Curating Perspectives: Incorporating Virtual Reality into Laptop Orchestra Performance

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ABSTRACT

Despite a history spanning nearly 30 years, best practices for the use of virtual reality (VR) in computer music performance remain exploratory. Here, we present a case study of a laptop orchestra performance entitled *Resilience*, involving one VR performer and an ensemble of instrumental performers, in order to explore values and design principles for incorporating this emerging technology into computer music performance. We present a brief history at the intersection of VR and the laptop orchestra. We then present the design of the piece and distill it into a set of design principles. Broadly, these design principles address the interplay between the different conflicting perspectives at play: those of the VR performer, the ensemble, and the audience. For example, one principle suggests that the perceptual link between the physical and virtual world maybe enhanced for the audience by improving the performers' sense of embodiment. We argue that these design principles are a form of generalized knowledge about how we might design laptop orchestra pieces involving virtual reality.

Author Keywords

laptop orchestra, virtual reality, design, aesthetics

CCS Concepts

•Human-centered computing → Interaction design theory, concepts and paradigms; •Applied computing → Performing arts; *Sound and music computing;*

1. INTRODUCTION

There are many ways to incorporate virtual reality (VR) into a computer music performance. According to the resources of the ensemble and of the performance space, these methods vary by their ability to transport the audience to another reality, to feel like they are a part of that reality, and to feel like their physical reality is subsumed by the virtual one. Many specialized performance spaces exist for facilitating audience immersion, but most ensembles wishing to incorporate VR into a performance still find themselves performing in a typical concert hall. How do we make the best use of VR technology for presenting an authentic and robust virtual reality separate from (or overlapping with) our own?

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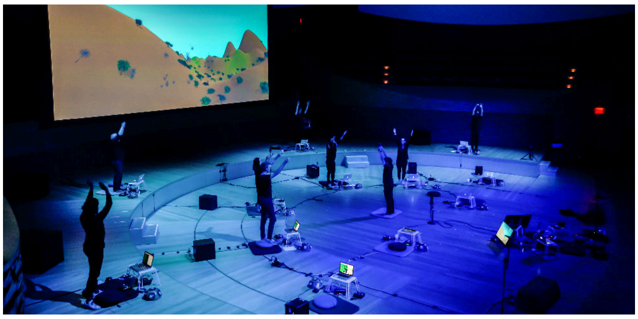

Figure 1: *Resilience*, for laptop orchestra and one VR performer (recording at `https://ccrma.stanford.edu/~lja/vr/Resilience/`).

How can we artfully incorporate this newly-commercialized technology into existing performance practices?

Here, we examine the laptop orchestra, a performance practice wherein members create their own bespoke instruments for pieces, with a frequent emphasis on the aesthetics of performance [20, 19, 23]. Laptop orchestras often employ design methods, using rehearsals to critique and improve works before they are performed. Thus, it is reasonable to employ design methodology in the discussion of developing performance practice for this type of ensemble. Specifically, one can encode knowledge and perspective gained during the composition process into design principles, intended to inform and be further refined by future work.

This paper describes a work created for and performed by a laptop orchestra, led by a VR performer. First, we explain in more detail the epistemological theory behind design principles as knowledge that is contextual to a community. We then describe the context of related works involving VR and computer music performance. We present existing perspectives from computer music performance practice on how to compose artfully. Next, we present the design of *Resilience*. We begin with our motivating goals and values for the work, then describe the end result and some of the changes made along the way during rehearsal critique sessions. The primary contribution of this paper is a set of four design principles intended to inform future work incorporating VR in laptop orchestra performance, abstracted from the insights gained during the development and performance of this work.

2. DESIGN EPISTEMOLOGY

Composing for laptop orchestra involves a fair amount of design. How is (academic) knowledge codified in design fields? For many, the basic unit of knowledge in design research is the design principle: a short aphorism intended to guide designers during moments of ambiguity in the design process [22, p.33]. A design process begins with goals and a set of values underlying those goals. Then, a designer attempts to accomplish their goals, allowing themself to be guided along the way by design principles that originate from their values. Goals, values, and design principles are not universal; they are contextual to the community that the designer operates within [5]. In design communities, tentative new design principles emerge from abstracting insights gained during the design process and from analysis of designed works [5]. Over time, the design principles that are most useful to a community are tested, refined, and implicitly codified as canonical to the community. But, design principles are not facts, nor are they scientifically provable via study. Rather, they must always be critically interpreted by a designer to determine whether they are appropriate for the design process at hand [22, p.120]. That is to say, designers are always responsible for determining which design principles are pragmatic for achieving their goals while remaining true to their underlying values.

Despite originating nearly 30 years ago, the "HMD and detached screen" scenography discussed below still represents a fairly novel performance practice. Therefore, the contributions of this article are (1) a synthesis of existing values and design principles for laptop orchestra and virtual reality into a designed composition and performance, and (2) four design principles intended for the design context of this scenography, abstracted from this performance. The design principles will be evaluated not via an exacting user study, but can only be evaluated over time insofar as they are useful to future designers operating in the same community (people composing for the laptop orchestra), looking to achieve similar artistic goals under similar constraints.

3. BACKGROUND

3.1 Prior Work

There is a long history of music performances involving the manipulation of virtual instruments or virtual environments. One of the earliest known performances is Lanier's Sound of One Hand (1993), featuring instruments such as the "Rhythm Gimbal" [12, 13]. His piece established the scenography of a performer wearing a head-mounted display (HMD), with the performer's current view projected on a flat screen for an audience to see. (More variants on VR performance scenography are discussed in [3], also below.) Mäki-Patola et al. (2005) discussed early considerations for virtual reality musical instruments [16], elaborated by Serafin et al. in [18]. *Virtual_Real* (2011) is an early example of a performance that superimposes the virtual world onto the real world so that the audience experiences both simultaneously, via a system employing 3D projection and goggles [24]. In an evaluation, the creators found that the audience's ability to be immersed and to interact with the visuals increased their feeling of involvement with the work. In the paradigm of laptop orchestras, *SoundBounce* (2010) was an early piece involving virtual objects with their own presence and physics, though they are experienced only sonically and not visually (enabling the audience to have the same fidelity of immersion as the performers) [6]. *Carillon* (2016) is a piece that evolved the headset-and-projection paradigm used by Lanier to include multiple VR performers acting together in a virtual environment [10]. *Coretet* (2019) is an ensemble that involves four VR performers, as well as a projection of a rotating third-person view of the virtual scene the performers inhabit [9].

Some specialized performance spaces have been created to allow the simultaneous immersion of the performers and the audience. For example, the stereoscopic projection wall Powerwall [24], or the projection domes Allosphere and Satosphère [11, 4]. In many other cases, however, prioritizing the immersion of the audience comes at the expense of the performer, and vice versa [3]. The widespread lack of immersive performance venues has emphasized the predominance of the scenography involving a detached projection screen and a performer wearing an HMD.

3.2 Existing Perspectives

It is often useful to reflect on existing perspectives on the values and aesthetics of computer-mediated performance before embarking on the creation of a new work for a laptop orchestra. Here follow a few perspectives:

Gesture. Many consider expressive gestures to be fundamental to computer music performance. In an early article on the laptop orchestra, Truman asserts that the medium allows deep involvement of the body alongside computational processes, and stresses the importance of creating gestural vocabularies that allow performers to feel a sense of exploration and flow [20]. Dahl writes that basing the gestures of a piece on a physically motivated metaphor improves transparency and visibility (the ability for both performers and audience to understand a piece) [6]. Gurevich notes the power of human movement for contributing to aesthetic experiences [8]. Hamilton asserts that the gestures that are sonified in *Carillon* to link the physical space with the virtual space have the effect of communicating without language for both the performers and the audience [10]. Waite defends the use of non-audible gestures for communicating performer intentions and interactions, and asserts that the use of gestural metaphors encourages "embodied understanding" that facilitates a shared mental model between audience and performers [21, 15].

Pieces vs. Instruments. It is typical for laptop orchestras to focus on developing pieces, with the creation of new instruments only insofar as they serve a new piece [23]. The creation of instruments without a musical composition in mind can result in instruments without a clear use case [5, 22]. A more productive attitude is to focus on developing "a performance practice where instrument building itself plays a central role" [20].

Effort and Audience Understanding. Most agree that some display of performer effort is key to the audience's ability to understand and enjoy a piece. Schloss develops several design principles regarding the aesthetics of performance, including (1) "cause-and-effect is important," (3) gestural aspects of sound are easier to experience when accompanied by a visual component, (4) a preference for subtle, virtuosic gestures over larger "cartoonish" ones, (5) "effort is important," and (7) ensure the performers' presence enhances the performance [17]. Emotion can be transmitted visually through subtle performance gestures [7]. Others support the use of exaggerated performance gestures, asserting that they give the performers an aura of expertise [8] and that they can incorporate elements of theater and dance into a performance [10]. For performances not involving gesture, screen sharing can communicate effort [14]. Above all, Trueman asserts the need for balance between automation (which makes use of the computational medium to do things that a human could not do) and human effort and control (which keeps the human in the loop) [20].

Conducting and Coordination. Laptop orchestras can support diverse models for control. Trueman writes that the metaphor of a conductor can take the form of a traditional conductor, centralized networked control, or distributed control and decision-making across the ensemble [20]. Networking and conducting allow for the ensemble to be treated as a macro-instrument [19]. Virtual (reality) instruments can be designed for participatory multi-performer approaches [25]. Also, when working with VR, it may be more fruitful to consider paradigms of artful collaboration instead of the common focus on competition that originates in gaming [9].

Effects of Scenography. Now, we will discuss considerations specific to the use of virtual reality in performance. Berthaut et al. contribute a set of dimensions to evaluate the stage setups of performances involving VR: musician immersion and audience immersion (for which there is often a tradeoff), audience visibility and musician visibility (how well each can see the other, important for understanding and potentially adapting the performance), gesture continuity (how well gestures performed in physical space are connected to the virtual space; this depends partially on audience immersion and musician visibility), and "from virtual to physical" (how much the virtual world is perceived as separate from or merged with the physical world) [3]. They use this framework to evaluate several preexisting scenographies; for example, the "HMD and detached screen" used by Lanier's 1993 performance [12] was rated high on musician immersion and musician visibility, but low on all other parameters. Another scenography, "semi-transparent screen," rates high on all parameters, but requires specialized technology: stereoscopic projectors, 3D glasses, and a semi-transparent projection material. The authors assert that audience immersion allows audience members to perceive the performers' gestures to be more natural and less awkward; meanwhile, performer immersion is essential for expression, control, and confidence.

Along another dimension, *Virtual_Real* demonstrates that a piece may exist along a continuum between scripted performance and installation, allowing some aspects of the virtual world to be interactive and thus increasing audience presence [24]. The scenography of this piece (a stereoscopic projection wall with motion capture) allows the audience to interact with visuals and sound spatialization parameters, but the audio otherwise proceeds in a scripted fashion according to the musician's desires. This piece also demonstrates the importance of audience size; it is often easier to facilitate the audience's presence (a phenomenon originating in immersion and interaction [2]) in smaller venues.

The merging between physical and virtual space need not occur in all modalities. *SoundBounce* superimposes virtual objects with their own physics onto the physical world using only the sound of a mobile phone orchestra; virtual graphics are not used, yet gesture continuity is high [6].

(Virtual) Embodiment. *Virtual embodiment* describes the ability for a person to act and feel as if a virtual body is their own. In a virtual environment, this property is important for *doing* (taking intentional action in the world) as well as *being* (intentional stillness and reflection, perhaps in preparation for future action as in a music performance) [2]. Similarly, the philosophy of artful design encourages the creation of embodied interfaces that allow performers to "feel as one" with their instrument [22, Principle 5.17]. These properties are beneficial for performers to experience a kind of flow as a result of exploring their instrument [20].

Designing to the Medium. This refers to using the affordances of a new medium to accomplish feats impossible without it, thereby justifying its creative use. The use of virtual reality, for example, affords the use (and abuse) of virtual physics engines [6, 2] as well as the ability to create stylized realities that resist the bounds of realism in some aspects [2]. Each of these properties may help audiences understand and connect with the work [2, 6].

4. CASE STUDY: DESIGNING *RESILIENCE*

We created *Resilience* for a laptop orchestra performance in June, 2019 (Figure 1). It consists of three movements and a coda, and is described in the program notes as follows:

> *Resilience* is a piece for laptop orchestra and one VR performer. A prequel to the longer, individual VR experience *12 Sentiments for VR* (an aesthetic exploration of the emotional life cycle of a plant), it follows a group of seedlings as they search for a new home. The piece is an exploration of resilience through traumatic life events, finding peace and joy in small moments, and reconnecting with the ability to grow.

4.1 Motivating Goals and Values

Our primary goal was to create a piece involving one performer-conductor in virtual reality. We also hoped to make full use of the rest of the laptop orchestra ensemble not only as performers of gesture-based sound, but also as operators in the virtual space, able to affect the unfolding of the world despite not being immersed in it. In such a piece, the entire ensemble is responsible for both sound and visuals together.

Using the HMD and detached screen scenography in a large performance venue, we knew in advance that while musician immersion and musician visibility would be high, audience visibility and audience immersion would be low, and the virtual and physical spaces would not be merged. However, we believed that careful design of the gestural aspect of the piece could increase gesture continuity, and we directed significant attention here.

As an aside, it should be noted that merging physical and virtual spaces may not always be the desired outcome of a piece. In this case, our aim given the limits of the scenography was to give the audience a window into a virtual world, rather than making them feel immersed as if they belonged to the virtual world. Nevertheless, the representational link between physical performers and virtual environment is still crucial for the audience to understand how the virtual world works and how the performers fit into it.

In addition to the above, we considered the following existing values and design principles during the design process. These values will be referenced where relevant during the description of the piece.

- V1. Effort: ensuring the audience understands the significance of performer actions on stage (related principles: Schloss, #1, 5 [17])
- V2. Gesture interpretability: focusing on gestures that communicate intelligibly to the audience via the use of (physical) metaphor (value articulated in [6])
- V3. Varied group dynamics: throughout the piece, varying between modes where the ensemble members act semi-independently and modes where they act together, using the entire ensemble as a meta-instrument (value articulated in [20])
- V4. Making a piece, not an instrument: creating instruments that are meaningfully expressive within the context of this work, but quick to learn and not necessarily having a virtuosic skill ceiling beyond the requirements of the piece (related principle: Cook, #5 [5])

Figure 2: Swirling upward gesture, first movement.

V5. Gesture size: focusing on larger metaphorical gestures rather than subtler, virtuosic body movements (contrary to Schloss, #4 [17]; value articulated in [8, 21])

V6. Embodiment: paying attention to virtual embodiment and the ability of the performers to feel embodied flow (value articulated in [20], related principles: Artful Design, #5.17 [22], Doing vs. Being, #6.1 [2], Serafin et al., #7 [18])

V7. Designing to the medium: making justifiable use of specific affordances of virtual reality, such as virtual physics and stylization (related principles: Doing vs. Being, #2.1, 5.2 [2])

4.2 The Piece

Scenography. One performer sits in the center of the stage, wearing a VR headset and facing away from the audience so that (1) their left-to-right motions do not contradict those of the projection, and (2) they can conduct the rest of the ensemble (without being able to see them). The performers are arranged in two half-rings, with four performers in the inner ring and four in the outer. Each performer has their own laptop, speaker array, and tether controller to track the position of their hands. An oversized projection screen hangs behind the performers to display a two dimensional rendering of what the VR performer is currently looking at; thus, the VR performer curates the angle of the view into the virtual world by adjusting the angle of their head.

Movements. In the first movement, a cloud of floating seedlings jumps upward in the air (V7). In their own time (V3), the kneeling performers make swirling gestures that end with a fast upward movement and a slow descent back to the ground, causing one of the seedlings to jump at the apex of the gesture (Figure 2; V2,V4,V6). The swirling motion is accompanied by a chord with the timbre of granular synthesis on an "ahh" vowel, and the jump is accompanied by a strike on a virtual modal bar. Throughout the piece, the vocal "ahh" timbre is metaphorically associated with virtual wind, and the modal bar timbre is associated with sudden movements in the seedlings.

To communicate "excitement" as the seedlings rise, the VR performer stands as a cue, and one by one each of the performers stands and begins to perform the gesture from a standing height (V1,V5) until the transition to the next movement. In kind, the audio becomes denser with the addition of a subtle "super-saw" timbre.

In the second movement, the seedlings leap forward in regular arpeggiated rhythms, no longer controlled individually by the performers. The performers act together as a meta-instrument (V3), performing a large "wave" gesture to move the "ahh" wind timbre across the ensemble, as cued by the VR performer (Figure 3; V1,V5). Each time this happens, the direction of the cloud of seedlings is redirected to the direction of the ensemble's meta-gesture (V2,V6,V7).

Figure 3: Collective wave gesture, second movement.

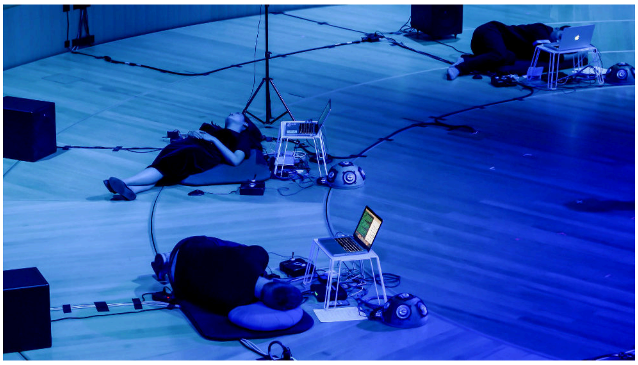

Figure 4: The performers lay down as the seedlings bury themselves in the third movement.

During this movement, the VR performer also triggers flashes of lightning, which correspond with thunderclaps that play out of different performers' speaker arrays (V7). When the seedlings are above an island, a loud crash of thunder plays, and the seedlings, the perspective of the VR performer, and the performers themselves all fall to the ground in reaction (V2,V4,V5).

The third movement features similar gestural control to the first. The main differences here are that the seedlings cannot float in the rain, instead falling back to the ground after each gesture; correspondingly, the performers make their gestures more harsh, jagged, and desperate (Figure 5; V6), and the timbres are muted and less pitched (V2). Occasionally, the VR performer looks up to the darkened sky to show drops of falling rain (V7).

Following a cue from the VR performer, the rest of the performers let go of their tethers and lay down in front of their computers one by one (Figure 4); their seedlings correspondly bury themselves (V2,V5). When all the seedlings have been buried and rained on, the coda takes place: the rain slows to a stop, the sun rises, and a single seedling sprouts, accompanied by a brief modal bar arpeggio.

Figure 5: A harsher, quicker swirling gesture.

4.3 Highlights from the Design Process

We made adjustments and improvements throughout the design and rehearsal of the piece. The rehearsals are a key part of the design process because they provide space for critical reflection on connecting our intentions to the current working version of the piece. In a way, rehearsals are where the theory meets the practice. Here are a few points that will help illuminate the design principles presented later on.

Performer Gestures. We knew from the beginning that we wanted the performers to have a sense of virtual embodiment as much as possible without having access to immersive headsets. The purpose of encouraging embodiment is to facilitate a sense of the performers' flow and to improve their resonance with the emotional aesthetics of the work. After seeing that our intended gestures were not immediately intuitive to the performers, we rehearsed them heavily on the intended fluid gestural aesthetic for the wind gestures of all three movements (Figures 2, 3, & 5). We also added small monitor screens facing the performers so that they could reinforce their sense of embodiment by seeing their gestures' impact on the virtual world.

Since the gestures were similar for the first and third movements, we conducted rehearsals specifically for the performers to practice imbuing their gestures with the differing intended emotional aesthetics for these two movements. Performers were instructed to make slower, broader, gradual round movements for the first movement to convey the intended aesthetic of "exploration, wonder" (Figure 2). For the third movement, they were told to make harsher, quicker zig-zag movements to convey "desperation" (Figure 5).

During rehearsals, the performers noted that the VR performer's gaze direction appeared aimless and unintentional, and had the effect of disorienting the audience. They were encouraged to more intentionally curate where they look during the performance. Thus, in the final iteration, the VR performer took specific care to center their vision on the cloud of seedlings in general. We also choreographed specific moments when the VR performer looked around slowly and intentionally; for example, at the beginning of the piece, the VR performer does this to give the audience a sense of the world beyond the edges of the projection screen; and in the third movement, they look up to emphasize the hopelessness perceived in the dark, rainy, empty sky.

Virtual World. In rehearsal critique sessions, our performers noted that much of the motion in the virtual world was difficult to perceive on the projector, though it looked natural in the headset. We increased the speed of the motion in the first and second movements so that it appeared cartoonishly fast in the headset, but reasonable in the projection. We also increased the audience's field of view so that it more closely approximated the VR performer's stereoscopic view. Finally, we smoothed the motion of the audience's projector view to reduce disorientation during quick head movements.

4.4 Technical Implementation

The performers' instruments are composed in ChucK[1], and the VR performer's virtual world is created in Unity[2] with Chunity [1]. The piece uses two-way communication over OSC using a wired local area network. For example, in the first movement, performer stations send messages to the VR performer's station to animate a seedling jump, but in the second movement, the VR performer's station uses strong ChucK timing to schedule each arpeggio note at a different performer's station. No sound emanates from the VR performer's station. The "ahh" granular synthesis is implemented with the LiSa UGen; the modal bar uses the STK ModalBar UGen; and the "super-saw" is created with a combination of sawtooth oscillators, delays, and filters. The projection is a view into the virtual world that follows the VR performer's head position with some delay to minimize jitter from their head movements, and with a wider field of view to compensate for the lack of stereoscopic vision.

5. DESIGN PRINCIPLES

Here, we abstract insights gleaned in the design process into design principles. These are intended for future designers looking to compose works with the same scenography ("HMD and detached screen"), with similar motivating values (see section 4.1).

1. Exaggerate. Subtle motion and physical layouts may be clear in a stereoscopic immersive headset, but often do not translate to a 2D projection screen viewed by a large audience. When the virtual world is designed to appear too fast or too grandiose in the VR performer's perspective, it often appears appropriately intelligible and reasonable to the audience's perspective. For example, the upward and lateral velocities of seedlings in *Resilience* were all magnified to appear cartoonish to the VR performer so that they could be perceived by an audience in a large venue.

2. Connect the real world into the virtual world with virtual embodiment and multimodal representation. Not all pieces using VR technology feature a virtual world that has some analogy to the real world. In the pieces that do, the HMD and detached screen scenography does not afford a merging of the virtual and real worlds, so careful attention to the design of the piece is necessary for the audience to maintain a mental link between the performers and the virtual world. To improve gestural continuity, enable the performers to feel virtually embodied as much as possible, and use multimodal representation. For example, in *Resilience*, the notion of performer gestures controlling virtual "wind" is consistent across the performers' movements in the physical world, the use of virtual physics rules in the virtual world, and the consistent use of the "ahh" timbre to represent wind. Then, the rehearsals reinforcing the fluid aesthetic of performers' gestures enhanced their feelings of embodiment with the abstract entity of the wind, with the intent of improving the legibility of the piece from the audience's perspective.

3. Embrace theatricality. Gestural performance can be more compelling when the performers are motivated by specific emotional aesthetics. Since the performers are representations of abstract or virtual real entities (e.g. the wind, or seedlings), theatrical performance can reinforce the link from physical to virtual and encourage the perception that

[1] `http://chuck.stanford.edu`
[2] `https://unity.com`

the relevant virtual beings are animated and alive. Our rehearsals training performers to differentiate their gestural performance between the fluidness of the first movement and the harshness of the third movement aimed to reinforce to the audience that the virtual seedlings were beings that could sense and feel emotion in response to their situation.

4. Curate the audience's perspective. Although this scenography does not have the strength of audience immersion that other venues like projection domes possess, it affords the VR performer the ability to curate the perspective of the audience's view into the world. Rather than using a static or automated viewpoint, pieces can make use of this unique affordance in the piece's choreography for specific pragmatic and aesthetic effect. For example, the VR performer looks upward to the dark and rainy sky in the third movement not because any of the virtual entities controlled by the performers can be seen there, but simply to further instill the sense of hopelessness suggested by the other elements of the movement.

6. CONCLUSION

Through this critical reflection on the design and performance of *Resilience*, we have shown how prior design principles and values from performance practice can inform the development of a work. We have also developed new design principles for improving the audience's experience of continuity between the physical and virtual worlds in scenographies with a head-mounted display and a detached projection screen. Though it can be easy to focus solely on what appears in the performer's headset, these design principles encourage composers to design works that artfully consider the audience and performers' relationships to the virtual world: how it appears to them, what is shown and not shown, and how virtual embodiment, multimodal representation, and theatricality can help perceptually link the gestures of performers to their results in the virtual world.

These design principles constitute generalized knowledge about how to design artful works for laptop orchestra involving VR, balancing and curating the perspectives of the audience, performers, and VR performer. Intentionally designed future works using VR can test and refine these design principles and develop new ones. The open questions we see for the use of this technology in computer music performance practice include: (1) What technologies are best for facilitating audience immersion and interaction in traditional performance venues? (2) Can the thoughtful design of a piece overcome a VR scenography's deficiencies in areas other than gestural continuity? (3) How can *large* audiences be involved in a piece through interaction, not just immersion, with the virtual world?

We look forward to a future where more researchers encode their implicit insights into straightforward principles for others to benefit from, contest, and develop so that we can grow together as a community and create more artful music.

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