VVRMA: VR Field Trip to a Computer Music Center

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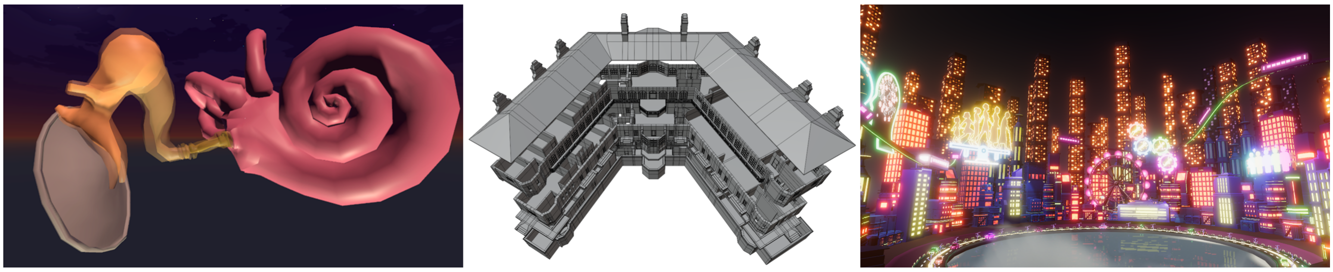

Figure 1: VVRMA's virtual field trip environment examples: the middle ear, centerpiece building, and musical city.

ABSTRACT

VVRMA is an interactive, audiovisual, fully immersive VR field trip to a virtual reimagining of CCRMA—Stanford University's Center for Computer Research in Music and Acoustics. Envisioned as a "VR interactive museum for computer music", VVRMA is the name of the virtual centerpiece building, meticulously modeled after CCRMA's physical architecture. Within VVRMA, visitors explore various Zones of Interest (ZOIs), which are collections of immersive experiences that thematically mirror various research labs at CCRMA. As design case studies, this paper examines the first two ZOIs: 1) "*From Sound to Brain*" (a boat ride into the ear canal to learn about the science of hearing), and 2) "*The World of Artful Design*" (a musical city for exploring interactive audiovisual design and humanistic implications of technology). VVRMA aims to create a playful, expressive, and immersive learning space accessible to a general audience, who are curious about music, technology, and the medium of VR. This paper chronicles the design of VVRMA through the lens of humanistic tool-building, emphasizing programmable audio and VR's immersive affordances.

Author Keywords

virtual reality, audiovisual interaction, artful design, virtual field trip

CCS Concepts

•**Applied computing** → *Sound and music computing; Interactive learning environments;* •**Human-centered computing** → *Virtual reality;*

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1. INTRODUCTION

VVRMA is a VR field trip to a computer music center, modeled after CCRMA in both architecture and content. It houses various Zones of Interest (ZOIs), which are collections of interactive, immersive experiences that thematically mirror CCRMA's different research labs and facilities: Neuromusic Lab, Music-Computing-Design lab, Physical Interaction Design lab, the Listening Room, the Stage, and more. The ZOIs' aim is not to replicate the facilities themselves, but to transport visitors to fantastical environments inspired by their respective topics (Figure 1. Each ZOI resides in its respective location within VVRMA's virtual model. For example, the Neuromusic Lab features a giant floating brain that serves as the entrance to the ZOI on the science of hearing.

We designed VVRMA within the framework of humanistic tool-building [28], which is a design created from and for humanistic values such as creative expression, aesthetics, and social well-being. It is neither an act of engineering nor art-making alone, but the two radically synthesized for a *total experience*, cognizant of both functionality ("what the design does *for* you") and aesthetics ("what the design does *to* you").

VVRMA adopts an audio-driven approach, leveraging Chunity [5] (ChucK in Unity game engine [3]) to prioritize programmable audio as a central modality of the overall experience. ChucK—a strongly-timed computer music programming language—enables temporally deterministic control over dynamic sound synthesis [29], with which we can precisely integrate real-time audiovisual interaction and immersion. This approach fittingly aligns with VVRMA's thematic essence on computer music as well.

We chose fully-immersive virtual reality (VR) for its unique affordances as a medium. Characterized by the use of head mounted display, VR provides a simulated environment that surrounds users, fostering an unmediated perception and interaction akin to the physical world. This engenders a heightened sense of presence and immersion even for environments that defy physical laws [15][7]. Leveraging these distinctive affordances, VVRMA offers novel, fantastical VR experiences, with all graphical elements rendered live in 3D (i.e., with no physical imagery like 360° photos or videos).

As a roadmap for the rest of the paper, Section 2 provides context to virtual field trips. Section 3 details the creation of the centerpiece building and the introductory ZOI. Sections

4 and 5 delve into the humanistic audio-driven VR designs of the first two ZOIs. Finally, Sections 6 describe future works and Section 7 concludes.

2. RELATED WORKS

A virtual field trip (VFT) can be broadly defined as a journey taken to a simulated environment representing an actual field site [30][20]. The term 'virtual' in VFT encompasses various types of media such as text, audio, photographs, and videos [26]. Recent designs emphasize the use of 360° imagery to create web-based VFTs on both desktop [2][1] and head-mounted displays [23][14][22]. However, surprisingly few VFTs use fully-immersive 3D-modeled, real-time rendered virtual environments [19][21]. Some studies suggest that 3D-modeled environments may be insufficient for VFTs requiring precise physical visibility, such as construction safety education [23], or they may demand substantial design and programming skills [13]. Nevertheless, we chose VVRMA to be a fully 3D-modeled environment because we aspire for visitors to be immersed and interact with fantastical learning spaces like the lyrics to the opening song of *Magic School Bus* (1994): "*Cruising on down Main Street, you're relaxed and feeling good... The next thing that you know, you're seeing... surfing on a soundwave, swinging through the stars, taking a left at your intestine, take your second right past Mars*" [9].

VFTs are commonly acknowledged to afford reduction in excursion costs [16], accessibility for individuals with mobility challenges [4], socioeconomic equity [26], mitigations of on-site risks [23], and a heightened sense of presence and agency in learning [18]. However, while these affordances form a significant aspect of VVRMA's outcomes, its true essence lies in the experience itself. Rather than merely serving as an alternative to a physical field trip, VVRMA aims to carve out a unique experiential identity. To accomplish this, we adopted an aesthetics-driven approach, in which we "*design not only from needs – but from the values behind them* [28]." With the computer music modality at its core, VVRMA integrates essential design principles from interaction design [10], visual design [27], VR instrument design [25], and VR design philosophy [6].

3. CENTERPIECE BUILDING

3.1 3D Modeling

VVRMA is the centerpiece building, rendered live in 3D (Figure 2). We undertook a detailed creation of a 3D model for several reasons: 1) to offer visitors a space to walk around and interact with the building as a virtual site; 2) to create a deliberate transition and contrast with the more imaginative experiences found within the ZOIs; and 3) to have flexible control over rendering and altering the building (e.g., a room dynamically morphing into a caravel).

We initially explored AI 3D scanning tools for creating the building model, only to find resulting vertices misaligned, inaccurate, and overly complex for our needs. Consequently, we opted for a more "hands-on" approach, utilizing primitive, yet highly controllable tools: our hands, measuring tapes, and floor plans. Using the 3D modeling software Blender [24], we crafted the walls, doors, windows, and stairways spanning three floors of the structure. While the sheer number of invested hours tempted us to resort to AI assistance, persevering through manual modeling yielded a virtual environment that is both precise and highly adaptable.

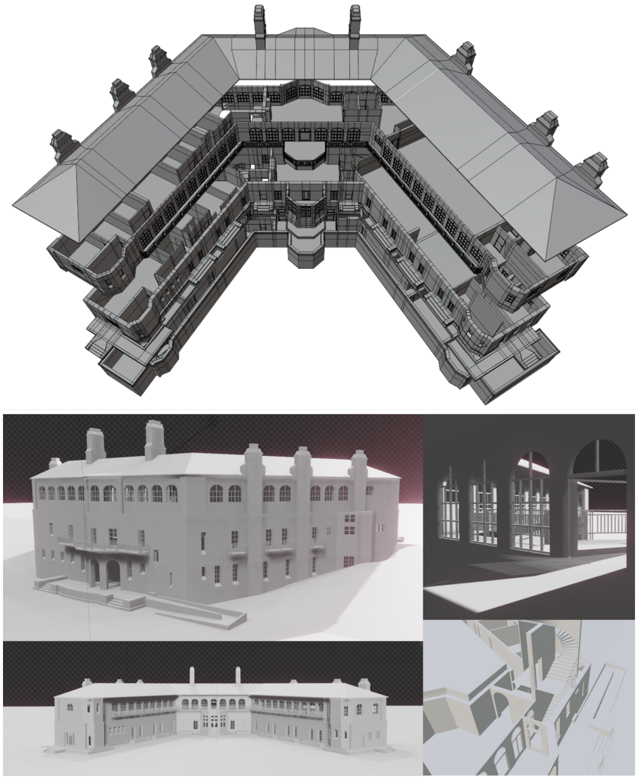

Figure 2: 3D models of the centerpiece building.

3.2 User Interface Panel

VVRMA visitors can open a user interface (UI) panel comprising four menu items: 1) a soundtrack playlist for potential audiovisual interactions during the visit; 2) a microphone setting with options for on/off toggle, volume adjustment, and reverb control; 3) a quick travel menu, facilitating instant movement to different floors within VVRMA or ZOIs; and 4) a locomotion setting, consisting of snap turn toggle (to enable/disable continuous rotation in VR that may induce motion sickness), snap turn angle adjustment, and movement speed controls (Figure 3).

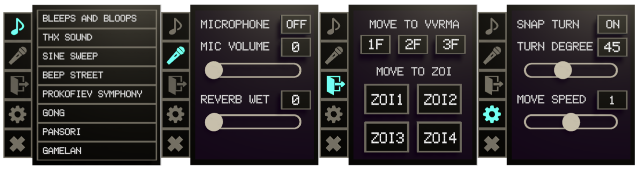

Figure 3: Common user interface of VVRMA: soundtrack playlist, microphone, quick travel, and locomotion settings.

3.3 ZOI 0: *The Arrival*

Visitors begin their journey through ZOI 0 – *The Arrival*, which serves as an immersive introduction to VVRMA. Its audiovisual form echoes the laptop orchestra composition called, *Crystalis* (2007) [11]. Within a white, snowy space, visitors listen to gusts of computer-generated winds from *Crystalis*, while reading a series of narrative text:

"*Here you are. Welcome to VVRMA... a virtual field trip to a computer music research center... where the improbable is reality. VVRMA is based on Stanford University's CCRMA and was created in its VR Design Lab. Here you will learn about–and experience–the science, technology, and* *art of computer music. . . The gusts of wind you hear are, in fact, being generated in real-time by the computer running this VR simulation. The sound synthesis was adapted from a Stanford Laptop Orchestra piece named, "Crystalis"...and coded in a music programming language called ChucK. . . For now, stay a while and listen, as we journey to our first Zone of Interest. . .*"

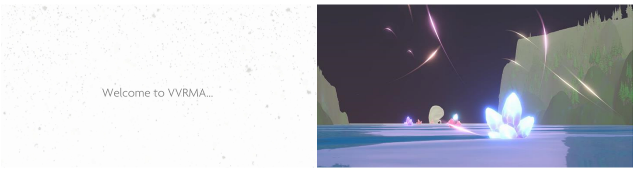

Figure 4: ZOI 0 - *The Arrival*, introductions to VVRMA and virtual experience of *Crystalis* (2007).

Following this, visitors embark on a tranquil boat ride across a lake with floating crystals, serenaded by the shimmering sounds from *Crystalis* (Figure 4). Each sound illuminates a crystal, casting a gentle ray of light to an ear buoying in the distance. The boat ride is unhurried and serene, providing a room for listening, observation, and reflection. As the boat gently glides into the ear canal, the scene transitions to the first ZOI, "*From Sound to Brain*."

4. ZOI-1: *FROM SOUND TO BRAIN*

4.1 Narrative Design

This ZOI draws its inspiration from the Neuromusic Lab at CCRMA. Visitors learn how sound pressure transforms to mechanical energy and electric signals as it traverses the ear to the brain. The narrative structure is akin a dark ride in an amusement park, where visitors travel via boat through the ear canal, eardrum, ossicles, cochlea, basilar membrane, and finally, the brain.[1]

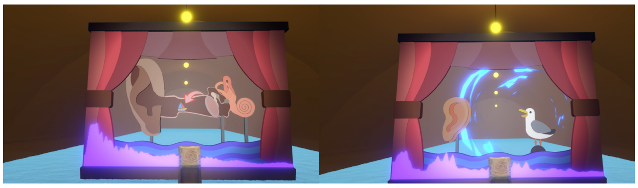

Figure 5: Narrated animations on the outer ear's functions.

Visitors begin the journey from the outer ear through the ear canal. Here, narrated animations elucidate the current location, the nature of sound, and its propagation within the outer ear (Figure 5). Then, as the boat slowly proceeds toward the eardrum, visitors are invited to interact with the surrounding environment by using their voice or the soundtrack playlist. For each sound they produce, its waveform is abstractly visualized as a pressure wave particle traversing through the ear canal, while its frequency spectrum is displayed in front of the boat. Upon reaching the eardrum, visitors use the "Sound Battery"—an audio UI for "confirm"—to advance to the middle ear (Figure 10).

[1]Video recording of ZOI-1: `https://vvrma.stanford.edu/videos/zoi-1/`.

Figure 6: Narrated animations on the middle ear's functions.

Upon arrival at the middle ear, visitors see the eardrum, ossicles, and cochlea from afar (Figure 6). Narrated animations explain how they convert sound pressure into mechanical energy. As visitors maneuver toward the inner ear, they are invited to freely create sounds (e.g., by vocalizing), which trigger animations of the eardrum and ossicles to demonstrate the conversion process in action.

Figure 7: The inner ear: the basilar membrane and the brain.

In the inner ear, visitors behold the spiraled basilar membrane and the brain (Figure 7). A narration describes how the inner ear converts mechanical energy into electric signals to the brain, while demonstrating the cochlea's role in frequency differentiation through a visualized sine sweep. At this point, the basilar membrane becomes a real-time audio visualizer, with each sound produced by the visitor undergoing Short-Time Fourier analysis, then algorithmically visualized to mirror the frequency mapping of the membrane.

About halfway toward the brain, a subsequent series of narrations elucidate how the brain interprets the sounds, emphasizing that what we hear as music transcends mere vibrations or electric signals, as music also carries meaning, emotion, and memories. It prompts reflection on how the science of hearing underlies our aesthetic experience. To underscore this, a computer-generated gamelan music accompanies a fantastical scene, where whales gracefully glide, jellyfish speakers ascend, and the brain releases a bloom of flowers. After this journey, visitors return to the Neuromusic Lab at CCRMA.

4.2 Audio-driven Design

ZOI-1 incorporates a number of audio visualizations to enrich the narrative of the science of hearing. Specifically, we implemented two spectrum visualizers. With each output audio buffer from Unity, we applied a Hanning window, performed a Fast-Fourier Transform, and utilized the spectrum amplitude data to dynamically adjust vertical scales of visual objects, or trigger visual particles to the brain (Figure 8).

Furthermore, ZOI-1 integrates signal power visualizations. In ChucK, each audio output undergoes digital one-pole filtering to estimate signal power, which is then sent to Unity, smoothed through linear interpolation, and normalized to a float value. We leveraged this data to activate sound particles in the ear canal, control animation frames in the middle ear (Figure 9), or flicker lights inside the brain. Consequently, the majority of dynamic visual elements within this ZOI respond to real-time audio signals, including narrations, visitors' voice, and sounds from the playlist.

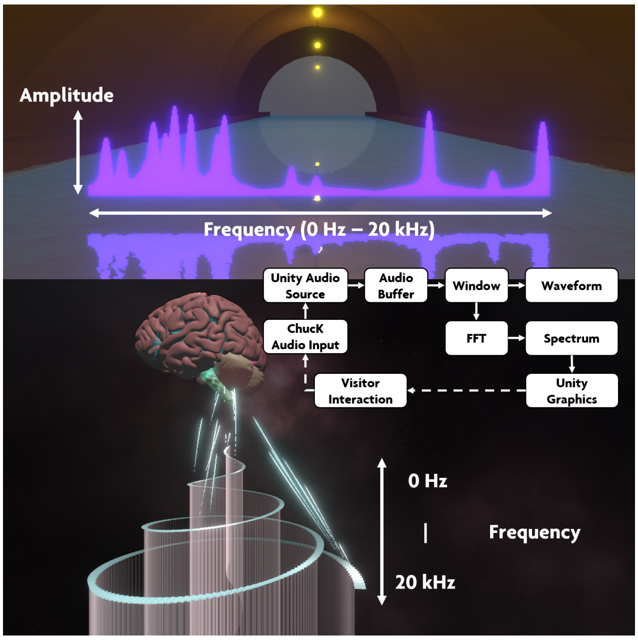

Figure 8: Real-time spectrum visualizations of visitors' voices in the ear canal and the inner ear.

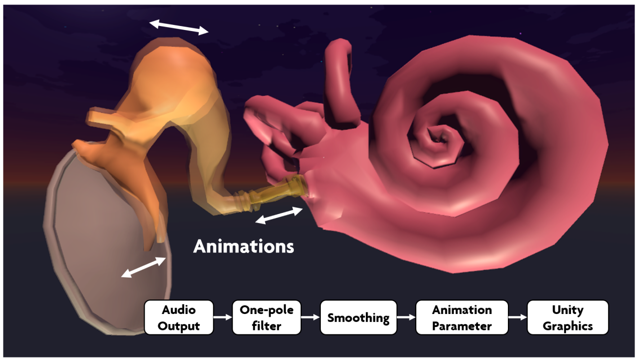

Figure 9: Real-time visualizations of the eardrum to cochlea in action. Visitors can talk and sing into the headset microphone and see the inner workings of the middle ear.

4.3 Humanistic VR Design

VR is a medium capable of creating infinite realities [7], empowering designers to harness this capability to craft experiences unattainable elsewhere [6]. ZOI-1 unveils a series of fantastical environments featuring not only scaled-up ear structures but also interactive visuals, responding to visitor-generated sound inputs. Moreover, as the brain unfolds to reveal blooming flowers and flying whales, ZOI-1 delves deeper into its imaginative layers, offering an aesthetic expression of how the science of hearing underlies the beauty of music.

Moreover, Lanier (2017) advocates for prioritizing bodily engagement over rigid button presses in VR to enhance immersion [15]. An instance exemplifying this principle is the "Sound Battery" (Figure 10), which replaces the standard UI for "confirm." For example, when the narration prompts the visitor, "*To proceed to the Middle Ear, fill this battery with some sound,*" visitors use their own voice via headset microphone to fill the "Sound Battery." Incorporating visitors' own sounds for even mundane interactions like "confirm" may offer more opportunities to infuse personality into the virtual environment.

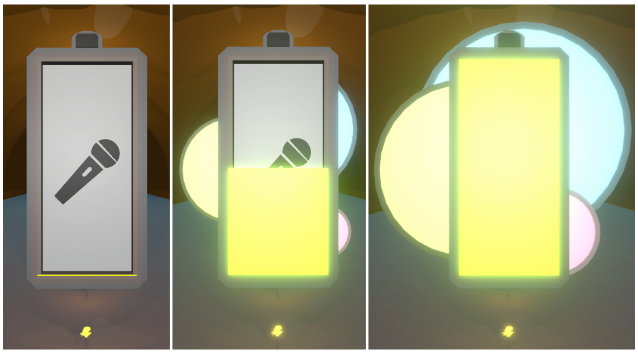

Figure 10: "Sound Battery UI" for "confirm."

5. ZOI-2: *WORLD OF ARTFUL DESIGN*

5.1 Narrative Design

Drawing inspiration from the philosophy of *Artful Design* [28], the theme of this ZOI is on the humanistic implications of technology. Visitors learn about the concept of humanistic tool-building, which is design that seeks to radically synthesize functionality and socio-aesthetic values. Rather than through telling, these ideas are experienced via visitor interactions within an immersive audiovisual environment (Figure 11).[2]

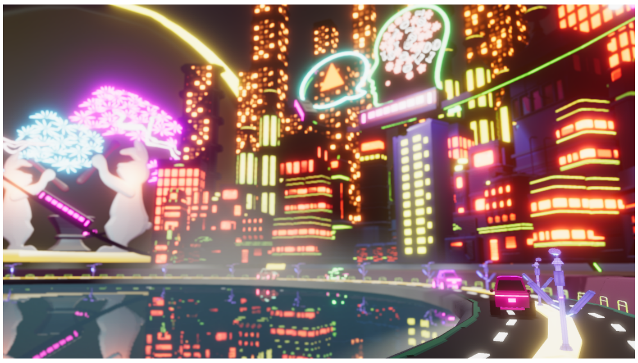

Figure 11: An experiential musical city with various audio-visual interactions.

The aims of this ZOI are twofold: first, to point out how technology has complicated our lives (ironically often in its pursuit to simplify); and second, to offer a hopeful perspective. If the way we shape technology serves as a vote for the world we would want to live in, then what would it mean to vote for the beautiful and the sublime? Bolton (2022) [8] postulates that while technology strives to simplify our lives and enhance connectivity, it has also brought existential challenges, including the monetization of daily activities, the exacerbation of the 'loneliness epidemic,' and the sacrifices of human well-being for profit. Is this the future we want? *Artful Design*'s manifesto asserts, "*In our age of rapidly evolving technology and unyielding human restlessness and discord, design ought to be more than simply functional; it should be expressive, socially meaningful, and humanistic. Design should transcend the purely technological, encompass the human, and strive for the sublime*" [28]. This ZOI serves as an interactive audiovisual metaphor embodying this manifesto: the city symbolizes technological society, the music represents artful design, and the experiential changes reflect humanistic aspirations for the beautiful

[2]Video recording of ZOI-2: `https://vvrma.stanford.edu/videos/zoi-2`.

and the sublime. Unlike ZOI-1, which focuses on delivering information about the science of hearing, ZOI-2 centers on the experience itself, in which visitors conduct a musical cityscape and witness its evolution in tandem with the musical narrative.

The scene begins with visitors transported into a floating city at night. Arranged in rectangular formation, the city buzzes with typical urban noises amidst animated neon signs. However, as visitors raise their conducting baton, the cacophony of city sounds gradually gives way to orchestral tuning sounds. The city buildings gently gather around visitors in a circle, while the distant Moon draws closer, revealing its inhabitants – rabbits pounding with a mortar and pestle. As the city pavements vanish, interactive buildings emerge from the ground (Figure 12).

Figure 12: The musical city in circular formation, awaiting for visitors in the center to interact with various elements.

Visitors now engage in conducting, breaking the silence with gradual development of music. With their right hand, they can wield the conductor's baton to select interactive city elements. With their left hand, they can adjust the audio parameters related to each element by raising or lowering their hand. The four high-rise buildings represent the drums, harmonic chords, melody, and bass, with the density of each instrumental layer adjustable through the amount of interactive window lights. Manipulating the low-rise building's window lights adjust the overall volume, while the rotating the Ferris wheel controls the tempo. Moon trees govern granular synthesis parameters such as gain and timbre for an atmospheric soundscape (Figure 13). Additionally, the UFOs descend from the sky to transform into virtual marimbas for improvisation (Figure 14). Detailed descriptions of the audio design are provided in Section 5.2.

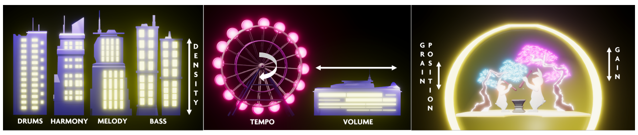

Figure 13: Interactable city elements and audio parameter mapping.

Figure 14: Playable UFO marimbas.

Musical developments made with visitors' conducting interactions prompt visual changes in the scene. In particular, the five animated neon signs each represent a design ethos of humanistic tool-building.

First, adjacent to the Ferris wheel, a neon sign features runners in cogwheels. As visitors raise the tempo by turning the Ferris wheel, the runners transition into dancers, symbolizing that artful design aspires fostering self-expression alongside productivity (Figure 15).

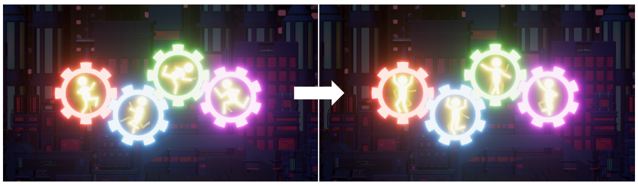

Figure 15: Poetic neon sign: "Design that fosters self-expression."

Second, near the drum building, a neon sign portrays a person's head with 0s and 1s spiraling from the brain to the mouth. Increasing the drum density introduces various flowers into the stream of binary digits, altering the responses in speech bubbles from right or wrong to colored geometric shapes. This signifies that artful design embraces the duality between function and aesthetics, where results can seldom be binarily categorized (Figure 16).

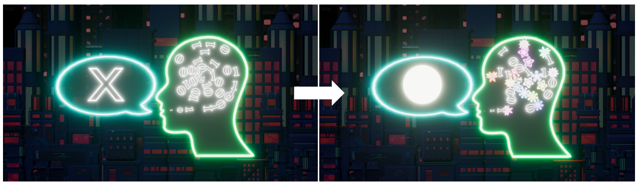

Figure 16: Poetic neon sign: "Design that embraces the duality between function and aesthetics."

Third, next to the harmonic chords building, a seesaw features a child on the lighter end and a money bag on the heavier end. Elevating the harmonic chord density causes the seesaw to flip, transforming into a bridge. Silhouettes depicting the life cycle of the child emerge above, illustrating that artful design resists the commodification of people and embraces human life in its entirety (Figure 17).

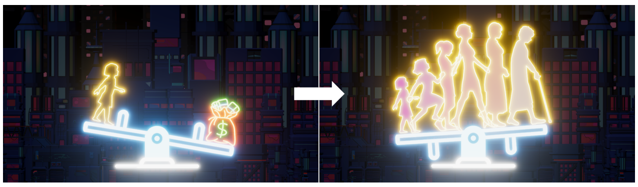

Figure 17: Poetic neon sign: "Design that does not commodify people."

Fourth, adjacent to the melody building, benches with dividers separate individuals. When the melodic density increases, the dividers disappear to connect people together, reflecting that artful design values human connection and combats the 'loneliness epidemic' (Figure 18).

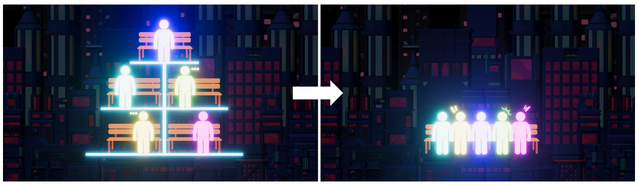

Figure 18: Poetic neon sign: "Design that promotes connection."

Lastly, near the bass building, there is a slot machine. Raising the bass density changes the reels from numbers to various art icons. Thereafter, every spin becomes a win, for art is variegated and inconclusive. Inspired by psychological manipulations used in video games that trap players with gambling elements, this underscores the value of freedom in play in artful experiences (Figure 19).

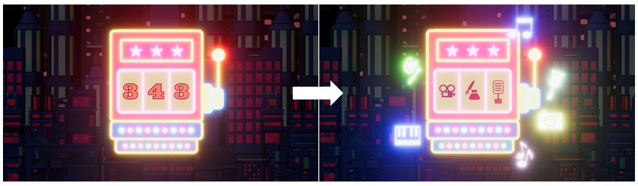

Figure 19: Poetic neon sign: "Design that values freedom in play."

In addition to the neon sign changes, the city becomes more vibrant in tandem to musical development (Figure 20). The city lights illuminate with the music. Cars appear on the roads, occasionally emitting honks, while trains depart from the Moon, weaving its way into the city, symbolically connecting the whimsical with the everyday ebb and flow of city life.

Figure 20: Various changes in the city in tandem with musical development.

5.2 Audio-driven Design

This musical city is essentially a massive drum machine with nine controllable parameters dispersed throughout: tempo, volume, drums, harmonic chords, melody, bass, granular synthesis gain, grain position, and directly playable marimbas [12]. An overarching ChucK script monitors three global musical parameters (swing, tempo, and volume) and updates any changes to local audio sources. Preassigned in the ChucK script, the swing parameter controls the delay percentage of odd beat releases to establish groove.

The four high-rise buildings govern the respective note density for each instrument (drums, harmonic chords, melody, and bass), with a density of 0.0 for no lit windows and 1.0 for all lit windows. This parameter facilitates a pseudo-randomized control for rhythmic complexity. Each instrument has a "trigger" array (prescribed sequence of 0, 1, and 2s) assigned in their respective ChucK scripts that decide "no", "yes", or "maybe" for sound playback on every minimum beat onset. A "trigger" element of 0 ("no") indicates no playback, 2 ("yes") signifies playback, and 1 ("maybe") involves random number generation (0.0 to 1.0) for playback if the result exceeds the current density parameter. Thus, 0s and 2s establish the basic structure of a sequence, 1s introduce intriguing complexities based on the density parameter (Figure 21).

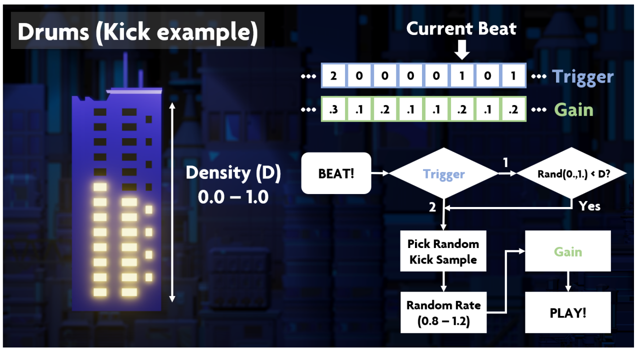

Figure 21: The flow of a sound playback based on the audio density parameter.

The high-rise buildings incorporate additional parameter randomizations. Firstly, the drums employ multiple sample pools for each element (kick, snare, hi-hats, and cowbells), with randomized playback rates (0.8 to 1.2) to keep each beat fresh. Secondly, four simultaneous unit generators in ChucK, employing the `Rhodey` STK instrument, generate the harmonic chords. On each measure onset, it selects one of three trigger array patterns to add rhythmic variety, with chords randomly switching between open and closed positions. Thirdly, melodies are generated by ChucK's `ModalBar` unit generator, with three different trigger array patterns composed solely of 0s ("don't play") and 1s ("maybe play") for added randomness. Melodies select pitches randomly from a pool of pentatonic scales of each chord with occasional tension notes for flavor. Lastly, the bass provides stability, with assigned trigger elements of 2s ("always play") on important beats and pitches grounded in common diatonic notes of each chord. All instruments undergo additional gain randomization. These methods ensure that the music in ZOI-2 remains dynamic and engaging within its 8-measure (128-beat) loop.

The Moon features two trees, enabling visitors to control the gain and position of a granular synthesis element that produces an atmospheric soundscape. Adjusting the grain position with the left tree allows visitors to choose from a range of orchestral and choral timbres. The volume of the soundscape can be managed with the right tree. Additionally, visitors can summon UFOs in the sky to function as marimbas for impromptu performances, using virtual mallets in their hands. Eight UFOs are pitch-mapped automatically in a pentatonic scale to correspond with each chord, offering a performance assistance for enjoyment.

In this ZOI, every sound generated in the scene has its own visual correspondence. For instance, each drum sample playback illuminates adjacent background buildings, with tempo dictating the duration of each light interpolation. Furthermore, the overarching narrative, including the alterations in neon signs, the appearances of cars and trains, and the animations of Moon rabbits, is influenced by the overall musical density present in the scene.

5.3 Humanistic VR Design

The concept of conducting inspired the interactions with the musical city (Figure 22). While various parameter adjustments could be accomplished through joystick maneuvering and controller button presses, deliberately framing them with conducting gestures enhances both physical and psychological connections to the virtual environment, enriching the overall experience with playfulness, expressiveness, and immersion. To further align with gestural motions, we incorporated visual particles, hand animations, and controller haptic feedback.

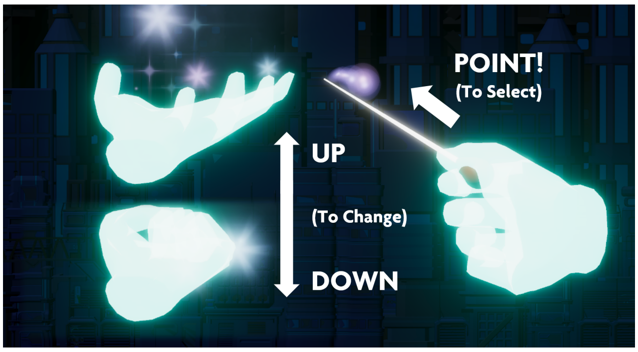

Figure 22: Conducting gestures: visitors use their right hand to select objects and left hand to adjust parameters.

Moreover, sound spatialization is essential in VR as it not only enhances the sense of presence through aligning sound objects with corresponding visual elements, but also mitigates confusion and potential disorientation [6]. In ZOI-2, five audio sources surround the visitor (Figure 23), employing binaural spatialization primarily through interaural level differences. We applied custom rolloff to volume (amplitude difference based on distance) and spread (angle of the audio source) to each sound source. As the visitor moves within the city, closer sound sources increase in volume, while rotation prompts binaural panning according to the angle of the source.

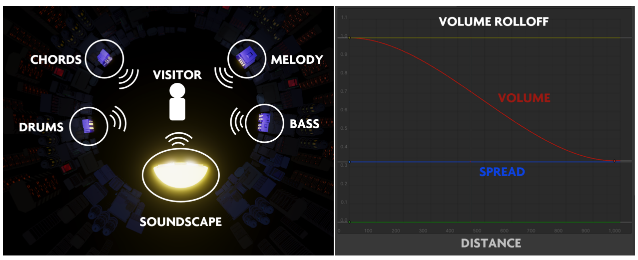

Figure 23: Sound spatialization in the musical city. Visitors are located at the center of the city, while five audio sources surround them with custom rolloff for volume (intensity) and spread (angle) for each source.

6. FUTURE WORK

6.1 The Future ZOIs

VVRMA currently hosts empty rooms awaiting to be filled with VR experiences. The learning space can expand alongside CCRMA's various other research initiatives. For instance, the Physical Interaction Design Lab could transform into a Virtual Instrument Creation Sandbox, using physical modeling and computer-mediated audio. The Listening Room could integrate visual models with convoluted reverberation data of the Hagia Sophia. The VR Lab could be renamed to VVR Lab (what does it mean to be in *virtual virtual reality*?! Could one put on a virtual head-mounted display *in VR*?! What?)

Two imminent ZOIs are planned for development. The first is a ZOI centered on a computer music concert, echoing experiences of the Stage, CCRMA's main performance venue. Currently in progress is the Stanford Virtual Reality Orchestra (SVOrk), where both performers and audience coexist in a shared virtual concert space. Unlike conventional orchestras, SVOrk does not involve violins or concert halls; instead, it conjures fantastical whales as instruments and uses flying caravels as the stage—experiences that can only exist in VR. As a ZOI, We intend to record the concert for full VR replay as part of VVRMA.

The second additional ZOI explores audio signal processing. The overall aesthetics of this experience is inspired by the Disney classic film, *Donald in Mathmagic Land* (1959) [17], where Donald Duck immerses himself in a fantastical animated realm to learn about various mathematical phenomena. In the signal processing ZOI, visitors take on the vantage point of a lost traveler, stumbling into magical and educational experiences on topics of Fourier Transforms and audio filters; perhaps even plucking a guitar string the size of the Golden Gate Bridge and hearing a computationally modeled string of such magnitude.

6.2 Additional Features

In addition to the new ZOIs, we have several new features planned for VVRMA. First, we aim to implement customizable avatars for visitors upon entering the field trip, with avatar kinematics closely connected to visitors' arm movements to enhance embodiment. Second, ZOI-2 will feature additional short scenes before and after the musical city, including an interactive library offering more context on *Artful Design* [28], and a scene exploring the sublime of the everyday, emblematic of humanistic tool-building. Third, we intend to conduct user studies to evaluate VVRMA's educational impact, potentially using the Cognitive Affective Model of Immersive Learning (CAMIL) [18]. Lastly, we aspire to publish VVRMA as an open, free application accessible to the general public.

7. CONCLUSION

We presented VVRMA, a VR field trip to CCRMA, and described its overall narrative, audio-driven approach, and design considerations tailored to the fully-immersive medium of VR. We unpacked the design of the first two interactive Zones of Interest (ZOIs) on the science of hearing, and humanistic tool-building, respectively. In chronicling these aspects, we hope to demonstrate that incorporating 3D models and animations, with their interactions governed by dynamically generated audio, can offer novel, fantastical contexts for virtual field trips. Moreover, while it may be tempting for virtual field trips to "check the box" on various educational outcomes, perhaps they can and ought to do more—and be artful experiences unto themselves.

For demonstration videos of VVRMA:
ZOI-1: `https://vvrma.stanford.edu/videos/zoi-1`
ZOI-2: `https://vvrma.stanford.edu/videos/zoi-2`

8. ETHICAL STANDARDS

This paper complies with the NIME ethical standards. No human or animal participants are involved.

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