GraviTone: A Tangible Musical Interface using Gravity Well for Sound and Music Creation

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Abstract

We propose a new musical interface, "GraviTone" that produces sounds and musical compositions via interaction with spherical objects in a gravity-well benchtop setup. The interface consists of several spherical objects in different colours orbiting around the centrally placed static object on the spacetime fabric. The spherical objects are launched at a certain angle from the setup's periphery, and the objects' motion is tracked by an overhead camera and mapped to different parameters to generate sound. In GraviTone, users can experience sounds generated from objects' parameters and have control over different configurations. We use the setup to send Open Sound Control (OSC) signals and Musical Instrument Digital Interface (MIDI) signals to map different sounds and musical scales (Indian classical ragas and Western classical scale). We mapped the moving objects' parameters to control synth parameters, VSTs, and DAWs. Users can also route generated MIDI data into DAWs using preset configurations or customizing their frameworks for sound generation. We also generate real-time visuals corresponding to the object's movements for further immersion and interactivity. This integrated interface combines various domains like musical mathematics, sonification techniques, sound synthesis, and sound design for live music creation and real-time audiovisual composition.

Keywords

Interactive Music Interface, Gravity Well Simulation, Data Sonification, OSC, MIDI, Real-time Sound Mapping, Immersive Audio

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1 Introduction

Interactive music systems have evolved to incorporate diverse physical and digital modalities. While traditional musical instruments rely on excitation methods such as plucking, bowing, striking, and blowing, emerging digital instruments have explored novel forms of interaction. In GraviTone extends this exploration by leveraging gravitational physics as a central mechanism for musical expression. By simulating a gravity well, the system transforms physical interactions into sound compositions, drawing inspiration from astrophysics. Inspired by astrophysical principles, GraviTone demonstrates a gravity well where performers launch spherical objects into an interactive space-time curvature model. These objects' movement, collision, and orbital trajectories dynamically modulate sound parameters, creating an evolving sonic environment influenced by intentional control and emergent complexity. GraviTone aims to entangle the stochastic interactivity of objects launched in a model space-time curvature with the artistic intentionality of the performer/musician, thereby merging causation, randomness, and expressiveness into a unified model. The motion of objects in the gravity-well influences parameters responsible for sound synthesis. Example: In Nebula

– a preset, the gradual movement of the spherical objects changes variables like reverb size, pitch, diffusion parameter for reverb, and depth of LFO of the sound. In contrast, these bodies' rapid movements generate echoes and sound distortions. In the presence of multiple spherical objects, the movement of one spherical object influences the sound generation of another spherical object, resulting in an entanglement between them. If an object is launched following another object launch, the new launch will be influenced by the current objects moving in the gravity well due to factors like collision inherent patterns that one would like to draw using the objects. Musical instruments operate on the principles of causations (a), synthesis (b), and their effects (c). The sound synthesis methods range from natural sources, such as vibrations generated by materials and collisions, to digital methods like electronic and algorithmic sound generation.

Causations involve excitation actions like plucking, bowing, striking, blowing, and pressing buttons. GraviTone explores projectiles as direct causation, which is relatively underexplored. The influence of physical phenomena like gravity and collisions act as further indirect causations over time. The presence of multiple causations creates novel feedback in every instance where performers engage in continual learning and an explorative musical experience as opposed to generating predetermined sounds. The option to select different presets at one time or play with the same preset with multiple spherical objects results in a dynamic and responsive musical experience. This makes the performance more exploratory and participatory, necessitating listening, adaptation, and discovery rather than just hitting buttons or playing predetermined sounds.

This paper presents the design and implementation of GraviTone, highlighting its contributions to interactive music performance, data sonification, and generative sound design. The following section discusses the related works to music and sound mapping in NIME. Section 3 explains the design of the instrument,and Section 4 illustrates different interaction modes followed by discussion and conclusion section.

2 Related Works

Existing musical interfaces, such as Reactable [7], and OrbSynth [12], have explored tangible and spatial interaction models. In GraviTone, we take inspiration from the idea of a gravity-well to provide a multi-user tangible interface for sonic exploration. AudioCubes is a physical user interface that allows dynamic digital sound generation by physical shaking of cubes, which can improve user interaction and exploration in the sound design process [11]. The paper discusses the creation of INVISO, a web-based user interface that enables the creation and development of complex 3D sonic environments that allow for the creation of immersive auditory effects [1]. The paper [4] introduces a user-centered method for designing machine learning-based interactive auditory feedback by mapping motions to individual sounds and using user demonstrations with feedback iterations. The paper [5] addresses Sonic City, a wearable music system that turns urban environments into interactive interfaces for individuals to express themselves naturally and pleasurably in an urban setting.

The paper [13] focuses on user-defined mappings for spatial sound synthesis and participant preference for control parameters. It also looks at developers' intentions to explore the effectiveness of these parameters compared to actual performance. The paper [8] describes Orb3 as a wireless interface for real-time synthesis and diffusion of sound where an array of mobile globes is used. Orb3 will facilitate collaborative composition via socially mediated communication platforms.

Music technology has widely applied sonification techniques to translate motion data into auditory feedback [6]. GraviTone builds upon this by employing Keplerian motion principles to map object dynamics onto musical parameters. Collaborative musical instruments, such as Tenori-On [10] and SoundSpace [2, 3], have demonstrated the potential of multi-user participation. GraviTone supports multi-user engagement, allowing up to four participants to shape the musical output simultaneously.

3 Instrument Design

Gravity well is a conceptual model that represents the gravitational influence of a massive object in space. It is often visualized as a curved distortion in spacetime, where the well's depth corresponds to the gravitational pull's strength. Objects with mass, like planets, stars, and black holes, bend spacetime around them due to gravity. The stronger the gravity, the deeper and steeper the well. This is shown in Figure 1.

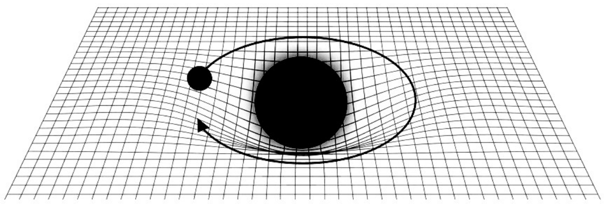

Figure 1: Gravity Well concept

3.1 Physical Setup and Gravity Well Simulation

GraviTone's core mechanism (Figure 5) consists of:

- A flexible fabric membrane acts as a spacetime well.
- A centrally placed static object representing a massive gravitational source (Figure 2).
- Multiple colored spherical objects that users launch at specific angles, mimicking orbital motion (Figure 3).
- A visual projection system for real-time feedback (Figure 4).

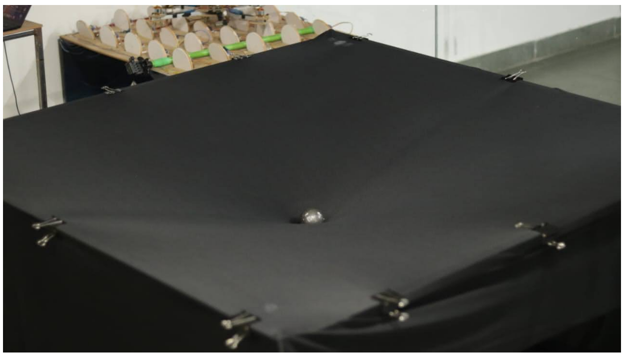

Figure 2: Gravity well with a static object at the center

The top and side views of the GraviTone can be seen in Figure 6 and 7 respectively.

Figure 3: Multiple coloured spherical objects

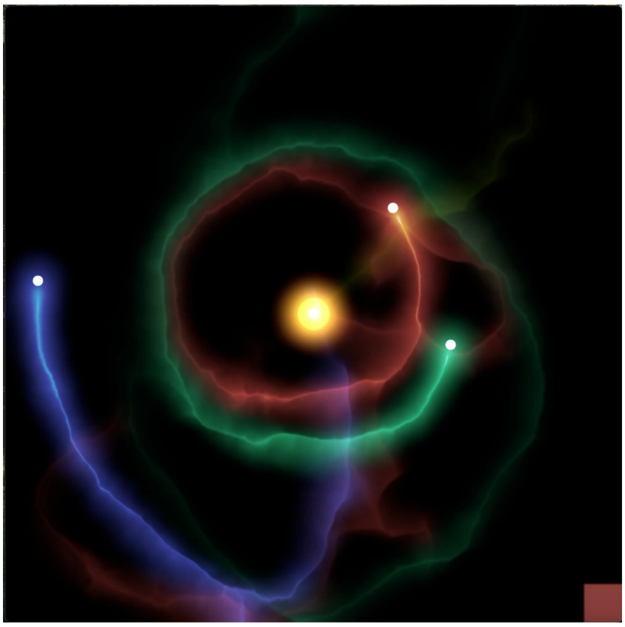

Figure 4: Visual Feedback System using TouchDesigner

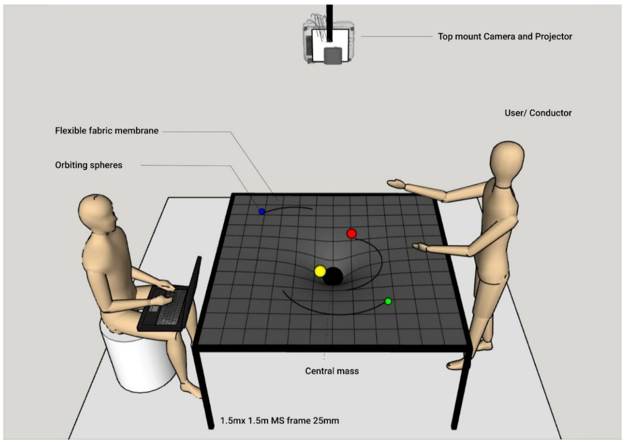

Figure 5: Illustration of the whole setup of GraviTone

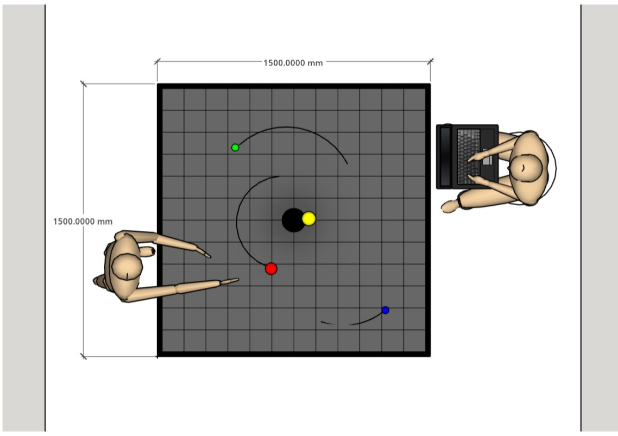

Figure 6: Top view of the GraviTone

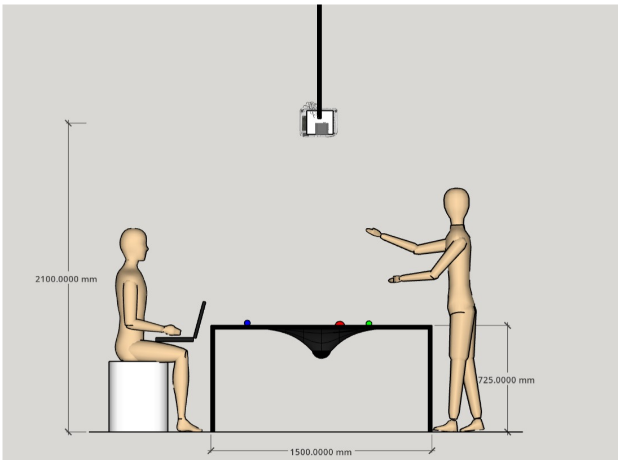

Figure 7: Side view of the GraviTone

3.2 Data Flow Architecture

Using OpenCV, we track each object's movement, extracting key 6 parameters like position(X, Y coordinates), velocity, acceleration, distance from the center, and angle. The data flow of the GraviTone is illustrated in Figure 8:

(1) Physical Interaction ⟶ Spherical object movement in the well.
(2) Computer Vision Tracking ⟶ OpenCV detects motion data and sends it via OSC
(3) Data Processing:
    TouchDesigner ⟶ Maps physical parameters to interactive visuals
    Max/MSP ⟶ Maps the parameters to sound synthesis using the techniques discussed in Section
    Also, it sends out MIDI signals.
(4) MIDI ⟶ DAW integration and live performance

3.3 Sound Mapping and Synthesis

GraviTone uses OSC protocols to send the parameters from Python OpenCV, and the signals are received in Max/MSP to generate sounds. The OpenCV starts with a perspective translation to identify the plane in which the object rotates. Here, OpenCV tracks individual objects based on their colour and gives the X and Y coordinates. These coordinates are then used to

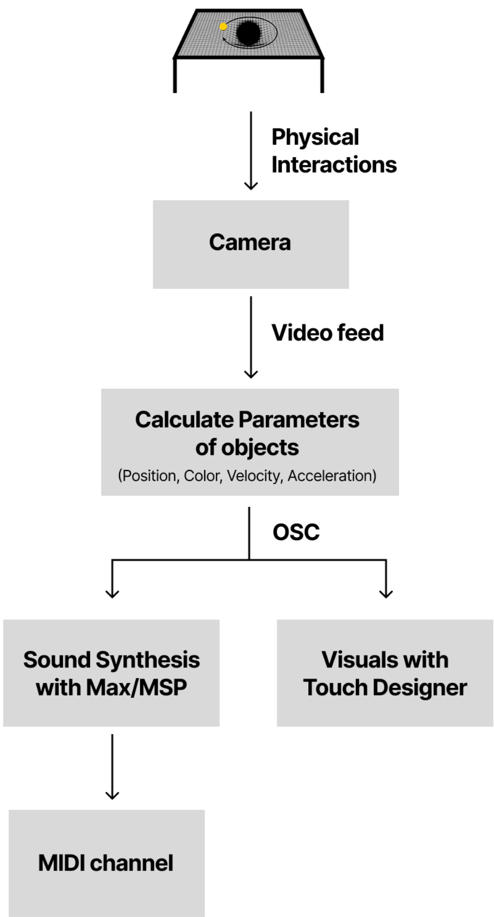

Figure 8: Data Flow Architecture Diagram

compute the angle and distance for the origin. We calculate the velocity and acceleration based on each frame and the change in the X and Y coordinates. Thus, all these parameters are computed per frame per object colour. These values are then sent as OSC signals. Further, some of the presets in Max/MSP, as mentioned in section 3.4, compute MIDI signals that are to be sent to a VST or DAW for sound generation.

3.4 Presets

There are four presets this gravity well includes:

(1) Kepler Harmonic Preset
(2) Nebula Preset
(3) Wave Preset
(4) Radial Preset

3.4.1 Kepler Preset. The Kepler Preset draws upon the principle that planets travel in elliptical orbits with the sun at one focus, causing their distance from the central mass to fluctuate constantly. In GraviTone, this shifting distance translates into real-time alterations in pitch: as an object moves closer to the center, the pitch ascends; moving farther away lowers the pitch. It is shown in Figure 9. This concept mirrors Kepler's Harmonic Law, where the geometry of orbital motion informs harmonic relationships.

From Python/OpenCV tracking, Kepler Preset primarily utilizes two of the parameters:

- Distance (from the origin) → Pitch When an object is positioned farther from the center, the generated pitch is lower, and as it approaches the center, the pitch rises. These pitches are quantized to fit a chosen scale, ensuring musical coherence. Objects typically begin at a lower pitch and shift toward higher tones as their orbital path brings them closer to the central mass.
- Velocity → MIDI Note Velocity (Intensity) The speed at which the object travels determines the intensity of the MIDI note, mapping physical velocity onto loudness variations. Faster-moving objects yield more forceful notes, while slower motions produce softer attacks.

A variety of Indian classical and Western scales are available to shape the melodic output. Indian ragas—such as Raag Desh, Raag Bhimpalasi, Raag Yaman—are explored with distinct ascending (aaroh) and descending (avroh) patterns, while Western options include C Harmonic Minor, and C Major. Ragas serve as a structured yet flexible melodic framework similar to Western scales.

Each spherical object sends its pitch and velocity data to Max/MSP, triggering MIDI messages that can be routed to any VST instrument (e.g., Omnisphere, Serum, Kontakt, Analog Lab) or further processed in a DAW. In one experimental configuration featuring Indian classical music, an Indian tanpura drone (sustained playback of a note/set of notes) was sustained in the background while the Kepler preset executed melodies in a selected scale (such as Raag Desh ascending) in real-time. This setup allowed dynamically changing pitches to blend seamlessly with the ongoing drone, resulting in a multi-layered and immersive sonic environment.

3.4.2 Nebula Preset. GraviTone generates sonic textures reminiscent of a Helix Nebula drone patch in the Nebula Preset. A nebula is a massive cloud of dust and gas in space, often formed from material expelled by a dying star (e.g., in a supernova) or serving as a region where new stars are born. Nebulae can appear dark, as light-absorbing clouds, or bright, reflecting or emitting light (Figure 10). This preset focuses on creating expansive, evolving drone-like sounds that capture these astronomical formations' mysterious and cosmic qualities.

From Python/OpenCV tracking, the Nebula Preset utilizes four of the six parameters:

(1) X (Horizontal Position) → Reverb Size The X coordinate reflects how far the spherical object has moved horizontally across the gravity well. This movement is mapped to the size of reverb effects. In an expanding nebula, items are spread out horizontally over immense distances. A ball traveling along the X-axis can symbolize an expanding nebula, increasing the magnitude of the reverb to create a wider, cosmic soundscape.
(2) Y (Vertical Position) → Pitch The Y coordinate indicates the object's position in the vertical axis within the well, determining whether the resulting note is high or low in frequency.
(3) Velocity → Depth of LFO (Low-Frequency Oscillator) The object's speed governs the intensity of periodic modulation (e.g., vibrato, tremolo). Higher velocities introduce a more pronounced LFO depth, adding turbulence and

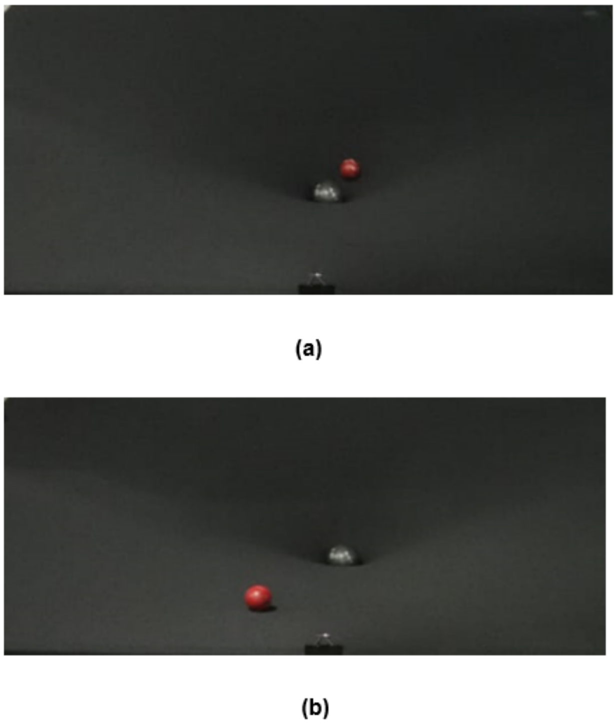

Figure 9: Kepler Harmonic law representing the position of the ball and the pitches of the ball (a) it will produce a high pitch as it is near to the center (b) it will produce a low pitch as it is far from the center.

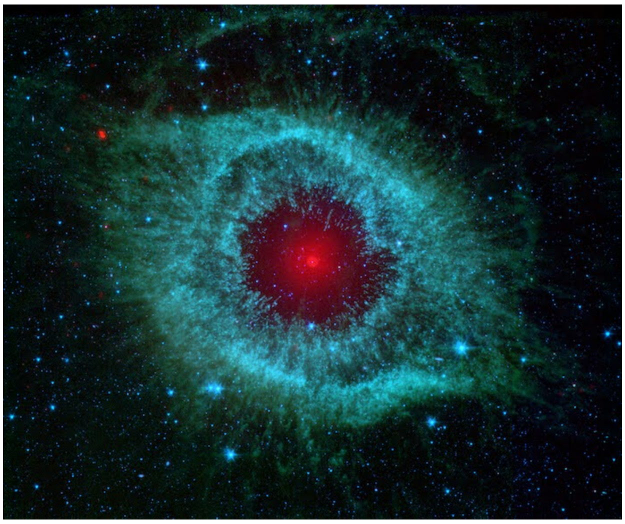

Figure 10: Helix Nebula by NASA [9]

energy to the sound. Higher velocity leads to increased energy, more intense movement, and a stronger modulation effect. This models how items in a nebula behave—faster particles cause greater turbulence and dynamic interactions. A fast-moving ball should provide movement to the music, giving it a sense of life and evolution, similar to an expanding nebula.

(4) Acceleration → Diffusion Parameter for Reverb The rate of change in velocity determines how quickly or slowly echoes disperse within the reverb. When the ball accelerates, it replicates unstable, dynamic motion, similar to how particles in a nebula disperse rapidly. Higher acceleration should result in a more diffuse, ethereal sound, whilst lower acceleration should provide a more structured, echo-like reverb. This depicts how nebulae have areas of dense and diffuse matter, resulting in a cosmic sound texture.

These mappings establish a framework in which each object's real-time motion influences the atmospheric drone character of the Nebula Preset. A higher horizontal movement (X-axis) increases reverb, while vertical movement (Y-axis) affects the pitch. Rapid speeds inject additional modulation through a deeper LFO, and sudden shifts in velocity reshape the overall spatial diffusion. This approach aims to emulate the slow, vast changes noticeably similar to cosmic formations, aligning with the audiovisual experience.

3.4.3 Wave Preset. The Wave Preset translates real-time motion data into continuous, wave-like sonic transformations, highlighting the cyclical and dynamic aspects of orbital behavior. A custom synth is made in Max/MSP with an oscillator, envelope, and passing it-through effects. Four key parameters—Distance, Angle, Velocity, and Acceleration—are used to shape both frequency- and effect-based modulations:

- Angle is mapped to a frequency modulation. As the object's angle changes, the resulting sound shifts through a defined frequency range, simulating the circular or elliptical motion around the gravity well.
- Distance influences the amount of reverb effect. When the object is farther from the center, the resulting timbre or spatial characteristic (e.g., perceived size or depth) expands, mirroring the gravitational relationship between distance and energy.
- Velocity affects the intensity of the sound. Faster movement produces stronger or brighter sonic output, reflecting higher kinetic energy, while slower velocities evoke gentler, subtler tones.
- Acceleration controls time-varying shifts in the amplitude envelope. Sudden speed changes can trigger pronounced alterations in volume, creating dynamic movement in sound.

By assigning distinct Wave Preset mappings to different spherical objects, performers can layer multiple waveforms that respond to diverse motion profiles. This multi-object interplay creates an immersive tapestry of cyclical modulations, allowing audiences to experience both the spatial paths of objects and the evolving musicality derived from their trajectories.

3.4.4 Radial Preset. The Radial Preset quantized each spherical object's 360° orbital angle into discrete segments, allowing for melodic output that seamlessly follows a circular path. As an object moves around the center, its angle determines which pitch is triggered within a musical scale or mode. This approach ensures that angular motion produces consistent, harmonically coherent changes in pitch while preserving the visual continuity of orbital movement. The Radial Preset employs three primary parameters:

(1) Angle → Pitch Selection The full 360° range is divided according to the notes of the selected scale (e.g., C Major, C Minor, or custom modes). Each segment triggers a unique pitch, enabling the creation of structured melodies and chordal textures as the object revolves.

(2) Velocity → MIDI Note Velocity Higher velocity translates to more forceful notes, providing dynamic expressivity. Slower speeds correspond to softer tones, reflecting the gentler movement of the object.
(3) Distance → Reverb Depth The radial distance from the center mass controls reverb parameters, with distant objects generating a more expansive, washed-out sound and closer objects yielding a tighter, more focused ambiance. Each spherical object's motion data is processed in Max/MSP, producing MIDI notes that can be routed to VST instruments such as Omnisphere, Serum, Kontakt, or Analog Lab. These notes may also be sent directly to a DAW for recording and further manipulation. The Radial Preset offers a versatile framework for generating evolving, scale-based compositions that respond fluidly to orbital trajectories by combining angular pitch quantization with velocity-sensitive dynamics and distance-based spatial effects.

Each of the four presets - Kepler, Nebula, Wave, and Radial - demonstrate a distinct mapping strategy for translating the six core motion parameters (distance, angle, velocity, acceleration, and optionally X/Y coordinates) into musical output. While the Kepler Preset emphasizes orbital distance and velocity to evoke elliptical motion, the Nebula Preset focuses on drone-like textures influenced by spatial position, velocity, and acceleration. The Wave Preset relies on the cyclic motion of the objects and the continuous change in distance, angle, velocity, and acceleration. The Radial Preset offers discrete, quantized notes based on angular subdivisions, complemented by velocity-sensitive dynamics and distance-based reverb. By assigning each spherical object a different preset, performers can layer these unique sonic behaviors in real-time, creating rich and dynamic, multi-parameter soundscapes that entangle the physical motion tracking with generative concepts in music.

4 Interaction Modes

Users can interact with the GraviTone by using spherical objects and visual and auditory feedback corresponding to the motion of objects. There can be a single or multiple users (Figure 11). It depends on how many spherical objects the user uses to create the sounds. One user can also have multiple spherical objects. There are many ways in which the user can produce the sound. GraviTone enables multiple users to interact with the system simultaneously. When launching an object, a real-time visual projection is also mapped for continuous feedback of the object's movement. The system's projection mapping enhances immersion by visualizing motion trajectories and corresponding sound modulations. Users can also record the MIDI sequences using DAWs like Logic Pro, enabling further creative manipulation and layering. The live demonstration of GraviTone can be viewed in Link: https://youtu.be/-RW2Qc_NljA.

5 Discussion

GraviTone opens up opportunities for performing with a continuous glide of pitches or notes by circulating radially instead of stretching the arm to a longer distance. We fix the area of play, and the notes can be glided within the area, bringing more control and ease of access with both hands. As the pitch transition is radial, the notes can be played for a longer duration until the object halts and can also be further extended by launching more objects consecutively. GraviTone brings multiple performers together on a single platform to express and co-create music.

Figure 11: Depicting multiple users can interact with the GraviTone

The configurability of presets opens up the potential of GraviTone to customize the musicality of the composition in terms of style, scale, and pattern. In the future, we are planning to map to percussive instruments and see the potential of GraviTone in percussion and rhythms. We will collaborate with musicians to compose and perform with GraviTone in different spaces with different instruments. Though we have not implemented projection mapping of visuals onto the fabric at present, we are planning to project it on the GraviTone once we procure and set up a roof-top short-throw projector. We are also planning to study the experience and acceptance of GraviTone across different trained and untrained musicians. One of the user of GraviTone said, "I really liked the concept—Kepler and Radial Presets felt quite musical and useful for composition, while Nebula and Wave were more experimental, suited for sonification. The experience was unique, as people interacted with GraviTone in unexpected ways, like moving the ball in the gravity well or mid-air using OpenCV to create melodies. Though only four presets were tried, I believe there's great potential to create more musically rich ones and explore its use in actual composition."

6 Conclusion

GraviTone offers a new method to perform and compose interactive sounds and music. We draw inspiration from gravitational physics and combine it with real-time sound creation using data sonification, sound design, and sound synthesis. This interface allows single-user as well as multi-user participation, customized sound presets, and DAW integration, broadening the creative possibilities for musicians and sound artists.

7 Ethical Standards

The Gravitone Project follows ethical guidelines in the design and use of new musical interfaces, prioritizing inclusivity, safety, and creative expression. No human subjects or harmful technologies were involved in its development.

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