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Metaphysical Instruments: Prototypes for Hybrid and Live Music-Making

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ABSTRACT

This paper explores the creation of electronic musical instruments designed for hybrid live performance. Following a Research-through-Design method, this study reveals findings on how internet-connected electronics afford the possibility of producing sound that is experienced simultaneously in tangible and virtual space. By making physical prototypes we analyze what these objects elucidate about the nature of instruments, live music, and networked performances in virtual and hybrid spaces.

1. Introduction

The digitization of sound since the 1990s has had unimaginable consequences for the ways in which music is produced, distributed and consumed. From the disappearance of the mixtape in favor of playlists on mp3 players to the sampling of online files in live music performances, digitality has offered possibilities in which the roles of musicians, distributors and consumers has become blurred (De Notaris and Savonardo, 2022). As internet connections became faster, mobile, and more broadly available, our lives have been increasingly mediated by online services and social media platforms. Since our tangible world has become so interwoven with software, in recent years the idea of inhabiting completely virtual environments—the metaverse—has gained momentum and is beginning to turn into reality (van der Merwe, 2021). In this work we explore how music can be played and listened to in-person and within the metaverse simultaneously, while focusing on musical instruments as both tangible and virtual objects.

As the metaverse begins to be recognized as a space of opportunity for music, we ask ourselves how live music can be performed and experienced within it. There has been extensive research around networked music performance, as discussed by Rottondi et al. (2016), and some companies (e.g. Sensorium Galaxy, Mizic.io) are starting to offer virtual reality (VR) and hybrid concerts with some of these happening within video game environments (Groux, 2020). There has also been a lot of focus on how networked music can enable collaboration between musicians and also enhance audience participation (Yamchareon and Herkenrath, 2005; Carot, Hohn, and Werner, 2009; Xambó et al., 2017). These studies tend to focus either on the technicalities of synchronization or on the social aspects of collaboration and how they exist online. There is however very little work that questions the design of musical instruments as interfaces for online and VR performance with (Serafin et al., 2016) and (Turchet, 2019) presenting some ideas and guidelines. We find that the instruments described for virtual and networked performances in these papers are very familiar and resemble or build upon traditional instruments such as guitars, xylophones and assorted percussion instruments. We thus center our study on what instruments for hybrid performance should look like, how they should be played, and how they sound.

Focusing on musical instruments as objects allows us to approach this project through a Research-through-Design (RtD) methodology. Following ideas from Frayling (Frayling, 1993), Gaver (Gaver, 2012) and Andersen (Andersen, 2014) we consider how the design and development of prototypes is in and of itself a generator of knowledge. Given that our research questions revolve around objects which do not yet exist and for which there is currently no established market, we find Critical Design (Dunne, 2008) to provide a useful space within which to frame our research.

2. Metaphysical Instruments

Having outlined the existing landscape for online and hybrid sound performances, we worked with seven undergraduate students from the Physical Computing and Digital Manufacturing labs at CENTRO. Students were divided into three groups and asked to develop prototypes of instruments that produce music in both the tangible and the virtual world at the same time. Our students were all starting the second year in the Design for Digital Media and Technology program. At this stage in their studies they all have a general knowledge of programming, 3D modeling, animation, and digital drawing but have never worked with electronics, embedded computing or any type of physical manufacturing.

We provided the students with a brief named *Metaphysical Instruments*, which focused on how music can exist both in the metaverse and in tangible space through the same interfaces. The brief's title is both a reference to philosophical metaphysics and a humorous pun in which the metaverse and physical are combined into a single word. From a design perspective we were interested in the aspects of metaphysics that deal with phenomenology, possibility, and necessity. The brief asked students to respond, according to their own interests, to the following key questions:

- How can the physical act of playing an instrument be transferred into virtual reality?
- What are some of the social opportunities and pitfalls for music in virtual environments?
- How can instruments be designed for hybrid performance? How should they be played? How should they sound?
- In what ways can live music be experienced in virtual reality?

These questions were intentionally quite broad and possibly ambiguous in order to avoid preconceptions of what music, instruments, and reality are so that they could narrow down the brief to suit their own definitions. As an additional material, students attended a lecture on experimental musical instruments and music. We wanted them to take distance from existing ontologies that categorize instruments (such as (Temilola, 2020; Turchet et al., 2022) and to come up with their own definitions of what an instrument is and can be. Following our RtD and Critical Design perspectives (Dunne, 2008) we encourage our students to follow a vision-driven design process, foregrounding the nonexistent rather than problem-solving or market demands.

Each group of students thus produced both a tangible object and its counterpart in virtual reality. A short description of each of the projects made follows.

CQNC: Community in Quest for Noise Connection
Patricio Pous-Pierson, Alejandro Lobo-Barrera, and Jordi Fragoso-Terreros

CQNC (pronounced sequence) is an experience that bridges virtual and tangible reality through real-time sound recording. This project explores how field recordings can be used to produce music and how a recording can function as an instrument. The experience relies on at least two players, one of them wearing a VR headset while the other carries a physical device (Fig. 1) capable of recording sounds and uploading them to a server.

FIGURE 1
CQNC Field Recording Device

Note: This is the experience's interface with the tangible world. Each time the trigger is pressed a sound recording begins. When the trigger is released, recordings are uploaded to a server.

Each time a sound recording is made the resulting sound file is downloaded into a virtual reality experience and represented as a ball (Fig. 2, left). The user in VR can pick up individual sounds and place them in a playback area (Fig. 2, right). All sounds in this area are looped and mixed together into a single output. Players can modify a sound's volume by moving it up and down in space and can also change its playback speed and pitch by rotating the sphere (left lowers the pitch and right increases it). As new sounds are captured more samples are available for mixing to VR users. The VR player can thus compose complex soundscapes, from samples that are being recorded live in distant environments.

In CQNC, interaction between players is blurry but existent. The player capturing real sounds cannot hear what is being composed in VR; however, as the creator of samples she can speculate on the type of composition being created and thus provide samples that reinforce her vision. Likewise, the VR player has no control over sample production and must work with what is being provided. We imagine this interaction as being either collaborative or adversarial, where the VR player either conforms to the recording's vision or tries to force her own onto the sounds being provided. It's worth noting that there could be several VR players, each receiving the same samples and composing them in unique ways.

FIGURE 2
CQNC VR Experience

Note: Each sound recorded in the wild is uploaded onto a server and appears in virtual space as a sphere containing it (left). Moving the sphere into the playback area (right) adds it to the composition. Moving the sphere changes this sound's volume and pitch allowing users to compose complex soundscapes by mixing several recordings.

From a technical perspective this piece is made possible by internet-connected electronics. CQNC uses a Raspberry Pi computer (Fig. 3) to process the sounds and upload them to a file-sharing server. Currently the sounds are transferred using a mobile hotspot created by the user's phone and the sounds take between 45 and 90 seconds to transfer from the field into the virtual world.

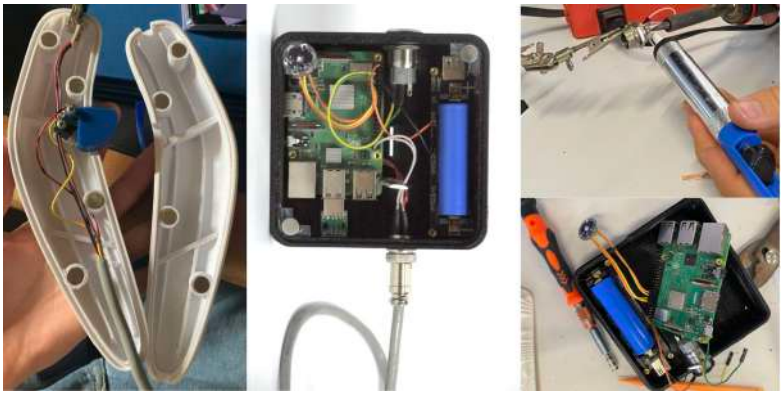

FIGURE 3
CQNC Electronics and Development

Note: The sound recorder was mostly 3D printed and works with a Raspberry Pi computer and custom Python code.

Conditioned Freedom (CF)
Paola Ferrari-García and Ximena Peña-Rios

In CF Paola and Ximena decided to take a more artistic approach and explore the format of an interactive installation that creates an experience that is drastically different for tangible and VR users. The project's title refers to creative freedom and how this is often constrained by personal drama. When describing the project, they mentioned that we often see the beauty of a finished artwork but seldom hear about the struggles of making it.

The installation in CF places the user in the role of the artist who enters a claustrophobic woven structure (Fig. 4) where several annoying sounds are played simultaneously. The user also sees several beams of light. As the user begins to interact with the light, she will realize that blocking a beam will mute one of the sounds and thus reduce the cacophony within the space making it more bearable.

FIGURE 4
Conditioned Freedom

Note: Users in the tangible world must enter a large woven structure to interact with this piece. Inside is an unbearable cacophony of individual sounds which can be turned off by blocking light beams.

In virtual space a different user experiences a beautiful landscape (Fig. 5), a space which is the opposite to the constrained and noisy environment of the physical installation. Each time one of the lights is covered in the installation a relaxing sound will be played in virtuality accompanied by a visual effect. The rationale behind this being that the more the player in the tangible world struggles the more beauty is produced in virtual reality.

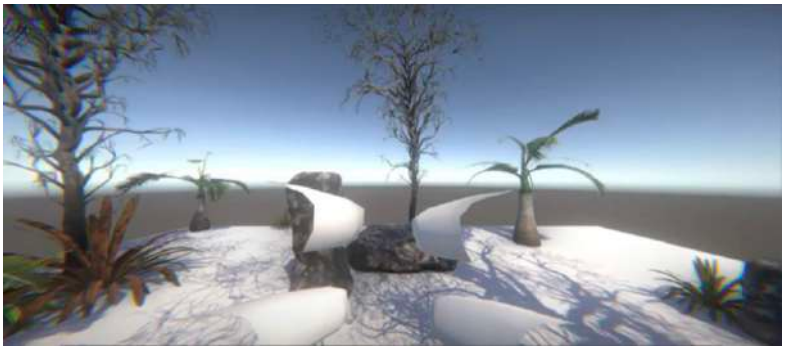

FIGURE 5

Note: Users in virtual reality experience an open landscape which grows more beautiful, both visually and acoustically, as the physical user attempts to turn off annoying sounds.

Despite the playful cruelty proposed by this piece, where one player's enjoyment depends on the other's suffering, CF can be seen as a large-scale musical instrument. The piece has a very direct mapping between the sounds it produces and the lights being covered, such that the person playing it can guide the viewer's experience. There is however an interesting aspect of the installation in terms of the feedback it provides; in a normal instrument, the hands will produce a gesture which results in a sound being heard, in this instance the opposite is true: silence becomes the feedback with which the musician must work.

Llum
Ana Fabiola Toledo-Galindo and Julio Torres-Cazares

What would it be like to be inside an instrument while it's being played? This was the starting point for Llum, an instrument that is played and listened to both from outside and from within. Llum is a small tangible instrument and a large virtual space, the project visually explores the connection between a real object and how its functionality changes when you alter its scale.

The instrument is shaped like a cracked sphere that emits light from within (Fig. 6, left). Each piece of the sphere is a key that can detect if it has been pressed and how hard, and it uses this information to synthesize a combination of sound and light in the real world. Its virtual counterpart is a scaled version of the same sphere (Fig. 6, right) within which the audience exists. The walls of this space coincide with the object's keys both in geometry and functionality; That is, if a user touches a wall it will synthesize the matching sound both physically and virtually.

FIGURE 6
Llum

Note: In the physical instrument (left), each section of the sphere works as a key. In the virtual space (right), each wall matches a physical key and when either of them are pressed a sound is played both in physical and virtual space.

Llum is therefore an instrument in which musician and audience collaborate to create music. One of the things we found interesting was that the difference in scale between the physical and virtual instruments allows the person playing in real space to access most keys at the same time while a single audience member can only reach one or two walls at a given moment. This gives much more control over the music to the person playing the tangible version. Should virtual players wish to play complex chords, they are forced to organize and play collectively.

For the instrument to work it was important that sounds could be added together when several keys were played simultaneously, either physically or virtually. The physical Llum relies on an internet-connected microcontroller to detect key presses, synthesize sound, and communicate with the VR version. We developed a simple sound synthesis method using a wave table that assigned values to each key, when more than one key was pressed the program would interpolate between the relevant table values to create a new wave. This allowed us to process all combinations of keys into novel sounds without having to define individual values for each combination. The same method was used in the virtual space so that sounds would be as similar as possible between the real world and VR.

3. Findings

Having seen how varied and seemingly unrelated the responses to our original brief were, we now turn to analyzing them and seeing what they tell us about our research questions. As expected, all three works responded to our inquiries in defining instruments and the role of liveness in virtual spaces. However, the approaches to these topics were somewhat different as we shall see in the following subsections. We also identified two emerging themes that run through all three projects, the first one seems to be an interest in control both within music making and in interaction. The second theme we spotted is to do with ideas of scale, all three projects rely on disrupting the scale of the experience between physical and virtual participants. An in-depth analysis of these approaches is presented in the next subsections.

3.1 Meta-instruments and meta-music

When analyzing how each project contributes to defining what an instrument for the metaverse is, how it looks, and how it should be played, we quickly realize that explorations centered mostly around shape and aesthetics while conserving some essences of playability. In the design principles for VR musical instruments detailed by Serafin et al. (2016) we find that including feedback and a clear mapping between senses are at the top of the list. This is something that both *Llum* and *Conditioned Freedom* do to an extent.

Llum has visual and tactile feedback mapped entirely to auditory feedback in the same way that many keyed instruments do. However, having a single output which amalgamates the sound being produced by all participants could make it difficult to keep track of where each sound came from. But rather than a defect, we think this is a feature. This form of collective feedback creates a space in which players must respond to each other's actions rather than on individual composition and reinforces the idea of the metaverse as a social space. While *Llum* maintains certain characteristics from other keyed instruments its shape is certainly distinct. We find that there is novelty in designing a physical object so that it can be translated into virtuality in a meaningful way. We see that the dialogue between the physical instrument and the virtual space which it becomes makes us read the tangible instrument not as an object but as a scale model of virtual space.

The other project that maintains feedback and mapping is CF. The tangible part of this work has a direct mapping between visible rays of light and sound. However, contrary to many instruments, rather than producing sound through gestures, CF eliminates sound. We see value in this form of contradictory interactions and agree with Dunne's view that there is something very engaging in objects that work contrary to established logic (Dunne, 2008). In this work the instrument also takes a narrative role; not only is it a means of sound production but also part of a story. The instrument's shape and the overwhelming experience for the player are all there to communicate the player's potential creative struggle.

In CQNC we find perhaps the most radical and challenging views of what an instrument and its music are. While there has certainly been research around field recordings as music (Shaw and Bowers 2020) and instruments with minimal electronic interfaces (Bowers et al., 2016), we find that CQNC approaches this from a very novel perspective. In this project it is difficult to decide what part is the instrument: is it the trigger on the sound recorder or is it the array of virtual balls sounding in virtual reality? This difficulty in assessing where the music-making happens and who the player is makes us think that this project succeeds in being truly collaborative and exploring musicality in a way which is only possible through networked collaboration. Looking back at Serafin et al.'s principles for VR musical instruments we find that CQNC breaks many of these: it has no direct feedback or mapping, it embraces latency and provides no visualization of a player's body. Nevertheless, it is extremely engaging and rewarding to use. We think this demonstrates that the definition of instrument in VR and the metaverse should still be fundamentally questioned as the field is still in its infancy.

3.2 Live and virtual

Another central issue that students were asked to consider was the role of liveness in their proposals. Existing research points out that live performances provide something not easily carried over to virtuality (Tarumi et al., 2017) and thus we wanted projects that steered away from emulating live events in VR.

We find that liveness is central to *Llum*, not only because its collaborative nature demands that participants be online at the same time but also in how it enables a wide range of audience experiences. In one scenario the instrument is sounding in physical space in front of a traditional live audience and possibly accompanied by other instruments, and this allows Llum to function within a well-established culture of live music and performance. For the virtual audience there are two possibilities: in one, the experience is individual and participants are each in control of their own virtual sphere; and in the other, all virtual members of the audience can share a gigantic virtual sphere which is played collectively. These three possible positions for

the audience provide a breadth of experiences that I traditional concert-goers, people who want to listen individually at home and those seeking the social experience of going to a concert but in the metaverse. We find that in this project liveness is essential to enabling audience experiences.

The way CQNC deals with ideas of liveness is less straightforward. Tim Shaw describes the activity of field recording as "a practical activity [that] often requires one to spend long periods of time outdoors hunting for sound" (Shaw and Bowers, 2020, p.?). This might seem contradictory to the idea of live performance and could be frustrating for players in VR if they have to wait very long for sound samples to play with. Using CQNC often proves the opposite, however. While there might be a bit of waiting at the beginning it is very exciting when a new sound sample appears. This element of unpredictability often caused us to restart our compositions when a particularly good sample appeared. While a mechanic simulating this could be developed with pre-recorded samples, knowing that these sounds were being recorded recently adds a sense of immediacy and temporality to the experience as a whole.

3.3 Control

In the projects presented herein there are several notions of control and power at play. We are not talking about control in terms of interface (i.e., how do you control the instrument or what are the controls in VR) but rather about people having power over one another. In a traditional musical experience, the musicians have complete control over the audience, they decide what to play, how to play it, and when. In our works we see that this is slightly harder to define.

The role of control is approached from an interesting angle in CF. The person within the installation has complete control over what the person in VR will hear. That control is nevertheless unpleasant to wield and endured for the pleasure of the virtual audience. This creates an interesting dynamic in which the person in the installation controls the content, but the audience controls that person.

In CQNC and Llum we see similar forms of creative control. Both of these experiences invite users to react to sound provided by other users. We imagine that these instruments will prompt either adversarial or collaborative interactions between participants as we mentioned before. However, we do not see these interactions as challenging the distribution of control.

In *Llum* we believe that control is dependent on the number of participants. If there is only a handful of people playing virtually, then control will surely shift towards the person playing physically. However, in a scenario with dozens of virtual participants the notes played by the physical instrument will be quickly outnumbered by emergent collective behaviors.

The issue of control in CQNC is somewhat simpler. Ultimately, every player has control over their own composition and if they do not like any of the samples they could choose to simply not engage. Virtual players, on the other hand, cannot control what samples are sent to them and must work within the constraints created by the person recording. It is also possible that the recorder, despite not knowing what each player is doing, could feel pressure to provide them with adequate samples to work with.

From our experience designing these instruments, we find that many of these notions of control emerged on their own and were not necessarily designed from the outset.

3.4 Scale

Our final finding looks at how scale played a role in all three of the projects presented. While ideas of scale in digital design have been extensively explored we see value in presenting how these emerged from the perspective of music-making.

Of all the works presented, *Llum* has the most obvious relationship with scale. The fact that the virtual and physical instruments are scaled versions of one another demonstrates how virtual environments allow us to inhabit spaces that would otherwise be inaccessible. In the case of *Llum*, the space is less interesting than the changes in interaction that the change in scale enforces. Likewise, the way in which sound is experienced varies completely. In the physical instrument, sound is emitted from a single point in space but in the virtual world sound is spatialized to simulate that it's coming from the key that was pressed. We find this to be one of the main differences between how sound is experienced physically versus virtually.

CF also plays with scale very directly, but this is done with narrative effect. The interior of the installation is a constrained physical space designed to overwhelm the user. Its virtual counterpart by contrast is a large, well lit, and calming landscape. The interplay between the virtual and the physical space provides a point of entry into the ideas of the project, simply thinking about the difference in scale is enough to begin to understand what the piece is about.

In CF and *Llum* the virtual world is much larger than its physical companions. In CQNC, however, the scale of virtual space is fairly small, your range of movement is limited, and most of your interactions will happen at a circle in the middle of space. This limited space serves as an interface for an instrument that could be of global scale. The size of this experience is as large as the area navigated by the person recording. We find this link between small virtual space and worldwide physicality very exciting as it suggests that the metaverse is not merely an alternative reality but could also serve as an interface with the tangible world on a global scale.

Conclusion

In this paper we described an RtD approach exploring different forms that live music and its instruments could take in online virtual environments (the metaverse). We presented three prototypes that were used as research foci and examined their rationales, design decisions, and interactivity to identify what forms instruments can take and how they can be used in hybrid live performances. We also identify how notions of scale and control relations between players can be used productively in the design of interfaces for the metaverse.

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