Concerto for Ferrofluid and 7 String Violin – An Interactive Musical Instrument

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Concerto for Ferro-Fluid and 7-String Violin is a duet between a 7-String Violin and a novel instrument, in which sound is transferred from the medium of air to the magnetic field, visible through magnetic fluid that responds in real time. The Ferro-instrument has no sound of its own — rather, it captures the “voice” of whatever is played into it and allows one to freeze that sound in time and change it, using magnets to alter the quality of sound.

CCS Concepts: • **Human-centered computing → Sound-based input / output**; • **Applied computing → Sound and music computing**.

Additional Key Words and Phrases: hyper-instrument, ferrofluid, real-time sound interaction, magnetic field, electronic control

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Fig. 1. Real-time Hyper-instrument Performance (A. The ferrofluid patterns changes during the performance; B. The violinist is interacting with the ferrofluid; C. The DJ joins the interaction by controlling two permanent magnets.)

1 INTRODUCTION & OVERVIEW

Computational material and engineering help us to understand material behavior and mechanisms and to explore the potential applications of the material in the real world. It largely influences the future of human-computer interaction fields by providing new programmable mediums. Instead of making the material into multi-function applications, we are more interested to extend the ability of the material in a more poetic way during the interaction with music. We ask ourselves: what the future holds for sound creativity? Therefore, there are two aspects that we want to investigate in this artwork:

- Materials for Musical Tangible Interface: In 1997, Ishii Hiroshi emphasized the important transition from desktop digital devices to physical environment augmentation in his paper [1]. The tangible interface is becoming more and more paid attention to by researchers because it involves more senses of the human body during

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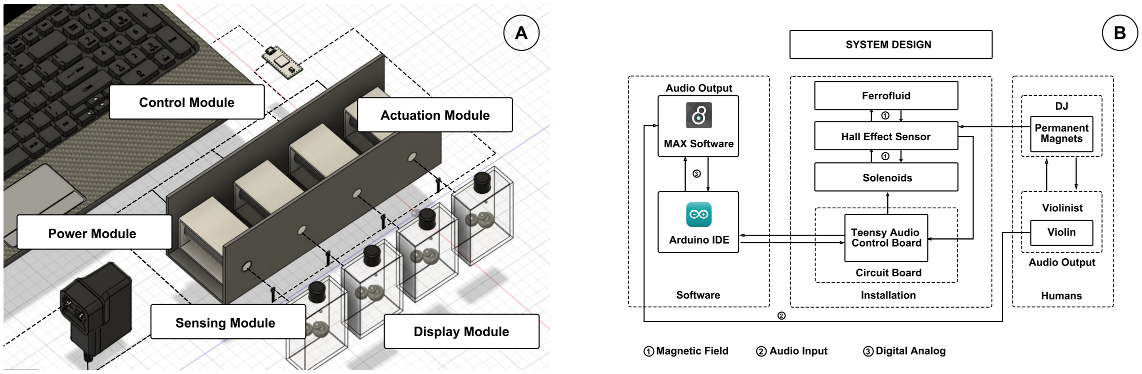

Fig. 2. Installation Mechanism Design and Human-computer Interaction Framework (A. Basic components for our hyper-instrument. B. System Design for the hyper-instrument)

the interaction, from traditional senses like "see" and "hear" and extends to interactions like" touch", "grasp" and "drop" etc, which helps to get rid of the "cold" and "isolated" digital screen and augment the real physical world by coupling digital information to everyday physical objects and environments. For example, researchers developed a knitted keyboard [4] and used it to compose music like a piano. Another example is MirrorFugue [5]. It visualizes the hand gesture of a remote collaborator so as to break the boundary of the two distant physical worlds and create a new music creation style. Both these two examples emphasize the experience of the musicians in the process of creating music. Therefore, how we can use the material to facilitate expression for both the performer and the audience?

- Sensor for Musical Expression: In 2001, during the conference of CHI, the concept of New Interfaces for Musical Expression was brought out and created a new trend for making innovative music interfaces. A number of NIMEs have appeared that seek to exploit the unique characteristics of hand, arm, and finger movements using different kinds of sensors and transfer the signal into sounds and music. For example, bend or shape sensing technology has been widely used to explore the relationship between shape and sound [3]. Some researchers create electronic music controllers using magnetic field sensing (hall effect sensors) [2]. Therefore, how we can use sensors to compute the liquid interactively and intelligently and also map the shape of the liquid to the sound reversely?

In this artwork, we re-imagine the scenarios of poetic human-computer interaction and develop an innovative hyper-instrument by introducing a magnetic liquid – ferrofluid in our real-time performance. During the performance, the ferrofluid can create dynamic patterns when the magnetic field changes. In the system, the magnetic field is controlled and manipulated by the sound created by the violin, the existence of permanent magnets, and the computer. We also compose a piece of music in order to show the beauty of the ferrofluid patterns to a large extent. We examine these aspects in detail and contribute:

- Provide an innovative way for computing liquid by controlling magnetic fields;
- Explore the relationship between the dynamic patterns of ferrofluid and the sound;
- Create an interactive performance that includes feedback loops between artists and the installations.

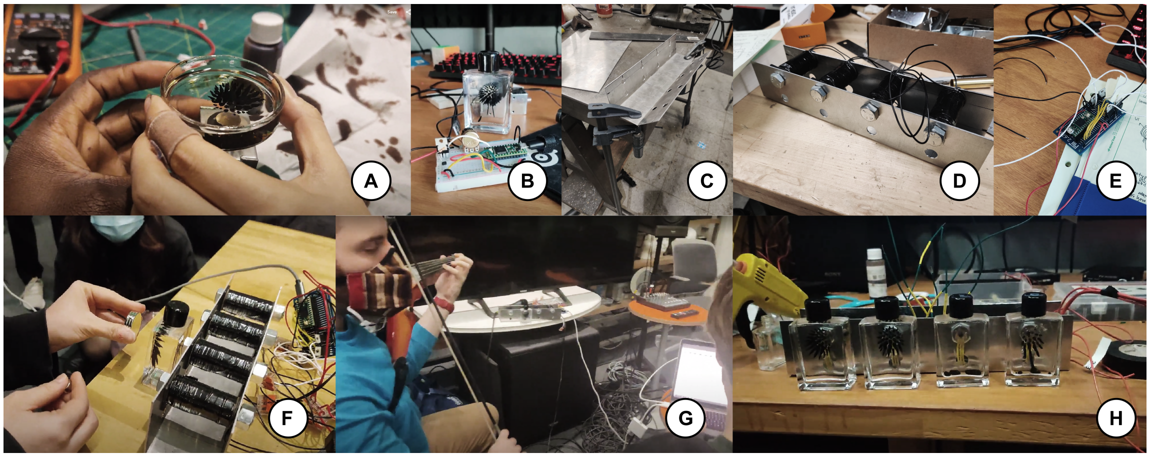

Fig. 3. Installation Design, Making and Testing (A.Exploring the ferrofluid pattern using a solenoid under the glass holder; B. Making one unit for testing the ferrofluid changes based on the change of the sound; C. Fabricating the installation case; D.Assembling the installation; E. Making the circuit board for the interaction; E. Testing the magnetic processing in real-time; G.Testing the audio processing in real-time; H. Final combination of the hardware, software and computer and creating the real-time interaction.)

2 MECHANISM AND TECHNIQUES

We achieve the artwork by considering both the hardware and software. The hardware part is responsible for manipulating and measuring the magnetic fields while the software part processes the sound signal and creates the real-time audio for the whole performance.

2.1 HARDWARE - MAGNETIC FIELD DETECTION & CONTROL

The ferrofluid instrument hardware consists of two main subsystems - manipulating and measuring the magnetic field. The manipulation is done using 4 electromagnets, which can vary the strength of the magnetic field by changing the voltage of each independently, in response to the sound input. The measuring is done using 4 pairs of Hall effect sensors - 2 for each electromagnet. By having two electromagnets, we can measure the magnetic field introduced by the magnet in the performer's hand while ignoring the field due to the electromagnets. This lets the Ferrofluid instrument detect the polarity and distance of a magnet from the coils.

All of the sensing and manipulation of the magnetic field is done digitally using a Teensy 4.0 Microcontroller that can receive audio over USB to vary the magnetic field in response to the music, as well as send the Hall effect sensor data back to the main computer over USB. The Ferro-instrument audio input is then analyzed in the frequency domain such that (from left to right) the ferrofluid responds to the magnitude of Volume, Bass, Mids, and Highs, of the input sound.

2.2 SOFTWARE - AUDIO PROCESSING

The sound signal flow is processed using Max MSP. When one of the solenoids is engaged, the magnetic field information is changed and transferred into Max. Using that information, there are four functions that are triggered using the magnets. When a magnet is engaged with the solenoid, the magnetic field grows exponentially. If the leftmost solenoid is engaged, a granular freeze is taken into effect, which traps any input coming into the device, and freezes that moment

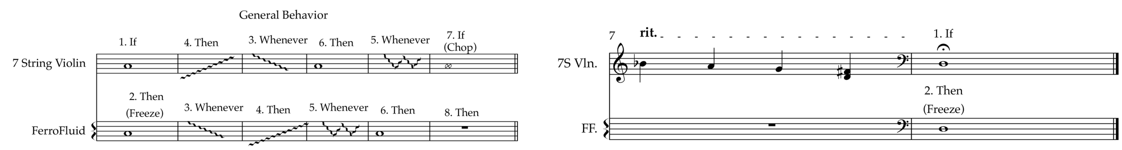

Fig. 4. Music that we composed for the final interaction.

in time. When a moment is frozen, it can be altered further. When a second magnet is engaging each of the remaining solenoids, different functions for altering sound are taken place:

- We have the option of altering the pitch of the frozen moment with either positive or negative values taken from the magnetic fields of the solenoids (controlled by the magnet). That's the second most left solenoid.
- We have an option of enabling/disabling an LFO, using the second most right solenoid.
- After the previous solenoid is engaged, we can control the rate of the LFO with the positive/negative values.

The sound then transfers to the output, and a collaboration between the "magnetist" and violinist can take place.

3 COMPOSITION & PERFORMANCE

The musical intention of this concerto was created with the properties of magnets in mind. The dichotomy of the obsolete -/+ had to be shown in a matter that is more than visual, but audible and present. It's all about contrast. When the magnets are engaged with the solenoids, the ferrofluid will drop to the ground and a moment would be captured. The interaction between the violinist and magnetism is a crucial component of the piece. According to the behavior of one, the other has to react. According to the pull of the magnet, the violinist has to push. The musical intent of the piece is also one of exploring timbre with magnets. The textures, colors and rhythms all have a meaning within the complexity of the movement of the fluid, and within the context of the piece itself. The music had to be both engaging, melodic and familiar, but also radical and new. In the performance, we included four acts:

- 1st Act - Introducing the fluid's behavior. The general behavior is a combination of thematic and rhythmic ideas that will return throughout the piece. The Ferrofluid is responsive.
- 2nd Act - Dramatic Conversation. Consists of mostly long notes that alternate between the Violin and the ferrofluid according to general behavior. Contrasting frequencies must be applied - when the ferrofluid is low in pitch, the violin is high; when violin is low in pitch, the ferrofluid is high.
- 3rd Act - Magnetic Exploration. The cover comes off. The ferrofluid is removed. The magnetist is playing the magnets on the audience side.
- 4th Act - Explosion of Energy. The ferrofluid is placed in front without cover. Impressive, gradually developed rhythmic ideas are being developed.Explodes with high energy at the end of the act. End with a long, harmonically compelling solo note of a violin and the ferrofluid is in responsive behavior for the ending.

4 REAL-TIME PERFORMANCE VIDEO

We have already made a live performance at MIT Media Lab in December 2021. The recording video can be watched through the link: https://www.youtube.com/watch?v=L137Kr320ts

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