Spatial Orchestra: Locomotion Music Instruments through Spatial Exploration

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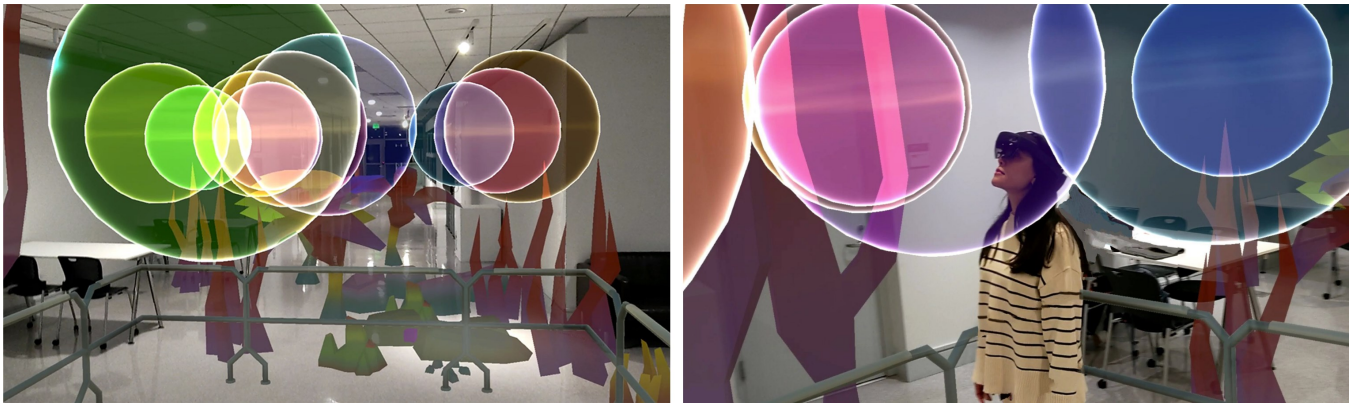

Figure 1: Spatial Orchestra. Left: From the point of view of the user experiencing Spatial Orchestra, where they are in the augmented stage, freely moving around and interacting with ten virtual bubbles that are ever shifting and simulate cello chords. Right: A user immersed in the augmented environment.

ABSTRACT

Spatial Orchestra demonstrates how easy it is to play musical instruments using basic input like natural locomotion, which is accessible to most. Unlike many musical instruments, our work allows individuals of all skill levels to effortlessly create music by walking into virtual bubbles. Our Augmented Reality experience involves interacting with ever-shifting sound bubbles that the user engages with by stepping into color-coded bubbles within the assigned area using a standalone AR headset. Each bubble corresponds to a cello note, and omits sound from the center of the bubble, and lets the user hear and express in spatial audio, effectively transforming participants into musicians. This interactive element enables users to explore the intersection of spatial awareness, musical rhythm that extends to bodily expression through playful movements and dance-like gestures within the bubble-filled environment. This unique experience illuminates the intricate relationship between spatial awareness and the art of musical performance.

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CCS CONCEPTS

• **Applied computing** → **Sound and music computing**; *Media arts*; • **Computing methodologies** → **Mixed / augmented reality**; • **Human-centered computing** → *Virtual reality*.

KEYWORDS

Do, Not, Us, This, Code, Put, the, Correct, Terms, for, Your, Paper

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1 INTRODUCTION

In a world where not everyone has had the opportunity to acquire the skill of playing a musical instrument, the art of musical expression remains elusive, akin to a second nature for a select few. Those who possess this ability often find themselves in awe of those who

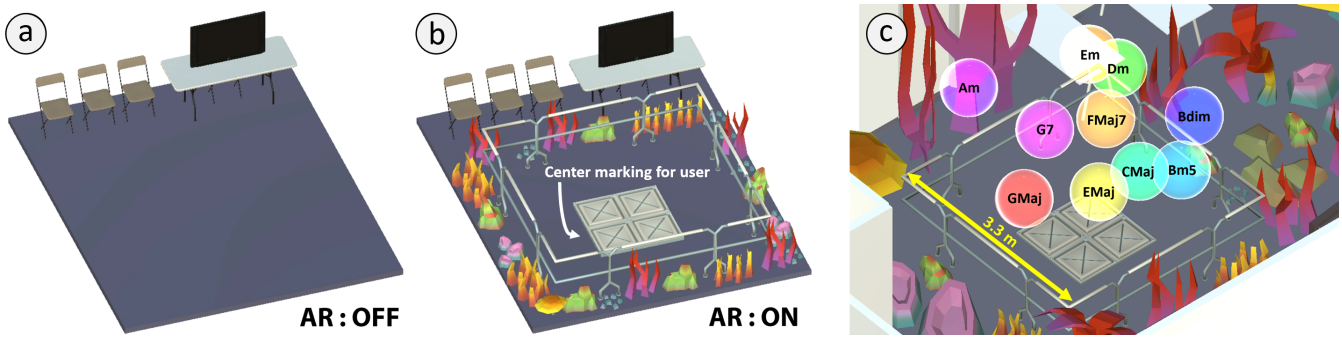

Figure 2: An aerial perspective of the stage arrangement that the user explores. a. The physical space used for the Spatial Orchestra. b. The fencing and virtual stage are all augmented. c. There are ten augmented virtual bubbles set up in the area. Each bubble emits unique cello notes that are color coded to enable user interaction.

can skillfully wield musical instruments to convey their emotions. This universal yearning for musical expression resonates with many individuals.

Within this context, we identified a novel application that seeks to answer the question, "What if individuals could create music using actions that are inherently familiar and well-practiced, utilizing the muscles and movements they employ in their daily lives?" This led to the conceptualization of a musical instrument designed to be played entirely through locomotion and spatial awareness, engaging users in an intuitive interaction with gently drifting bubbles. Within this defined area, color-coded bubbles, each emitting a distinct cello note, float at the user's head level. User can freely move around the play-space, engaging with these bubbles to compose music by entering them. Users are encouraged to navigate to areas where multiple bubbles are present, as user can create harmonies of mixed cello notes.

Spatial Orchestra demonstrates research that utilizes on natural locomotion within mixed reality in open spaces [4, 8–10], focusing on spatial awareness facilitated by spatial audio [7, 11, 17, 19] in recent years. Our system leverages the spatial awareness that we employ in our daily routines, eliminating the need for users to acquire traditional music notation or score-reading skills. Instead, users can engage with the floating bubbles in a manner analogous to real-life interactions. By merging spatial awareness with the act of navigating their environment, individuals can become adept at playing an augmented reality (AR) musical instrument right from the start, offering a unique opportunity for everyone to become proficient music player. Moreover, users can further refine their skills with practice and experience. This means the users can not only produce incidental sound but also can develop their virtuosity to play sophisticated music. As proven by recent work, there are physical input-based and predictive approaches to musical embodiment [3, 7, 13, 14], our work, Spatial Orchestra fully engages this concept and utilizes musical embodiment and the role of prediction, designing interactions through user input and action-based effects on music perception.

2 RELATED WORK

Advances in digital medium facilitates new ways of musical expression. The electronic medium gave freedom from the acoustic and physical design of the instrument, allowing the development of wireless embodied interaction. While conventional instruments require years of training and mastery, this circumstance encouraged the researchers to propose unique and easy ways to expand the users' creativity and think outside the box.

2.1 Digital Instruments

Gehlhaar's work [6] uses an ultrasonic echolocation system to specify the locomotion of participants within the space, and the computer synthesizes the sound using the information. Morreale's installation [15] invites the audience to compose music by moving in the space using the distance between the participants. Lee's work [12] utilizes machine learning-based gestural recognition using smartphones' accelerometers and gyroscopes to interact with simulated physics within an immersive projection space. In Junior's work [5], non-experts create coherent music through graphical elements in a virtual environment.

This circumstance has allowed a proactive music experience for conventional music consumers through more familiar mediations, including new instruments and games, while engaging in compositional techniques [22]. Rasamimanana's work [16] mapped the sports ball's movement and status into rhythmic sounds. These types of musical games utilize the concept of the trigger and playback-based composition methods.

2.2 Musical Experience in Mixed Reality

The advance of XR technology has revolutionized the way we interact with our surroundings, seamlessly blending the digital and real worlds. One intriguing area of research involves the experimentation of Spatial Audio in mixed reality.

Schlagowski et al. (2023) explored the fusion of Spatial Audio with hand motion-controlled interfaces in Virtual Reality, enabling users to collaboratively mix and play music in a Mixed Reality environment [18]. Another noteworthy project, DuoRhythmo by Riddershom and Bargum (2023), introduced a collaborative and accessible digital musical interface in mixed reality, focusing on designing a user-friendly experience [7, 17].

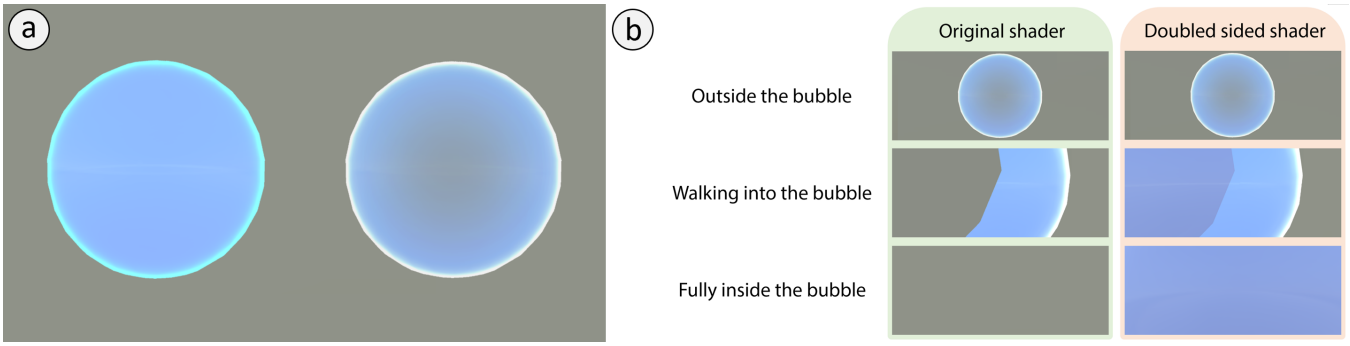

Figure 3: a. The bubble rendering model underwent improvements based on user feedback. Left: The original bubble featured a color highlight at the edge, representing the bubble's assigned color. Right: The original bubble used had a color highlight of the bubble's assigned color at the edge of the bubble. Right: A new shader incorporated a white highlight for improved visibility of the bubble's boundaries. Adjustments were also made to the transparency and illumination levels, addressing user concerns about clarity when multiple bubbles are stacked and colors are mixed. b. We addressed a critical issue with the original shader – users struggled to identify if they were inside the bubble. To solve this, we added a visual cue. Now, when users entered the bubble, the scene adopted a translucent color within the bubble's view. This was achieved through a double-sided shader, rendering both sides of the mesh.

In the realm of education and entertainment, there have been efforts to leverage VR and Spatial Audio to enhance the way humans perceive and interact with games [19]. Additionally, projects like those enhancing auditory immersion in interactive VR environments demonstrate the diverse applications of Spatial Audio in immersive experiences [11].

Turchet's research in 2021 highlighted a significant surge in the historical distribution of musical XR research over the past five years. The study aimed to define the Musical XR field by analyzing 260 research characteristics [20]. Bilow (2022) proposed an Augmented Reality (AR) experience allowing participants to explore audiovisual elements through movements and to interact, using hand gestures [1]. Furthermore, Wang (2022) conducted an empirical study comparing three audiovisual interface prototypes for head-mounted AR environments [21].

These advancements collectively underscore the evolving landscape of XR technology, particularly in the integration of spatial audio for diverse applications ranging from collaborative music creation to educational experiences.

3 DESIGN OF SPATIAL ORCHESTRA

In the virtual environment, to guide users to stay safely within the area, 3.3 m by 3.3 m space with a virtual fence. The fence is stylized realistically to differentiate it from other augmented objects in space. Ten bubbles, each measuring 80 cm in diameter, travel at a constant altitude level with the user's height, one meter every five seconds. Bubbles travel at random and bounce around the area while maintaining their altitude. Such behavior establishes a stochastic model like molecules in the closed space.

Each bubble contains synthesized cello sounds that could be made from a single bow stroke. Sound omitted from the bubble's center can only be heard when the user's head is in the bubble. The colors of the ten bubbles represent the fundamental chords comprising: $[EMaj, Em, FMaj7, GMaj, G7, Am, Bdim, Bm5, Cmaj, Dm]$. These are deliberately selected to guide participants in generating a musical structure that can fold and unfold over time through variant chord progressions. While the bubbles travel like molecules in space, the user's vibrant motion will increase the probability of triggering the cello strokes. Through the integration of melodic framework with their spatial and visual perception, users can craft imaginative multimodal experiences. (Figure 2c).

4 EXPERIENCING SPATIAL ORCHESTRA

Users were instructed to stay within the virtual fence and to move slowly around the play-space. They were further informed that each bubble encountered would contain cello sounds. Color coded bubbles matched specific notes encouraging users to interact with the bubbles individually or in clusters to compose music (Figure 2c).

The size of the space, bubble dimensions, number of bubbles, and bubble's surface shaders were meticulously adjusted to ensure an optimal user experience. The goal was to create an environment full enough for creative music composition but not to the extent that users felt a lack of control.

4.1 User Feedback

During our university public event, we showcased the Spatial Orchestra, allowing interested participants to sign up and experience it. Over the course of two days, 60 users had the opportunity to engage with the Spatial Orchestra.

While the majority of feedback was positive, some users mentioned that they couldn't easily discern whether they were inside the virtual bubble or not, as the visual cue disappeared once they entered the bubble. To address this, we modified the rendering of the bubble texture to be visible from both inside and outside, providing users with a translucent color cue to indicate their position within the bubble (Figure 3b).

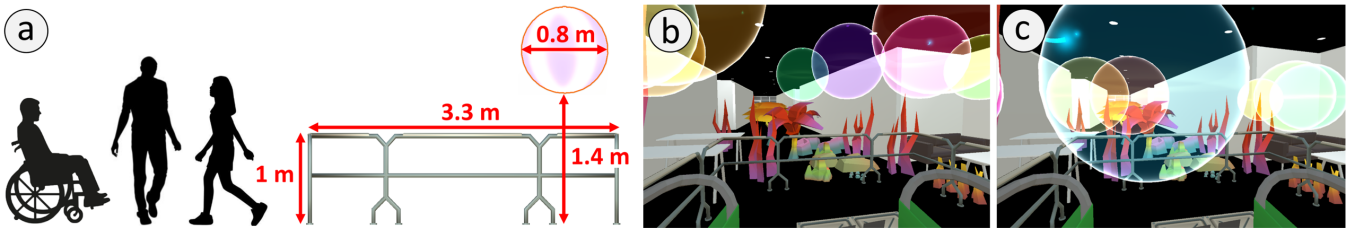

Figure 4: a. Compares the virtual bubbles' size to the virtual fence's height. Based on individual viewpoint heights, it may be challenging for some people to interact with bubbles directly. b. View from the person in a wheelchair engaging with the bubbles. c. We implemented an accessibility mode that allowed manual adjustment to the height of the bubbles. As you can see, the bubbles appear at the correct height when viewed from a wheelchair.

In response to user feedback, we also adjusted the transparency levels of the bubbles to enhance visibility, especially when multiple bubbles overlapped. This modification allowed users to better perceive individual bubble colors and easily identify and mix multiple cello notes in the same area. Experienced musicians told us that if they could see clearly when bubbles stacked in a crowded area, they would be able to play music more effectively (Figure 3a).

Based on participant comments, we observed that many reported favorable experiences with high levels of engagement and felt immediately able to produce music while interacting with bubbles. Some participants even spent more than 20 minutes exploring and mastering the rhythm of the composition, exceeding our expectations for user engagement.

4.2 Accessibility and Safety

For users to understand their location in the play-space and proximity to the center, we included an augmented marker indicating the center. Colorful plants signified the boundary of the play-space and the proximity to the fence, adding a visual cue and safety buffer.

Azure Spatial Anchors precisely aligned augmented objects during user motion [2]. Multiple anchors ensured alignment throughout the experience; if one failed, others maintained the objects' locations. Only one anchor failed in a continuous five-hour test. The participant remained unaware, highlighting the system's reliability. Lastly, to accommodate wheelchair users and children, we also implemented Accessibility Mode, which allowed us to manually adjust the height of the bubbles that float.

5 CONCLUSION

In conclusion, we introduced Spatial Orchestra, a spatial musical instrument that utilizes natural locomotion. Playing this instrument is not only an immersive experience but also an expression of physical movement. Utilizing a stand-alone augmented reality headset, we showcased a music instrument that leverages walking as a means of interaction. It is designed for anyone to learn quickly and play effortlessly, even without prior musical training.

During a university event, participants discovered various patterns and techniques to play music. They adjusted the rhythm by entering bubbles more or less frequently, showcasing their virtuosity through empirical user tests. Some users also found creative ways to produce specific sounds by combining bubbles or waiting before entering them.

Users enjoyed the distinctive experience of interacting with bubbles to create sounds. Despite the challenges of generating precise notes and rhythms, the simplicity of using natural inputs like walking offers users an accessible and enjoyable way to play music.

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