DOI: 10.61782/fa.2023.0935

forumacusticum 2023

COSMUSICA: A DIGITAL MUSICAL INSTRUMENT FOR INTERACTING WITH THE UNIVERSE

Zhaorui Liu[1] **Yiyun Qiu**[2] **Chuyi Cui**[3] **Danqing Shi**[4] **Zijin Li**[5*]
[1] China Conservatory of Music, Beijing, China
[2] University of Washington, Seattle, USA
[3] Longy School of Music of Bard College, Cambridge, USA
[4] Tsinghua University, Beijing, China
[5] Central Conservatory of Music, Beijing, China

ABSTRACT

Cosmusica is an innovative digital musical instrument enabling a novel form of interaction between humans and the universe. It comprises two critical components - a silicone ball located on a low earth orbit satellite and an earthly installation. The silicone red ball serves as the 'gesture' input of the musical instrument, moving slowly and unpredictably due to the space microgravity environment. This motion is captured by a vision sensor installed on the satellite and transmitted to earth, replicating the performance gesture. The satellite also receives electromagnetic wave data from the universe, which is audibly converted into multiple audio clips, forming the preset sound. Max/MSP's real-time sound synthesis function further enriches these sounds. When the silicone ball enters a predetermined trigger area in space, the earthly and space sound materials are simultaneously activated, thereby establishing a connection between the ball's trajectory and the audible space sound. Visit our website for a live demo: https://www.yiyunqiu.com/cosmusica.

Keywords: *digital musical instrument, sound design, Max/MSP, aerospace*

[*] ***Corresponding author***: *lzijin@ccom.edu.cn.*

1. INTRODUCTION

Before the end of the 19th century, musical instruments' evolution was intrinsically linked to the advancements in fields such as acoustics and machinery. However, with the advent of electronic technology in the late 19th century, a new breed of instruments emerged, the electronic/electroacoustic instruments. Theremin [1], for example, uses electronic oscillators to play both single and continuous tones. The recent progress in computer music has introduced numerous sound synthesis methods, allowing for real-time sound generation via computers. This development has expanded composers' creative horizons, enabling them to compose with synthesized timbres that traditional musical instruments can't reproduce. Alongside, technology to capture different postures has matured, paving the way for the creation of novel digital musical instruments, an intersection of digital and information technology like sound synthesis methods and posture control capturing.

1.1 Digital Musical Instruments

Digital Musical Instruments (DMIs) utilize computer digital sound synthesis technology for sound generation. DMIs comprise a control interface that modulates the music parameters of the sound synthesizer in real-time [2]. Unlike traditional acoustic musical instruments, a DMI's 'gesture control' and 'sound synthesis' can operate independently, allowing for flexible mapping strategies based on creative requirements. This is a significant feature of DMIs, where 'gesture control' refers to the ability to transform physical movements or positions into signals that the computer can interpret, and 'sound synthesis' is the computer-based technique of creating new sounds or altering existing ones.

The versatility of DMIs extends beyond playing notes, as they also facilitate new presentation modes using existing technology, alter complex music performance patterns, and perform higher-level functions. Additionally, DMIs can generate supplementary visual effects, such as graphics or lighting, to augment the sound performance.

As A. P. McPherson demonstrates, an optical measurement system can capture the continuous position of piano keys, allowing for flexible mapping to sound and thereby enriching the piano's performance form [3]. Similarly, the T-stick [4] employs a variety of sensors to extend the types of playing postures, resulting in a broader sound output and increased expression potential. Furthermore, as proposed by Irmandy Wicaksono et al., the Fabric Keyboard, a new deformable keyboard controller based on a variety of fabric sensors, combines the discrete control of the keyboard with various continuous controls of embedded fabric sensors, enabling multi-modal and more expressive control [5].

Digital technology can also be used to reshape traditional musical instruments, capturing their essential characteristics and providing innovative presentation methods [6]. This can lead to the stimulation of creativity among amateurs and professionals alike, inspiring new performance forms and thereby reshaping our understanding of music [2]. An example of this is the aforementioned T-stick and Fabric Keyboard, where new ways to control sound were developed, enabling richer and more nuanced music performances.

In the current paper, we present *Cosmusica* a novel digital musical instrument that utilizes a satellite in low-earth orbit to gather "gesture" input, and an installation on earth, that allows humans to interact with the system. The primary components of our system are a silicone ball installed on the satellite solar panel, a vision sensor, and the ground-based interaction installation.

The silicone ball, under the influence of space's microgravity environment, moves slowly and irregularly. Its motion trajectory is collected by the vision sensor and transmitted to Earth, where it is restored as the performance gesture. This approach allows us to utilize the unique conditions of space to introduce variability and unpredictability into our instrument, providing a truly unique experience for users.

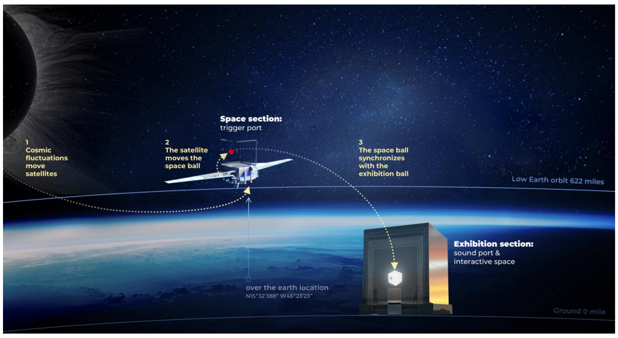

Figure 1. The sound interaction system of *Cosmusica*.

1.2 Motivation

In summary, Digital Musical Instruments (DMIs) hold significant potential for sound creation and interactive design. By constructing musical instruments based on data obtained from scientific exploration and crafting their interaction mechanisms, we can establish innovative instruments that engage with natural phenomena.

Over time, mankind has continuously sought to understand the auditory relationships in the undiscovered realms of the universe. Questions such as, "What does the universe sound like?" and "Can humans interact auditorily with the cosmos?" have persisted. Traditionally, the perception of the universe's sounds has been limited due to the fact that most of the cosmos exists in a vacuum-like state where mechanical waves, including sound waves, cannot propagate due to the lack of a medium.

However, our approach to this challenge transcends these physical limitations. By converting the electromagnetic waves that our satellite detectors receive from the universe into audible sounds, we can circumvent the constraints of traditional acoustic theory. These sounds can be perceived by the human ear, providing a novel and innovative interaction modality.

Consequently, based on the support of these electromagnetic wave data, we designed *Cosmusica* This system adopts the framework of new DMIs to facilitate real-time acoustic interactions with the universe. In this way, *Cosmusica* helps to bridge the gap between mankind and the cosmos, creating a unique auditory experience that allows us to explore and understand our universe in a brand new way.

2. COSMUSICA

This section introduces the interaction process, input and output terminal, sound design method, sound mapping strategy and other specific contents of the DMI *Cosmusica*.

2.1 Interaction Process

The sound interaction system of *Cosmusica* consists of three core components: input, output, and a mapping strategy, as illustrated in Fig. 1. The input module resides on a satellite in space and is responsible for recording the trajectory of a silicone ball and the satellite's geolocation data. The output component is an installation located on Earth, which produces sounds corresponding to various stars in the solar system and the distinctive sounds of different regions on Earth. The mapping strategy serves as the liaison between input and output. Through the integration of these three elements, the audience on Earth can experience and interact with the sounds originating from different stars within our solar system.

Cosmusica primary module is installed on a low earth orbit satellite. Inside this module, a silicone ball moves slowly and irregularly, influenced by cosmic fluctuations, satellite attitude adjustments, and the microgravity environment of space. The trajectory of this ball is monitored by a monocular camera on the satellite and transmitted to Earth. Once these data reach Earth, a ground installation's PVC ball mimics the space-based ball's trajectory, driven by an internal motor. When this ball enters a preset zone within the module, it triggers a pre-defined sound.

From *Cosmusica* vantage point, overlooking Earth, the system simultaneously sends the longitude and latitude data of its position relative to Earth. As the module passes over specific regions, the ground installation autonomously plays sound clips characterizing those regions. This function allows for an immersive blend of the most representative sounds from various Earth regions with the cosmic sounds, creating a unique auditory experience.

2.2 Input

The input mechanism of *Cosmusica* is composed of a transparent box and a monocular camera situated on the satellite's solar panel, as depicted in Fig. 2. The box is constructed from transparent quartz glass, within which a silicone ball is housed. Adjacent to the box, the monocular camera is tasked with recording the movements of the ball. Utilizing OpenCV visual identification code, the system identifies the silhouette of the silicone ball, computes the center point of the figure as the ball's spatial position, and

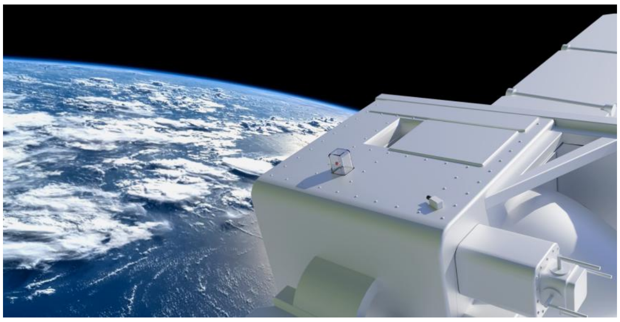

Figure 2. The input of *Cosmusica.*

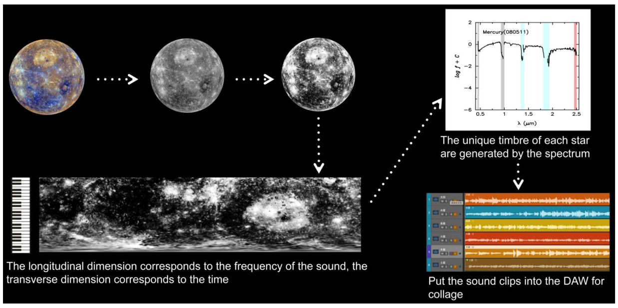

Figure 3. The process of sound conversion.

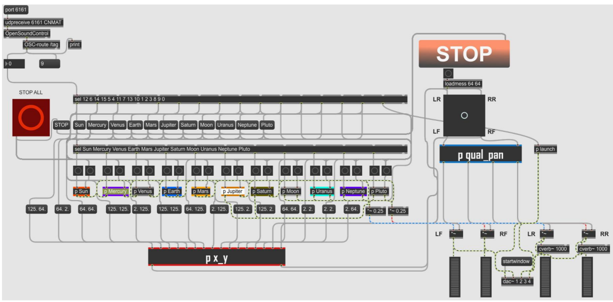

Figure 4. The interface for Max/MSP interactive program

traces the ball's motion path based on positional information from different frames over time.

Cosmusica's data intermediary is implemented in the Unity platform. Data transmitted from the satellite to Earth is then relayed to Unity and a PC via a TCP connection.

2.3 Sound Design

The sound component related to celestial bodies in *Cosmusica* is created by converting data from cosmic detections into audible forms, a method that has been validated through numerous experiments.

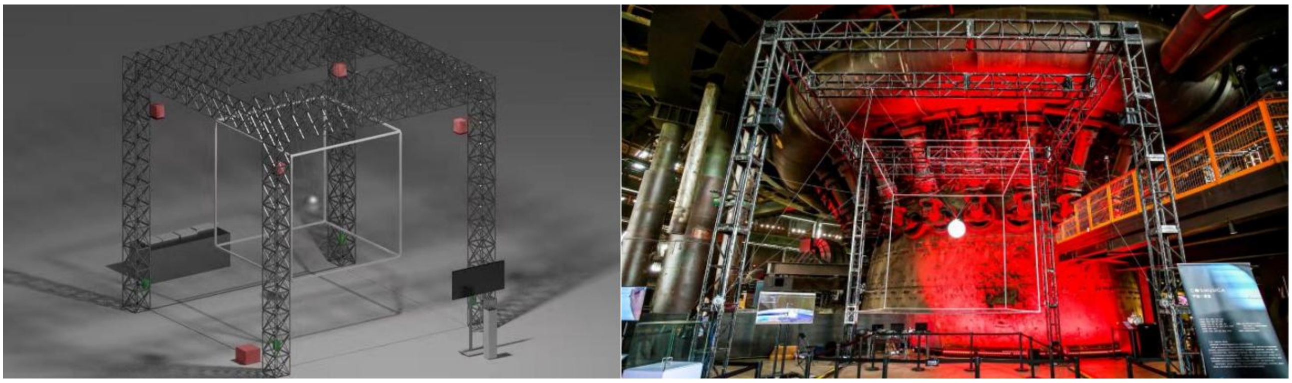

Figure 5. The output of the "Cosmusica". (The left picture shows the rendering of the installation structure; The right picture shows the actual display effect)

Initially, we undertook an extensive collection of raw cosmic ray data (including gamma rays from the moon, solar storms, spectral information of various stars in the solar system, etc.) detected by various spacecraft throughout history. This data was then subjected to an audible conversion process in Matlab, setting predetermined parameters such as selected data areas and sound frequencies to convert the raw waveform data into ten different acoustic waves perceptible to the human ear. However, the resulting sounds were overly harsh, indistinguishable, and failed to accurately portray the unique characteristics of each star.

Consequently, *Cosmusica* employs visible light waves from the electromagnetic spectrum for the primary component of celestial sound conversion. The spectrum of each star is as unique as the timbre characteristics of every musical instrument. Therefore, once each star's image is scanned by radar along the radial direction, a characteristic waveform can be acquired. The vertical dimension corresponds to the frequency of the sound, the horizontal dimension corresponds to time, and the brightness information corresponds to the volume. Simultaneously, the harmonic component coefficient generated by the spectrum serves as the unique timbre of each star, providing each planet its distinctive sound clip. In addition, the sound design of each star includes elements conforming to its geological features, culminating in the final sound of each celestial body within *Cosmusica*. The sound conversion process is illustrated in Fig. 3.

2.4 Sound Mapping Strategy

The gesture input (space) and sound output (earth) of *Cosmusica* are related by specific mapping strategies.

There are multiple trigger zones preset in the simulation box of Unity program. When the ball and satellite move to a specific trigger zone, Unity will automatically send a trigger signal to Max/MSP through TCP, where the OSC module is used to receive data. Then Max/MSP selects the received trigger signal to trigger the corresponding preset sound (i.e. the sound designed in 2.3).

In addition, the Max/MSP program also adds sound effects that meet the characteristics of each star. For example, the gravity of the moon causes the tides of the earth. Therefore, the wave sound simulated by white noise is added to the "subpatch" corresponding to the moon, and the time of occurrence, duration and various parameters of the sounds are randomly generated by Max/MSP. The interface for Max/MSP interactive program is shown in Figure 4.

2.5 Output

The output of *Cosmusica* is a large musical installation, depicted in Figure 5, consisting of a sound playback system, a three-dimensional lifting structure, metal frames, and a PVC ball.

The sound playback system employs four studio monitors and a studio subwoofer (the red part on the left in Figure 5) to play sounds corresponding to the stars, with real-time control executed through Max/MSP. The positioning of the sound source aligns with the area triggered by the ball, aiming to create a superior auditory experience and immersive effect. The Earth-related sounds are played back through a Bluetooth speaker installed inside the PVC ball.

The metal frames and the PVC ball (the silver part on the left in Figure 5) form an enlarged version of *Cosmusica*. The PVC ball is maneuvered through a three-dimensional lifting structure to replicate the motion path of the silicone ball in space. After receiving the data transmitted from space, the Unity program commences movement simulation and sends real-time XYZ positional data, speed, transmission rate, and other parameters of the ball to the PLC. The servo motors (the green part on the left in Figure 5) installed on the four columns maneuver the PVC ball, thereby achieving synchronization with the ball in space.

3. FUTURE WORK

Cosmusica represents a long-term initiative, and we envisage its presentation in multiple formats in the future. We aim to develop an online platform to showcase the devices and sounds of *Cosmusica* digitally, facilitating a broader audience to experience the harmonization of Earthly and planetary sounds. Additionally, we plan to enhance autonomous movement features. By incorporating an independent power supply system and introducing several electromagnets within the box on the satellite solar panel, we could enable terrestrial users to remotely alter the motion of the ball inside the box.

4. ACKNOWLEDGMENTS

The authors would like to thank Hao Liu from Central Conservatory of Music for the technical support.
Funded by: Key Laboratory of Intelligent Processing Technology for Digital Music (Zhejiang Conservatory of Music), Ministry of Culture and Tourism (2022DMKLB003).

5. REFERENCES

[1] G. Albert: *Theremin: ether music and espionage*, University of Illinois Press, 2000.

[2] E.R. Miranda, M.M. Wanderley: *New digital musical instruments: control and interaction beyond the keyboard*, AR Editions, Inc., 2006.

[3] A.P. McPherson, "Portable Measurement and Mapping of Continuous Piano Gesture," in *Proc. of the 7th international conference on New interfaces for musical expression,* pp. 152-157, 2013.

[4] A. Nieva, J. Wang, J.W. Malloch, et al., "The T-Stick: Maintaining a 12 year-old Digital Musical Instrument," in *Proc. of the 7th international conference on New interfaces for musical expression*, pp. 198-199, 2018.

[5] I. Wicaksono, J.A. Paradiso, "Fabrickeyboard: multimodal textile sensate media as an expressive and deformable musical interface," in *Proc. of the 7th international conference on New interfaces for musical expression*, pp. 348-353*,* 2017.

[6] N. Bryan-Kinns, Z. Li, "ReImagining: cross-cultural co-creation of a Chinese traditional musical instrument with digital technologies," in *Proc. of the 7th international conference on New interfaces for musical expression*, pp. 1-6, 2020.