Telemetron: A Musical Instrument for Performance in Zero Gravity

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ABSTRACT

The environment of zero gravity affords a unique medium for new modalities of musical performance, both in the design of instruments, and human interactions with said instruments. To explore this medium, we have created and flown Telemetron, the first musical instrument specifically designed for and tested in the zero gravity environment. The resultant instrument (leveraging gyroscopes and wireless telemetry transmission) and recorded performance represent an initial exploration of compositions that are unique to the physics and dynamics of outer space. We describe the motivations for this instrument, and the unique constraints involved in designing for this environment. This initial design suggests possibilities for further experiments in musical instrument design for outer space.

Author Keywords

Musical instrument design, musical gesture sensing, humans, space technology

CCS Concepts

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

1.INTRODUCTION

The history of the design of musical instruments, while extremely diverse, is constrained to the conditions of gravity on Earth. As humanity progresses to a species that increasingly travels and lives in space for longer durations, concerns broaden from that of simply surviving in space to what human culture will be like in this new environment. To this end, as part of the MIT Media Lab's Space Exploration Initiative, we have built and tested the first musical instrument specifically designed to be played in zero gravity. This instrument, named the "Telemetron", consists of a chamber containing a number of electronic "chimes" outfitted with gyroscopes and wireless communication, allowing for a manipulable instrument that captures the poetic motion of objects in zero gravity, and translates this movement into music. The instrumented interior components collide with each other and the walls of the chamber when shaken. Because of the conditions of zero gravity, the chimes stay afloat indefinitely. Until they are damped out, they continue to move and collide. Sound from the instrument is created by detecting collisions and the speed of rotation of each of the internal components via gyroscope and translating these rotational values to messages on independent MIDI channels. The resulting aggregate events create a concert of sounds as each of the internal components are subject to the same agitation.

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2.RELATED WORK

Instruments based on colliding elements and the friction of grains have been created in various forms. Our device has a legacy in these instruments as well as the dynamics of wind chimes.

2.1.Design & Construction for Floating Objects

While not designed for zero gravity, wind chimes have similar dynamics to our design. Bart Hopkin wrote the book "Wind Chimes: Design and Construction", published by Experimental Musical Instruments [5]. In it, he details considerations for creating suspended instruments that generate music by the collisions of their constituent parts. The Telemetron has a number of elements in common with this style of musical object, from the size and shape of each element, to the tuning of the set of components to create the intended composition.

2.2.Motion and Gesture Detection In Electronic Instruments

The design of the Telemetron also draws from designs that leverage the detection of speed and motion. Instrumented elements with inertial sensors have been known for many decades. In their paper "Portable percussion MIDI controller" Guarnizo and Rios [4] describe their "accelerometer drumsticks" that leverage the detection of 3-axis motion in order to create MIDI messages.

Other novel gestures and interactions have been leveraged for the creation of musical notes. Georg Essl and Sile O'Modhrain created the Scrubber [2] and the Pebblebox [3], taking advantage of the unique interactions afforded by friction and physical grains of material. Inertial performance has also been explored in the wireless gestural accelerometer-based instruments created for "The Urban Musical Game" by Rasamimanana, et al. [11]

Further experiments with gestural control came from the design of an augmented baton. Keane and Wood's MIDI Baton [6] integrate gesture response in real time. Teresa Marin and Joe Paradiso's "Digital Baton" [8] added functions, integrating pressure sensors to augment natural gestures with additional ability to capture interactions from the performance. Paradiso and Hu created "Expressive Footwear" [9], augmenting the foot to capture the poetic human gestures of dance. Related work was done in wireless IMU sensors designed to capture the expressive gestures of dancers [1], providing precursor work to the new expressive gestures we have attempted to capture with our work in a new set of environmental conditions. Also relevant to this space is the gesture capture work that

Matt Reynolds and team did with Neil Gershenfeld for the Karamasov Brothers [10], enhancing their juggling batons, expanding the expressive capacity of a performance that involves the human body interacting with an instrument spinning in free fall.

2.3.Instruments In Space

We have additionally been inspired by the history of instruments that have traveled to space with human travelers. A number of instruments, designed for performance on earth, have been performed in space. Some of the earliest examples of this are the harmonica and set of bells taken on the Gemini 6a mission. Other instruments that have been carried to space include a keyboard, a flute, a guitar, and a didgeridoo. While ultimately a fated mission, Robert McNair brought a saxophone on the Space Shuttle Challenger flight with the intention of recording a solo on the NASA shuttle orbiter.

Each of these instruments needed to be vetted before flight, as their construction poses potential hazards, from potential electromagnetic radiation in an electric keyboard to the flammable nature of the acoustic guitar, pointing to the unique design considerations of instruments both intended for space and not.

Astronauts who have brought instruments to the International Space Station have referred to them as a “link to home” [12], evidence of how material culture from Earth plays a unique and important emotional component in outer space.

3.DESIGN

There are a unique set of design constraints to consider when creating an instrument both for zero gravity, and for the momentary dynamics of a parabolic flight, which led to material, functional, and spatial choices in the design of Telemetron. Polycarbonate and sufficiently thick metal were chosen to mitigate the risk of shattering, preventing the chance of small pieces floating and endangering others in the craft during flight, and avoiding the possibility of impalement.

While the shape of a dodecahedron was chosen in part because it would reduce sharp angles that might pose danger, we consider this a poetic choice. The form nods to suggestions that the shape of the universe is a dodecahedron [7], as well as to the form of the Cupola observatory on the International Space Station.

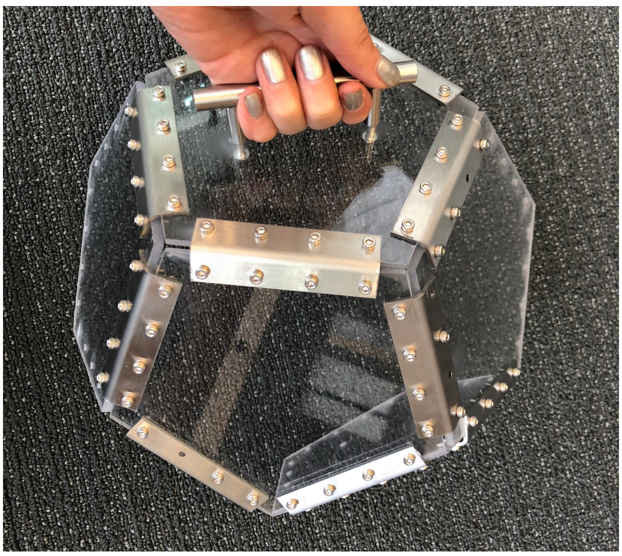

Figure 1. The design of the Telemetron chamber.

3.1.Physical Interaction and Restraint

In order to provide the unique degree of safety required during zero gravity flights, the Telemetron was outfitted with a series of handles that functioned both to manipulate the instrument as well as to hold onto it so that it would not injure others during gravity transitions. In addition, an eyebolt was added to one of the instrument faces to secure it to the floor of the aircraft. Attaching the instrument to the floor via climbing rope and carabiner constrained its radius of movement a distance that prevented contact with other experiments, without unnecessarily constraining the motion of performance.

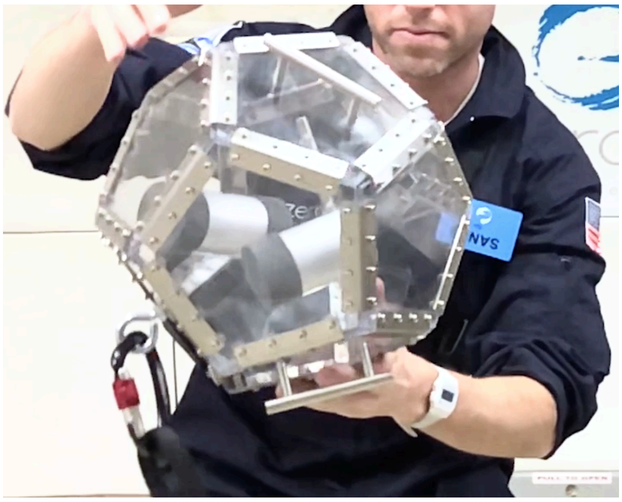

Figure 2. The chimes floating inside of the Telemetron.

3.2.Hardware & Electromechanical Systems

Due to the nature of electromechanical system of accelerometers, this sensor is not sufficient to capture motion in zero gravity. Gyroscopes were necessary to capture rotational momentum that we hoped to translate into MIDI notes during zero gravity performance. For each “chime” we included inside of the Telemetron, we build a circuit containing a 3-axis digital gyroscope, an nRF24L01 transceiver for data transmission, and an AVR microcontroller to integrate these components. Each of these circuits were enclosed in an aluminum cylinder thin enough not to inhibit RF transmission.

Attached to a collector/synthesizer laptop via USB cable was a receiver module of identical design to the circuit used for the chimes, though without a gyroscope module. This receiver module was programmed to receive datagrams from the multiple chimes, and retransmit each of these to a MIDI processing and capture program designed to split each set of rotational momentum values into a separate MIDI channel, such that each chime could be represented as an independent MIDI instrument and synthesized separately.

3.3 Software

Upon retransmission from the receiver module, gyroscope values were captured by custom software written in the Processing language. This software translated each of the chime IDs into MIDI channels. Each of these MIDI channels were then used to transmit gyroscope data. In order to represent two of the axes of rotation, the X-axis values were interpolated to MIDI pitch values, and the Y-axis values were interpolated to velocity values. These parameters, combined into single notes, creating dynamic notes that were a direct result of the motion of each chime. These MIDI notes were then recorded via MIDI bus in Logic Pro X for synthesis, performance, and data capture.

4.RESULTS

The instrument was flown with and performed by its two creators (Sands Fish and Nicole L'Huillier) on a flight chartered by Zero G corporation, along with a number of other (unrelated) experiments. The flight progressed through 20 parabolas, starting with two parabolas to simulate Martian gravity, and one parabola to simulate Lunar gravity. The remaining 17 parabolas created a micro-gravity environment equivalent to the zero gravity conditions of outer space. Each parabola lasted for approximately 17 seconds, providing a series of brief opportunities for performance and recording. Each of these parabolas are identifiable in the time-series visualization of captured MIDI notes.

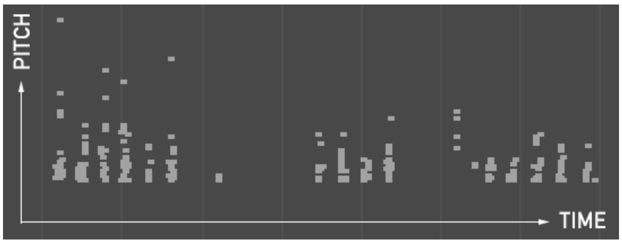

Figure 3. MIDI data collected on each flight parabola.

A number of gestures—including spinning, shaking, and setting the object into a controlled drift—were tested during the series of performances during the flight. These gestures focused how zero gravity might afford performances that would not be possible in earth's gravity. We were able to, for example, set the instrument spinning and remove our hands from it completely, allowing for an interactive dance with the instrument that would otherwise not be possible.

Reviewing the synthesis of data captured from the 18 parabolas recorded (Figure 3) after the flight, it is clear that, in contrast to some generative performances designed around randomness, the Telemetron tends to convey a sense of collective performance, as each of the chimes impacts and affects the others.

Figure 4. The first zero gravity Telemetron performance.

5.CONCLUSIONS

It is clear from our initial performance of the Telemetron that the environment of zero gravity, found in space and simulated in parabolic flights, affords a unique set of physical dynamics and allows for a range of modalities that are not possible on Earth. The multi-element design of the Telemetron allows for a performance that captures the dynamics of objects in zero gravity, while, like wind chimes, allows a single gesture to create a concert of events. This provides the ability for the physics of zero gravity dynamics to be "performed". We have observed that the shape of the chamber constrains these dynamics in a unique way and that different chamber shapes could be constructed to refine the type of interactions of its internal elements, creating a different performance. Zero gravity also affords the opportunity to set objects in motion that will continue autonomously until damped by air friction or collisions, providing unique gestural opportunities, perhaps extending to the possibility of interaction with a number of instruments by a single performer. In general, we believe zero gravity provides a large potential space for experimentation in the design of musical instruments, resulting in novel forms of composition unlike any composed by humans before.

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