xCoAx 2019 Conference on Computation, Communication, Aesthetics & X Milan, Italy

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serraE: Re-Visioning the Chinese Yu as Mechatronic Musical Instrument towards Revitalization and Preservation

Keywords
mechatronic musical instruments
ancient musical devices
new interfaces for musical expression
music archaeology

The *yu* is an ancient Chinese scraper-class percussion, used to indicate time (specifically, the end of a piece of music) in court and ritual music. The *yu* was played by scraping across 27 serrates and striking the body of the percussion, using a bamboo brush mallet. Although the *yu* had limited musical function, it was included in court and ritual ensembles due to its unique design and distinct playing schema. Despite its cultural significance, the *yu* is not used today and is only seen in museums. This paper describes an approach to re-vision the *yu* towards revitalization and preservation through its reconstruction as a mechatronic musical instrument.

1 INTRODUCTION

Musical instruments and traditions are important because they inform the development of music technology, creative processes, and musical interaction modalities (Tanaka 2009). As such, their preservation is important because they are culturally significant and contribute to the body of knowledge about our past and are great inspirations for what can be possible with technology. Ancient musical instruments are usually exhibited in museums and this is only possible if such artefacts are excavated. In other cases, we would learn about these instruments through representations of musical scenes and textual evidence in literary works. As such, even when the ancient musical instruments are available, the engagement with them remain rather limited, contributing to the decline of their knowledge and inheritance.

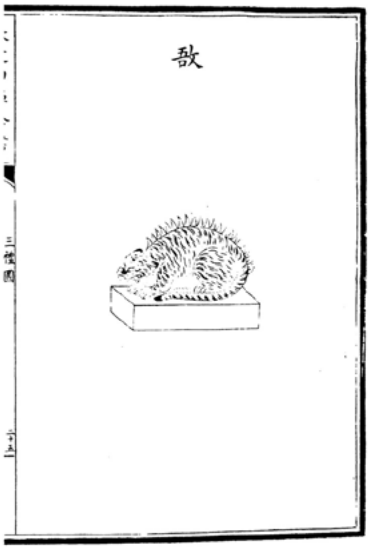
In recent years, the use of new musical interfaces in preserving and revitalizing musical instruments and heritages has increased. Serafin and Gotzen reconstructed Russolo's intonarumori as digital musical instruments with sensors, microcontrollers, and computer-based sound synthesis engine (Serafin and De Götzen 2009). Their enactive approach focuses on gestural interaction to illustrate and enhance the playability of the lost twentieth-century musical instrument towards preserving and revitalizing the intonarumori. Aaron Kuffner's *Gamelatron* creates sound-producing kinetic sculpture by augmenting traditional Balinese and Javanese gamelan instruments with motors, allowing them to be controlled via Musical Instrument Digital Interface (MIDI). This enables uncommon or lost gamelan traditions to be presented in new contexts, contributing to its revitalization and outreach (Kuffner 2008). Through a series of works that augment North Indian musical instruments with sensors and developing North Indian music inspired mechatronic musical instruments, Kapur's approach towards preservation focuses on sustaining the developments of music traditions by integrating new technologies (Kapur 2008). The use of these new musical interfaces in new performance scenarios and contexts, such as the Machine Orchestra, also contributes to the revitalization and outreach of North Indian classical music. While the use of new musical interfaces in preserving and revitalizing musical instruments and traditions are not new per se (a comprehensive survey of prior works can be found in (Kapur 2008; Hochenbaum 2013; He et al.,)), there has yet to be works that reconstruct ancient musical instruments as new mechatronic musical instruments, specifically the reconstruction of ancient Chinese musical instruments.

Inspired by ancient Chinese sound worlds, this work builds upon prior research to combine methodologies in music archaeology and new interfaces for musical expression to re-vision the ancient Chinese *yu* percussion. Through its reconstruction as a mechatronic musical instrument (MMI) and re-contextualizing its application beyond traditional contexts, it is hope that this work will contribute towards the outreach, revitalization, and preservation of ancient musical devices by sustaining their development and enhancing their playability in today's context.

To this end, this paper presents the modern re-visioning of *yu* as serraE, an ensemble of mechatronic scraper-class percussions. Section 2 introduces yu, providing a background overview and its cultural significance. With an understanding of the ancient Chinese scraper-class percussion, Section 3 describes the design approach towards its re-visioning as a mechatronic musical instrument, and presents its system overview and applications in mechatronic sound art performances. Finally, the paper concludes with a discussion of the work presented and future works.

2 BACKGROUND

The *yu* is an ancient Chinese scraper-class percussion with a long history, recorded amongst 105 ancient musical instruments in historical literature such as *Shi Jing* (Classic of Poetry) and *Shang Shu* (Book of Documents). The musical function of the *yu* was to indicate time, specifically to mark the end of a piece of music, in *Ya Yue* (Chinese classical music and dance performed at royal court) and *Li Ji* (*ritual music*). Despite its limited musical functionality, the *yu* was included in the royal court and ritual ensembles due to its unique construction and distinct playing schema. The *yu* is not used and made today, and is most often found in historical museums, such as the *Gu Gong*.



敔 **Fig. 1.**
Illustrations of *yu* from historical literature (left) *San Li Tu* (Nie 1673)and (right) *Gu Jin Tu Shu Ji Cheng*, also known as the Imperial Encyclopaedia (Chen 1726).

While the Esteemed Documents and Book of Documents provided information on musical instruments and their functions, later literary works, such as Song dynasty's *San Li Tu* and Tang dynasty's *Jiu Tang Shu Yin Yue Zhi*, depicted variations in the structure of *yu* (as illustrated in Fig. 1.), the materials used for its construction, and playing schema during different time periods. This informed the non-prescriptive re-visioning approach of the *yu* as serraE in its design and reconstruction, which will be described in Section 3. While there were variations in materials, form,

and playing schema, three characteristics remain consistent: structure, sound-producing mechanism and musical function.

Fig. 2.
Yu from the Beijing Gu Gong Museum's collection of ancient musical instruments (Zhao 2009).

Structurally, the yu is shaped into the silhouette of a tiger resting on a pedestal (as shown in Fig. 2.). On its back, there are 27 square serrates. The *yu* is played with a bamboo brush (similar to a multi-rod drum stick) that is made up of 10 fine bamboo dowels. As recorded in historical literature, the performer stands adjacent to the *yu* and plays the instrument via two gestures using the bamboo whisk — 1) striking the body of the percussion, and 2) scraping across the serrates. The combination of typically three strikes and one scrape in succession forms the musical gestalt used to mark the end of a piece of music. While the combination of strikes and scrapes remained consistent, their order and count varied. Sonically, the characteristic of tones produced by the *yu* is not prominent and not distinctive.

With an understanding of the *yu's* structure, form, and its sound-producing mechanisms, the following section describes the re-visioning of *yu* through its reconstruction as a mechatronic musical instrument.

3. *serraE*

serraE (as seen in Fig. 3.) is an ensemble of mechatronic scraper-class percussions, which is a modern re-visioning of the traditional Chinese *yu*. *serraE* consists of four units of *serra* and a microcontroller that controls scraping and so-

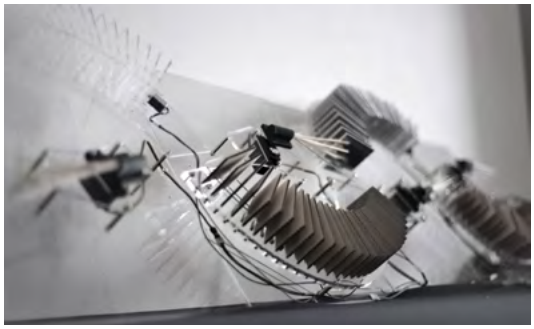


Fig. 3.
serraE: An ensemble of mechatronic scraper-class percussions.

3.1 Design Overview

The overall design of *serraE* takes a minimalist approach towards its design, form, and structure (as illustrated in Fig. 4). *serraE* also utilizes repetition and iteration, resulting in 4 units of *serra* with variations in the materials used for each group of serrates. This is a common feature in contemporary mechatronic sound art and representative of today's practice (Zareei et al. 2014).

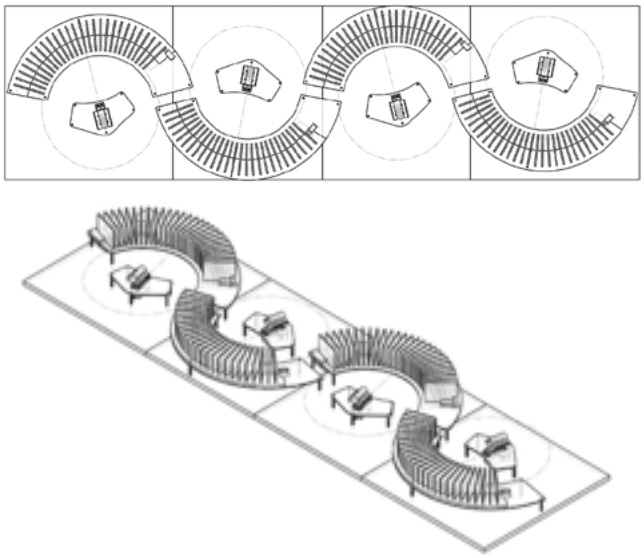


Fig. 4.
sketch of *serraE* with 4 units of serra repetition and iteration in top view (top) and isometric view (bottom).

serra is mainly constructed of acrylic. The variations in *yu's* construction materials over the different time periods in historical literature motivated the choice of materials used for the serrates of each *serra* unit — acrylic, cardboard, wood, and steel (as shown in Fig. 5). As synthetic polymers are some of the most common materials today, Acrylonitrile butadiene styrene (ABS) is used to create the dowels for the four scrapers. Furthermore, the different materials, when struck and scraped, result in a variety of timbres. This extends the characteristic of tones produced, and enhances the non-distinctive tones of the ancient *yu*.

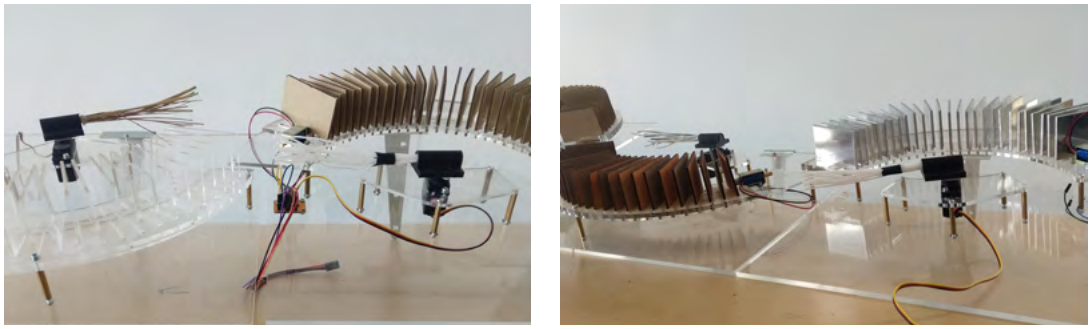


Fig. 5.
Four units of *serra* fitted with serrates of different materials.

3.2 *serra*

Each *serra* unit consists of 27 serrates, one solenoid, one servo, and a scraping apparatus. The sound-producing mechanisms of *yu* is mechanized through a solenoid to strike the surface of a serrate, and a servo to scrap the 27 serrates. These emulate the sound-producing mechanisms of the ancient *yu* percussion. The bamboo brush of the *yu* is reconstructed with the combination of a custom 3d-printed holder that attaches to a X servo horn, and 10 fine dowels of ABS filament as illustrated in Fig. 6.

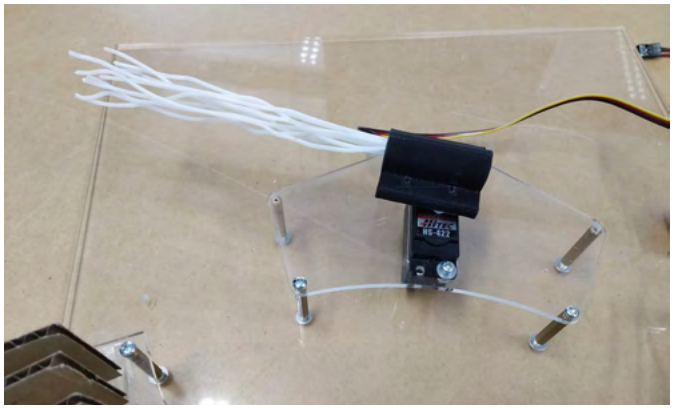


Fig. 6.
Scraping apparatus made of 10 fine dowels, made of ABS filament.

3.3 System overview

Fig. 7 illustrates the system diagram of *serraE* and its data flow. Each *serra* has a custom PCB that houses the electronic circuits for driving a solenoid and a servo motor. Each unit of *serra* then connects, via 2x3 connectors, to the main *serraE* PCB. The main PCB comprises of a Teensy 3.6 microcontroller (flashed as a USB-MIDI device) and a 5V step-down voltage regulator circuit. serraE connects to the laptop via USB and is controlled via MIDI.

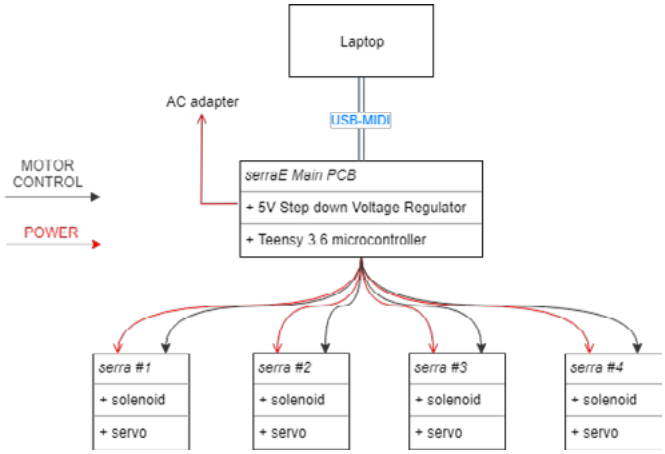


Fig. 7.
System diagram of *serraE*.

MIDI messages from the computer is interpreted, by the microcontroller, to appropriate motor instructions that are sent to each serra unit. Table 1 provides an overview of the control interaction scheme employed by *serraE* to parameterize MIDI messages to actuating the servos and solenoids of each *serra* unit.

Sound-producing Mechanism	**Dimensionality of Control**	**Physical Attribute**	**Control Modality**	**MIDI Type**
Solenoid - strike	2 dimensions	On/ off	discrete	Note On/ off
		Strength of strike	Quantized continuous	Note Velocity
Servo - scrape	2 dimensions	On/ off	Discrete	Note On/ off
		Speed of scrape	Quantized continuous	Note Velocity

Table. 1.
An overview of *serra's* control interaction

3.4 Application in Performances

serraE was used in two major occasions — *serrate study no. 1* at Si17 Soundislands Festival 2017 in Singapore, and *knowing one's sound* at the 2017 International Computer Music Conference in 2017. The pieces explore *serraE's* musical functions through two performance scenarios. Furthermore, they enable the outreach of *yu* to communities that are unlikely to engage with it.

serrate study no. 1

In *serrate study no. 1*, presented at Si17, the approach to play *serraE* is via an instrument-performer relationship, where spatial and temporal information transfer from human to instrument through dynamic encoding in body movements (Pressing 1990). As seen in Fig. 8, a custom hand gestural controller and a grid controller were used to control *serraE*.

Fig. 8.
Excerpt of previous performance at Si17 Soundislands Festival 2017, Singapore. (https://vimeo.com/310240604)

The strike mechanism is activated when there is high jerk in the vertical axis, while the scraping mechanism is activated when high jerk is present in the horizontal axis. The magnitude of jerk is then parameterized as either the strength of strike, or the speed of scrape. To enable the independent control of each mechanism among four units of serra, the grid controller is used as a switch to enable/ disable the effects of the instrumentalist's motions. This strategy allows *serraE* to be played as a traditional musical instrument, affording a good range of tones (inherent from the different materials used), dynamic control and freedom to lock in/out of metric-rigidity for the instrumentalist.

knowing one's sound

knowing one's sound is a human-mecha performance that features a human guqin instrumentalist, *serraE*, and *Swivel*, a highly parametric mechatronic chordophone. In this piece, the interaction between the mechatronic instruments and the human performer is mediated by the modalities of custom interfaces and abstract mapping schemes to render imagery of sonic and movement choreography. Both *Swivel* and *serraE* are programmed to perform with agency and autonomy, reacting to the physical hand gestures of the guqin instrumentalist as seen in Fig. 9.

Fig. 9.
Excerpt from performance at the International Computer Music Conference 2017, Shanghai. (https://vimeo.com/317641742)

4 CONCLUSION

In this paper, the ancient Chinese scraper-class percussion, *yu* was introduced. With an understanding of its background, significance, and its 'lost' status, this paper presents the approach of re-visioning the *yu* as a mechatronic musical instrument. Following the description of its design and system overview, *serraE's* application in two contrasting performance scenarios is presented. The re-visioning of *yu* not only brings the ancient scraper-class percussion to live, but also enables further engagement, continued development and utilization in new contexts.

With the modern re-visioning of the *yu* as a mechatronic musical instrument, the ancient instrument revitalizes with an extended range of tones due to the use of different materials and actuating mechanisms that can operate beyond the limitations of a human body. The mechatronic movements further emphasize the unique playing schema and sound-producing mechanisms. These further enhances the aesthetics that the ancient *yu* percussion embodies.

From a cultural heritage perspective, the preservation of ancient musical instruments is important. Nowadays, few can describe what *yu* is, not to mention its design, sound producing mechanisms and musical function. This further reveals the importance of inheritance. Since the few original instruments are only displayed in museums and the instrument tradition 'lost', it is important to revitalize this unique ancient musical device of ancient Chinese musical heritage. It is hope that *serraE* will encourage further reconstructions of other ancient musical devices.

Future works will include the development of *serraE* towards an interactive installation, that accompanies its excavated original artefact. This will provide additional engagement and dimensionality to the *yu* in the displays of museums. With the success of the first reconstruction, it is hope that the presented approach of re-visioning as mechatronic musical instruments can be extended to other ancient Chinese musical devices, as well as ancient devices of other musical traditions.

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