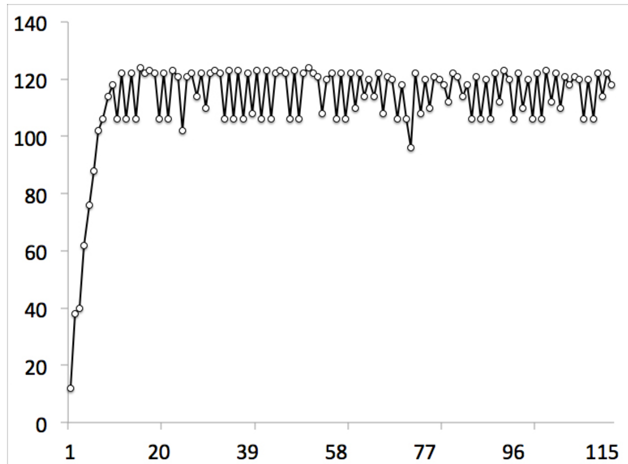

Figure 4. The dynamic response of a 128 linear output events (X Axis), compared to the recorded, calibrated output value (Y-Axis).

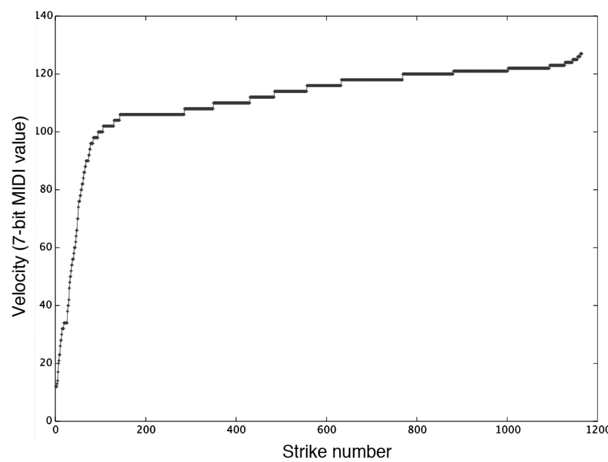

Figure 5. The dynamic response of a TrimpTron rotary solenoid drum beater averaged over nine trials. The nonlinearity of the response is clearly visible, with velocities from 0-100 underrepresented and higher velocities favoured.

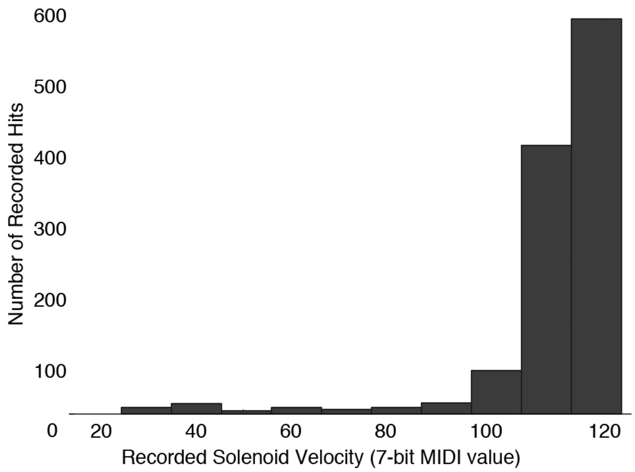

Figure 6. A histogram of the dynamic response of 1152 recorded strikes of a TrimpTron. The tests consisted of nine linear iterations of output velocities from 0-127, with results favouring values above 100

4.3. Experimental Conclusions

5. INTEGRATION

5.1. Calibration and Lookup Tables

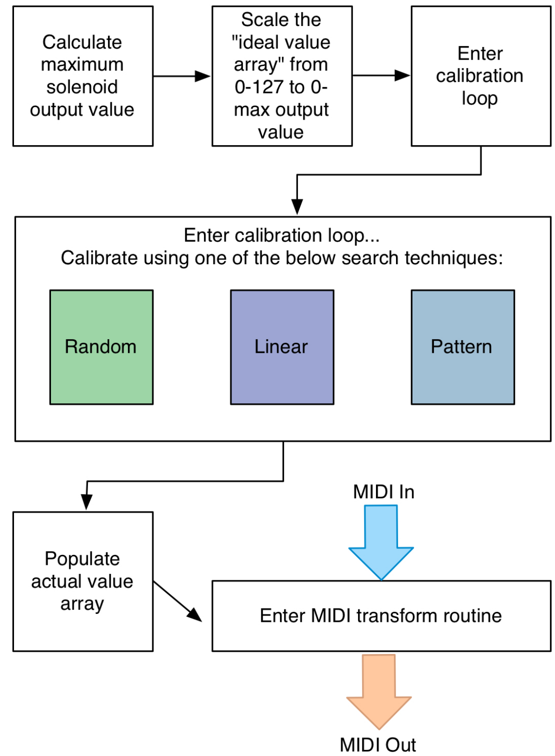

Figure 7. The signal flow for a pre-performance calibration routine for solenoid drum beaters.

5.2. Traditional Dynamic Markings

6. CONCLUSIONS

6.1. Closing The Loop

6.2. Current and Future Work

7. REFERENCES

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