RHUMBLINE: PLECTROHYLA EXQUISITA — ACOUSTIC SIMULACRA & SPATIAL SOUND IN HYBRID ARTWORKS

MA Schedel Stony Brook University, Stony Brook, New York, USA
N Hwang University of Wisconsin-Whitewater, Whitewater, Wisconsin, USA
BD Smith Texas State University, San Marcos, Texas, USA
R Cosgrove Stony Brook University, Stony Brook, New York, USA

1. INTRODUCTION

Wildlife ecologists and conservation biologists have established the importance of bioacoustic data through acoustic monitoring to assess numerous behaviors in the animal kingdom, including migration, hunting, mating, local navigation, and defense.[1] Among various instances of sonic species monitoring, acoustic monitoring of amphibians has highlighted the importance of audio data. Not only has audio played a crucial role in raising the awareness of global amphibian species decline, audio data has helped to determine the acceleration of this decline, revealing the value of environmental acoustics as diagnostic and analytical frameworks in numerous scientific fields.[2] However, ecoacoustic content plays an equally important role in artistic contexts, particularly electroacoustic installations that attempt to reproduce or invoke environmental soundscapes through the creative deployment of environmental field recordings through stereo or multi-channel speaker arrays.[3] Yet, this preoccupation of phonographic audio in artistic contexts that has pervaded ecoacoustic artworks in the 20th and early 21st centuries neglects the rich multivalence and indeterminacy inherent in acoustically produced sound and devalues the aesthetic of instability embedded in acoustic mediums. Acoustically reproduced environmental sounds are understudied for their potential in ecoacoustic sound works.

RhumbLine: Plectrohyla Exquisita (RLPE) features the acoustically reproduced calls of amphibians to draw attention to the significance of their devastating global population declines, creatively leverage the wide variety of amphibian calls, and reproduce the unique spatial deployment of amphibian calls in physical and virtual artistic contexts. Because of their need for moisture, many amphibians and other herpetological species congregate around aquatic environments, resulting in a physical circumscription by these anurans of the bodies of water they inhabit. This unique congregational behavior also results in a unique parallel sonic circumscription of amphibian calls emanating from the shores along which they gather and from which human observers can infer the relative size, shape, and contours of the amphibians' aquatic environment because of the stable location-origin audio data they acoustically transmit.

This paper explores an interest in reproducing this intersensory audio-visual perceptual process through the acoustic reproduction of ecoacoustic sounds in physical and virtual artistic contexts. We selected the species *Plectrohyla exquisita* as the namesake for this installation not only because of the means by which ecoacoustic sounds are reproduced in the installation—robotically activated wooden plectra on zoomorphic reproductions—but also because of the lack of data regarding *Plectrohyla exquisita's* call, which is unknown.[4] Reproducing the sound of *P. exquisita's* unknown call is an ideal context for the artistic reproduction of acoustic sound because creative design and sonic imagination can be deployed as artistic tools to voice the call of this critically endangered species. However, what emerges from this pursuit of sonic reproduction is not reproduction *per se.* It is instead an ecoacoustic simulacrum, a sonic copy with no original, and it is through these simulacra that audio is not only reproduced, so too is the experience of encountering spatial audio.

The Covid-19 global pandemic forced an evolution of RLPE from a physical, then virtual, and ultimately hybrid interactive soundscape installation. In its physical form, prior to the pandemic, RLPE acoustically reproduced the calls of frogs in an in-person installation. When the pandemic struck and global lockdowns ensued, devastating physical artistic mediums[5], the selective pressures of the lockdowns motivated a reimagining of the installation as a virtual experience where the acoustically produced ecoacoustic content was translated and transmitted to a virtual platform because a virtual modality was the only viable modality by which to resolve the problems of audience-artist engagements posed by the pandemic. However, as the pandemic-endured lockdowns dissolved and physical engagement with the world returned, retaining RLPE's virtual modality while returning its possibility of in-person engagement produced an enticing hybrid physical/virtual concept of the work that meshed with one of the pandemic's primary pedagogical silver linings: rediscovering the importance of sonic ecologies.[6]

RLPE's current hybrid model maximizes the interaction with the work through simultaneous deployments in physical and virtual environments, and it introduces new possibilities of engagements between these environments by corresponding physical and virtual participants (e.g., a virtual participant in Chicago and an in-person participant in New York). Because of this dynamic possibility for interactivity, the hybrid model provides physical and virtual audiences multimodal creative opportunities to produce acoustically *re*producible ecoacoustic audio. RLPE's hybrid environment mirrors the terran-aquatic hybrid environments of amphibians and accordingly asks participants to engage in inter-sensory hybrid acts of visual listening and auditory seeing by engaging with ecoacoustic sonic simulacra.

2. BACKGROUND

RLPE is an installation-sized systematic instrument contending with ecosystem silencing in the Anthropocene[7,8,9] by emphasizing the spatial properties of acoustic sound and the bodies that produce them. Portending a dystopic future in which acoustic ecology is encountered only through the mechanical reproduction of environmental soundscapes, the interactive audio of our installation is created by a chorus of robotic frogs—a recognition of the catastrophic global population collapse amphibians are facing.[10]

RLPE leverages the acousmatic listening experience—listening to a sound whose source is unseen—to highlight the spatial attributes of acoustic sound and organize them for expressive purposes.[11] As an interactive installation-instrument, its focus on spatial sound allows it to function as a new interface for spatial musical expression (NISME)[12] with a hybrid acoustic/digital framework. Although the acousmatic experience is fundamental to RLPE, it also critiques one of the fundamental conditions of acousmatic music. Acousmatic methods often conceal the labor and technology needed to produce the act of veiling upon which acousmatic experience depends.[13] In this work, a chorus of robotic frogs on the bank of an imaginary pond creates an acoustic soundscape from behind an acousmatic veil, which shields their view from the listener. The conspicuous veil deployed in this installation critiques the practice within acousmatic music of concealing the labor required to create the acousmatic experience itself. When experienced in person, the veil is made of black speaker cloth that is visually opaque but acoustically transparent; for the interactive telematic version, the veil becomes a technological shielding of the visual signal through the use of multiple webpages that the listener must click through.

This instrument/installation invokes rhumb lines to incorporate the physio-spatial attributes of sound—attributes that are often discarded in acousmatic music.[14] Rhumb lines are historic cartographic tools of oceanic navigation which rely on true or magnetic north to establish a constant bearing. In this installation, spatial sound becomes the bearing; visitors focus on the spatial properties of acoustic sound to engage in a form of sonic navigation. In the telematic version, audiences use a mouse to perform a short rhythm on a button that is then performed by the specific robotic frog linked to that button. This rhythmic seed is then sent to the on-site computer and evolved using artificial intelligence (AI). When two or more frogs have been activated, we multiply the rhythms to get two new resultant rhythms. Analysis of the original rhythm determines how quickly a rhythm gets sent to the next frogs, the direction the signal passes, how many frogs will play the seeded signal, and the amount of evolution allowed by each AI.

The following section of this paper discusses the construction of the robotic amphibians that constitute RLPE and situates them in the history of musical robotics. Section 3.2 describes the in-person experience, which asks visitors to record their individual listening experiences by drawing sound maps. Section 3.3 details how the original physical installation was adapted to function remotely, allowing RLPE to evolve from a sound installation to an interactive networked installation-instrument system with an embedded ambisonic listener. Section 3.4 describes the artificial intelligence that generates the chorus of robotic frog calls from user input. The paper concludes with comments regarding the future of the RLPE project and its broader interactions with acoustic ecology and environmental activism.

3. CONSTRUCTING THE INSTALLATION

3.1. Frog Design

RLPE features zoomorphic spindle-motor “frogs” that mimic the sound produced by frog guiro/rasp idiophones. Each frog has one harvested DC DVD spindle motor with an affixed plectrum that scrapes wooden dowels built in to the body of the instrument, composed of lightweight paperboard. The scraping of the plectrum against the dowels produces the characteristic “croak” of a frog guiro. (See Fig. 1) Each frog has two feet to elevate the open end of the paperboard body away from the surface one which the frog rests, allowing the body to function as a resonance chamber and amplify the sound of the frog’s call. While the contemporary field of musical robotics is subdivided by typologies of anthropomorphic robots, musical automata, and robotic instrumental arrays designed to feature the unique capabilities of robotic performers[15], RLPE is unique in its deployment of zoomorphic musical robots who interact with—and comment upon—human ecology.

Building on the legacy of MIDI-driven musical robotics[16,17,18,19], each frog in RLPE is connected via a DC-power cable to one of 12 ports on one of 2 Dadamachines ”automat” motor controllers that process MIDI signals.[20] The frogs are activated by a Max/MSP patch[21] that sends a MIDI “call” to one frog, which then cascades through the instrument system. In the internet installation, calls are initiated by audience members via the internet. Interestingly, the Dadamachines were not designed to be deployed in an installation and we have experienced port burn-outs.

Each frog is hand-crafted to ensure a variety of timbres using a variety design variables, including the size of the body (a round paperboard box), the number and type of wooden dowels, the positions of the dowels, and the density of the wooden plectra. In addition to these discrete analog sounding materials, interaction with the frogs over the course of the exhibition causes changes in timbre as sounding materials get pushed out of place through the physical act of sound production and motors die. The curators are instructed to manually adjust the dowels and plectra when rearranging the frogs, but not replace the burnt out motors. The burnt out ports on the automats decreases the number of playable frogs without investing in new hardware. The current installation can only support 19 robotic instruments. We have embraced this condition as it serendipitously mirrors the decline of amphibious populations[10].

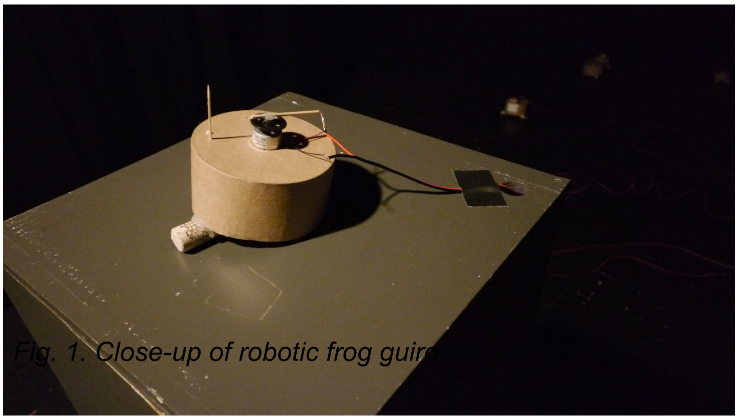

Fig. 1. Close-up of robotic frog guir

3.2. In Person Installation Experience

In the in-person installation, there are multiple stations and experiences for the audience: 1) entering a door into a small corridor defined by a wall on one side and an acoustically transparent veil on the other; 2) triggering an underfoot pressure sensor that initiates the robotic frog sequence; 3) listening for the shape of the frogs’ formation as suggested by the spatial properties of their calls; 4) drawing the shape of their formation around their imaginary pond; 5) walking behind the veil to see the actual shape of the frogs’ formation; 6) displaying their drawing (i.e., sound map) on the wall behind the curtain; and finally 7) observing and triggering a single frog at eye level.

Using philosopher Edward Casey’s concept of artworks as a map-form[22], in-person audiences are invited to interact with the installation as sonic surveyors, drawing maps “with/in” their individual experiences of the acousmatic image by plotting the perceived locations of the frogs and using sound as a sonic-spatial bearing. Only then are they allowed to pass behind the veil. Curators change the shape of the pond every day, encouraging multiple visits. Listeners are asked to display their sound maps by attaching them to directly to the veil that shields the frogs from view, which causes an anthropocenic coloring of the sound as layers of drawings slowly accumulate and muffle the frogs the longer the installation is active. In the physical installation, approximately 50% of visitors were able to accurately map the gestalt of the frogs' formation. (See Fig. 2.)

In NIME literature, mapping often refers to the correspondence between a system's input and its audiovisual output. In our ecologically inspired work inspired by physical mapping, we also took an ecological view on mapping that "takes into account a wider scope of the original action, including aspects which are non-technical but rather psychological and perceptual and are more closely related to a given socio-cultural context and the perceptual or cognitive aspects of expressing musical intentions through digital means."[23] The perspectival sound maps produced by RLPE visitors reify the complex psychological, phenomenological, and perceptual aspects of spatial listening and project them materially onto a page that becomes part of the installation itself.

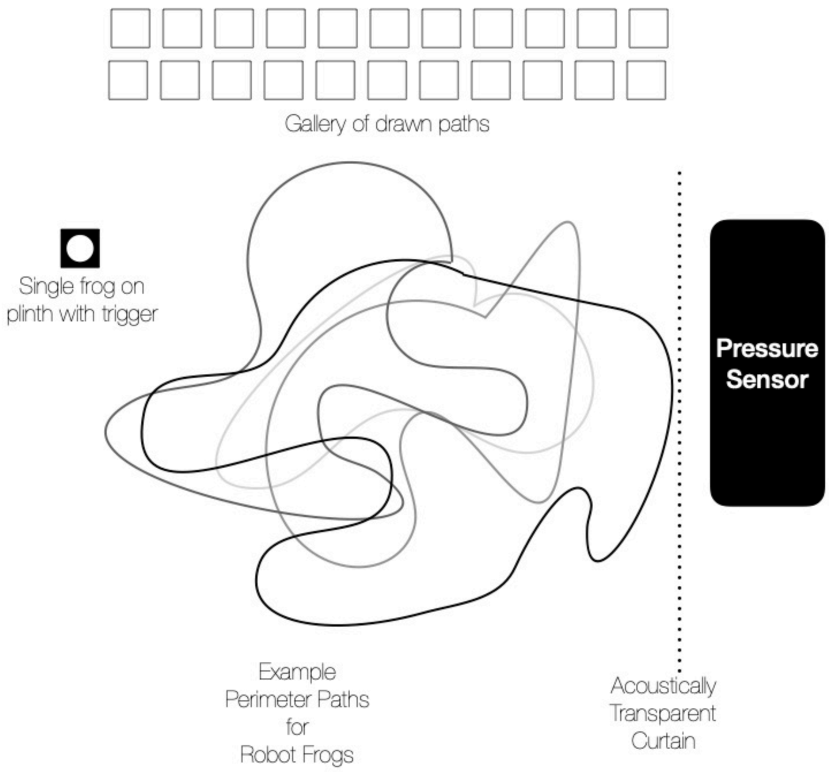

Fig. 2. Layout of in person installation

3.3. Porting to the Internet

The 2019 global pandemic imposed several challenges on the original installation. How could audiences experience the work virtually? How would they engage in spatial listening in an online environment? These challenges not only produced a platform that allows more people to access the installation, they led to adaptions that allowed RLPE to transform from a physical sound installation to a globally accessible interactive networked installation-instrument system with an embedded ambisonic listener. The piece evolved, and when we are allowed to have in-person exhibitions again, we will keep the virtual access in tandem with the physical because of the global access the online component permits.

With the telematic version, we created an interactive experience that kept the same sense of enchantment[24] as the in-person experience. The virtual environment the robotic frogs currently inhabit invites visitors to become members of an online ecosystem. The first page creates an acousmatic listening experience in which the frogs are heard but veiled from view. It contains an array of buttons representing the individual frogs (but not in their actual physical formation). The audience is invited to click a button on the webpage in an improvised rhythmic pattern lasting 5 seconds or less. This rhythm is sent to the host computer connected to the Dadamachines automats and frogs through Collab-Hub[25], a server-based internet connectivity tool. The timing of the signal is not precise because of latency and packet loss; however, users are able to identify the performance of their own rhythm. The audience member's rhythm is played by the selected frog and then sent to at least four frogs in turn before the rhythm begins evolving through AI.

The web server is aware of each connected audience member, and as one member clicks on a particular button, the same button becomes greyed out and non-functional for all other connected audience member. After the 5-second window, that button becomes interactable again for all users. We send a live audio feed out to the web from in-ear mics on a Soundman Dummy Head mounted on a rotating platform connected to a stepper motor. (See Fig. 3) Due to head related transfer functions, if listeners are wearing headphones, they receive an accurate 3D image of the sonic environment.[26] On the first page audiences can seed rhythms and listen to the results. Visitors use the spatial audio on this page to imagine the shape of the frogs' formation and are encouraged to draw a sound map of the perceived shape at home. The web-installation does not currently have the ability to host visitor-produced sound maps because we know we will need to filter/censor the images. Once an audience member is satisfied with the audio-in-itself[27] experience, they can advance to the second page and see a live visual stream of the installation.

The second page allows visitors to peer behind the acousmatic "veil" that occludes the sound source from the visual field, observe the robotic frogs, and control the listening experience of other visitors. We use two cameras for the live stream—an overhead view of the entire installation giving the shape of the pond and a second close-up view of a single frog. There is a button under this close-up feed that triggers a slow scrape for the camera on frog 19; this input is not sent to the other frogs through the AI system but is still heard on the live feed. Using a dial on the second webpage, listeners are also able to rotate the Soundman Dummy Head 180 degrees in the horizontal plane. If multiple listeners send commands to the dial, the input is averaged; we smooth the signal to ensure that the motor is not stressed. Unlike the physical installation where visitors listen from the "bank of the pond" behind an acoustically transparent veil, internet listeners are embedded inside the pond vis-à-vis the Soundman head, instead of on the outside of the soundfield, making it easier to determine the pond's shape. Combining binaural sound with the power to adjust the listening experience by turning the Soundman head gives visitors agency over their spatially-rich listening experience—as with physical environments—and allows them to construct "sound narratives" as they move through virtual space[28] and pursue virtual sonic explorations of place.[29]

Moving RLPE online allowed it to transcend its origins as a physical sound installation. It now has the capacity to function as a rhizomatic multiplayer instrument that can be played simultaneously by a global ensemble of visitors, constructing a networked ecology of sounds in real-time in collaboration with AI and automation. Networking these technologies creates an analog facsimile of the natural world, engaging solo and collaborative performances that leverage the spatial properties of sound for expressive purpose.

Fig. 3. Soundman Dummy Head with In-Ear Microphones

Existing between an installation and an instrument, this work was created collaboratively and engages multiple performers/listeners, forming "a system that includes external factors such as genre, historical reception, sonic context and performance scenarios."[30] RLPE's ecological underpinnings, and the multiple processes by which players engage with it, positions this installation-instrument to advance critical questions about what makes a musical instrument "good" and even what a musical instrument is or can be.[31]

3.4. Rhythmic Evolution Through AI

From a very simple input we generate a complex soundscape through AI-driven rhythmic evolution. By taking rhythmic inputs from human users we mutate them based on a variety of parameters. This creates a system where motifs entered by the user develop their own fitness and lifespan—a genetic algorithm that allows the frogs to manipulate and morph the users' calls. This AI is constructed in the visual programming language Max, using Bach and Cage, tools for computer-aided composition (CAC) created by Daniele Ghisi and Andrea Agostini.[32]

As previously stated, each user is given a 5-second window to interact via click (or tap, on a touch screen) on a frog of their choosing. Each click initiates a bang in Max, recorded as a rhythm in a bach.roll on the frog's corresponding MIDI note. The bach.rollobject allows for high accuracy recording because it notates rhythms based on actual temporal markers (milliseconds) rather than quantized, metric features (as is done in the bach.score object). Again, this transcription may deviate slightly from the user-performed rhythm because of the nature of time and the internet.

Immediately following the user's input, the rhythm is iterated through the system 18 times. These 18 iterations correspond with the 9 frogs clockwise and counterclockwise from the initial frog (as arranged on the website)—and so the MIDI note is transposed accordingly (with an added note 15ma or 15mb to ensure the pattern continues when it reaches the higher or lower extreme of the MIDI outputs). The further the iteration from the original frog, the more denatured the rhythm becomes. (See Fig. 4) The rhythm is repeated strictly by the closest 1-4 frogs, with certain sections of the rhythm reordered by the next 1-4 frogs, followed by the granulation of certain sections of the rhythm by the final 1-4 frogs.

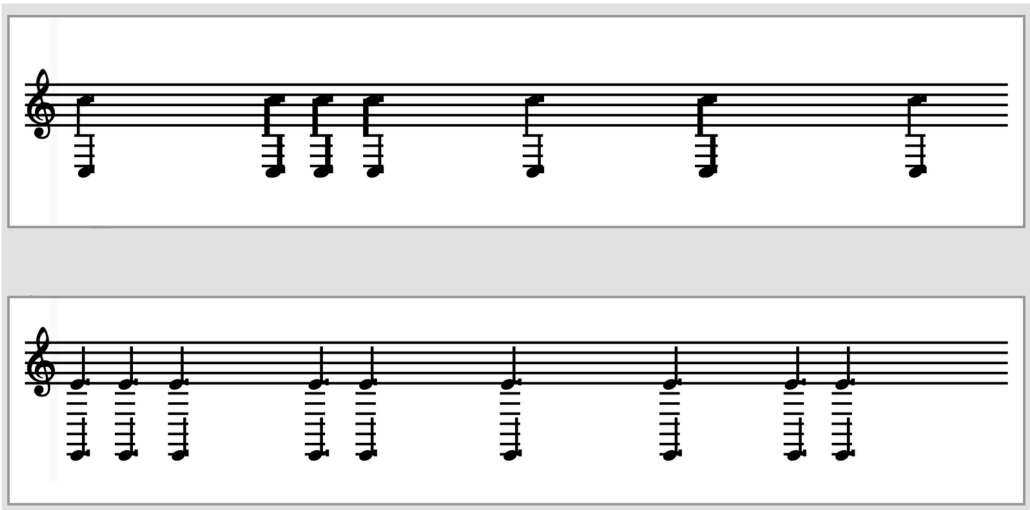

Fig. 4. Example of an inputted rhythm in a bach.roll object and below, the eighth iteration of its rhythmic evolution.

Analysis of the timing of the inputted clicks determines how quickly the rhythm is sent to the next frog (between zero and 5 seconds based on the total number of clicks), the direction the signal passes (clockwise or counterclockwise based on the how many clicks are in each half of the five second motice), how many frogs repeat the rhythm strictly (based on how "regular" the initial pattern is), and how many frogs will reorder or granulate the rhythm (based on the shortest rhythmic unit), as well as the size of the sections that are reordered/granulated (based on how symmetrical the original pattern is).

4. FUTURE WORK

Future internet iterations will incorporate audience-produced sound maps, along with an efficient method for vetting and compiling them, and a gallery attendant will print and post images from the web to the in-person exhibit to reincorporate the anthropogenic aspect of the installation. We also plan a research project investigating the spatial verisimilitude of sound maps produced by in-person and virtual listeners.

Future in person iterations will always include virtual components, allowing for in person and virtual visitors to interact simultaneously. We hope that this hybrid format becomes more prevalent for interactive installations as it increases engagement and accessibility. The new rhythmic interface will be incorporated into the installation, and the pressure sensor will be removed.

RLPE will become the first in an ongoing series of works that combine spatial listening, AI, telematic performance, mapping, and acoustic ecology in the Anthropocene. Our next planned iteration is Rhumbline: Myotis Lucifugus, in which we will create zoomorphic bats that create ultrasonic sounds. Only when multiple bats are triggered will the resultant difference tones be audible to the human ear. There will be a visual component which responds to the ultrasonic sounds and creates an interactive map on screen in real-time.

5. CONCLUSION

RLPE poses critical questions regarding the experiential and phenomenological differences between spatial listening vis-à-vis speakers and acoustically reproduced ecoacoustic environments. Is sonic spatiality easier to experience in-person? What role does audio fidelity to an original sonic source, of any kind, play in the context of creative and artistic reproductions of natural auditory phenomena?

Navigation and mapping of sound depend on acts of projection to interpret perceptual information and create meaning within our social, virtual, and natural environments. RhumbLine: Plectrohyla Exquisita is an analogue for this ecology of projections, where communal meaning is created from listener input and becomes more vivid in its mounting complexity. When presented telematically, additional layers of projection occur with rhythmic evolution through AI and creative interaction by a community of virtual participants. Just as a compass deviates because of local magnetic fields, the sound maps we imagine become as unique as the listeners who experience and reproduce the sounds themselves.

The broader impacts of RLPE's hybrid model are rooted in the model's premise of direct engagement the interconnectedness of ecological systems, physical environments, virtual simulacra, and the acoustic contents that manifest within them. As climate change continues to impose devastating impacts on species survival through anthropogenic weather disturbances, habitat loss, and disease emergence, additional species will begin facing increased selective pressures of ecological silencing cause by species decline. RLPE's hybrid model and methodology of acoustic sound reproduction represents an artistic platform for new an creative engagement with acoustical ecology and critical conservation biology via novel acoustic artistic environments.

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