and we continue

by

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Abstract

“and we continue” is an interactive online performance that tells a story about the behavior of complex systems through the lens of water. Each participant starts out as an iconic representation of various forms of water, such as Ice or Cloud, and explores its individual existence. Later, real-time interactions between participants are explored along with influences of outside actors to the system, creating unpredictability. In the last stage, participants come together to form a system that acts as an individual once again.

The story is told through use of music, video and text, all of which react to the participants’ actions. Each of these three media, together with all participant interactions, plays a part in the story of water and complexity by highlighting shifting time scales as humans influence earth’s water systems and underscoring the unpredictable consequences of individual actions within such systems.

Keywords: Internet Art; Complexity; Systems; Interactive Art; Water

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First and foremost, I would like to thank my collaborator Meagan Woods, for all the positive energy she has put into the making of this project. Her input has helped me shape the story and her final text has added many layers of perception and thoughtfulness to “and we continue”. Furthermore I would like to thank Xinyue Liu for helping me create the panorama photo which is used as the background photo throughout the presentation. To my cohort, thank you for being such a supportive group, even when a pandemic has made it difficult to meet in person. Last but not least, I would like to thank my supervisors, Arne Eigenfeldt and Sabrina Schroeder for helping me reach my potential throughout the program.

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Defense Statement

“and we continue” is an online performance that tells the story of water. Throughout this performance you can participate in the chaotic journey from a single water particle that starts interacting with others, towards a system encompassing every participant’s input. The story is told from the perspective of water, shifting timescales expose the unnatural pace in which water systems change as a result of human input.

Individuality: Personal Background

“and we continue” is the result of integrating interests that have kept me occupied during my master’s study. These interests can be broadly described as interactive generative music, interactive video, the use of storytelling to structure compositions and composing by deconstructing. In general, it reflects an expansion from music composition to incorporate other art forms such as video and storytelling by applying the same stylistic principles of deconstruction to each discipline.

Entering the MFA program in 2018, I was interested in computational musicality and computational intelligence. In my first two projects within the program, I explored this concept from the outside by making compositions *about* it. During my MFA I have been searching for ways to implement or program artificial systems myself. Delving into this topic, I became aware that I am more interested in the interactivity and communication between humans and a system than in the complete autonomy of such systems. Interactivity between a musician and an artificial agent was explored during my Directed Study where I created a system called “Piano Duet” which reacts to an improvising pianist by finding, altering and playing back patterns the pianist is playing in real time.

As I was working on these systems, I started exploring visual interactivity as an additional medium which allows communication between the performer and the system. In my spring show project “What?” I started exploring ways in which interactive video can add to a performance. I found that many processes could be translated from the aural to the visual. I realized I could ‘compose’ video, just as I composed my music.

By collaborating and participating in the studio courses of this program, I came to appreciate the use of storytelling in an artwork. Using narrative became a way to structure my compositions on a macro level. As an artist with a background in mostly instrumental music, I was accustomed to creating music from abstract ideas that were directly related to music itself. Stepping out of this abstract musical world, I found the challenge of creating music from a story gave me inspiration approach music in different ways while bringing clarity to the audience for which contemporary music can be hard to grasp.

The last interest that is integrated in my graduate project is how I construct, or rather, deconstruct my music into a composition or interactive system. Ever since I started composing, I have always been interested in minimal music. Creating a composition from one idea or one source has always interested me the most. This idea stems from the general principle that restriction breeds creativity, or as Stravinsky put it: "The more constraints one imposes, the more one frees one's self"[1].

During my MFA, I became interested in one particular technique that applies the idea of creating a composition from one source: Deconstructing a sample of audio, stretching and rearranging it to reveal different sonic qualities hidden inside the sample. This technique allows me to restrict myself to one type of source material and creating everything else from that sound. Deconstructing and rearranging materials are techniques that aren't only applicable to music composition. Applying these techniques to interactive video or storytelling gives me the possibility to work with these media as a person with no prior experience within these art forms.

Interactions: Research background

The arc of the story in "and we continue" is based upon complex systems. Complex systems are found everywhere in nature. From animal brains, where individual neurons form a network, to ant colonies where each ant is an interacting component in the system. Although each system behaves differently, there are some common elements. A complex system is defined by Melanie Mitchell as "a system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via

[1] Stravinsky, *Poetics of Music in the Form of Six Lessons*, 65.

learning or evolution"[2]. This description aligns well with the deconstruction style previously mentioned. While the system as a whole can be viewed as the audio sample, I am interested in deconstructing this system into individual components to see how they can interact in different ways, restructuring the interactions between these components to allow new properties to emerge.

An aspect of complex systems that is important for my graduate project is chaos. It describes how the behavior of a system can never be predicted. A chaotic system is not random: chaos theory, as first discovered by Henri Poincaré, just states that even the smallest amount of difference in the initial state results in very big differences over time[3], in popular culture this is also called the "butterfly effect"[4]. So even though a system is chaotic, it doesn't mean that the outcomes will be completely random.

Philip Galanter describes different levels of complexity in music, where the most complexity is somewhere in the middle between very orderly and symmetrical, such as the serialist music from Boulez or Stockhausen, and the disorderly or random, one of the most extreme examples being 4'33" by John Cage. Galanter plots various types of generative music practices against the level of complexity.[5]

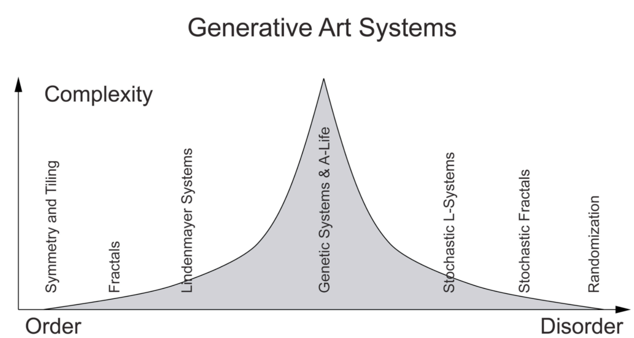

Image 1 Generative Art Systems[6]

[2] Mitchell, *Complexity*, 13.

[3] Mitchell, 21.

[4] The butterfly effect is sometimes misunderstood. While the butterfly metaphor states that the predictability of a chaotic system is inherently limited, the effect has wrongly become "a metaphor for the existence of seemingly insignificant moments that alter history and shape destinies." Dizikes, "The Meaning of the Butterfly."

[5] See Image 1.

[6] Galanter, *What Is Generative Art?*, 12.

Apart from generative music, I tend to find aspects of complex systems in different kinds of music as well, perhaps unintended by the composer. An example of emergence in music is the piece “I am sitting in a room” from Alvin Lucier[7]. In this piece, a recording of a narration by the composer is played back into a room, the playback is in turn recorded, creating a recording of the recording. This process is repeated several times until the recording changes in ways that are impossible to predict beforehand. However, the result at the end is not as uncomplicated as white noise or in any other way random. The sound is altered in specific ways depending on the original recording, the type of microphone used and most importantly the room in which the recordings take place. From the continuous loop of sounds bouncing of the walls into the microphone and played back into the room, a resonant pattern emerges similar to how patterns emerge from simple interactions in complex systems.

The concept of emergence I find in many compositions that are related to the minimal music scene. In this genre, small motifs are often times repeated many times, even though the motifs themselves can be very simple, the result of repeating these over and over again can create emergent patterns that differ from the original motif. An example is the list of compositions from Steve Reich, such as “Piano Phase”, “Clapping Music” and “It’s Gonna Rain”.[8] In these compositions, the different starting times or phase of the motifs create interesting patterns not found in the original motifs.

In “and we continue” the complexity within the music is not through direct repetition of motifs, but rather by deconstructing sounds, finding the complexity within a sound itself. It asks how building blocks of a sound such as frequencies and amplitude pairs are arranged, and how they can be re-arranged in order to create a different outcome or pattern from the same building blocks.

Influences: Working online and collaboration

Until March 2020, my project was supposed to be a participatory performance held in a room with participants interacting in the same place. COVID-19 made me choose internet art as a new form to present my project. While this interfered with some

[7] Lucier, *I Am Sitting in a Room*.

[8] Reich, *Writings on Music*.

of my plans, it also created new opportunities that revealed themselves as I started to create my project online. The most obvious opportunity is that creating a website meant that people from all over the world would be able to attend my presentation. Participants from the Netherlands, Vancouver and Australia would now be able to interact with each other, participating in the same project at the same time.

Aside from learning new web technologies, there were two hurdles I had to overcome. The first is the lack of good audio generation available on the web browser itself, which meant that I would have to do all the audio generation on my computer and stream it to each participant. Streaming good quality audio from my computer to my website caused a latency between the participants actions and subsequent feedback of at least two and up to ten seconds. The result is that participants would not hear direct feedback from the actions they would take.

In “and we continue”, the latency becomes a part of the story. Participant actions within the system only have consequences later on. The project also connects with the theory of chaos. Actions from the participants don’t always lead to the intended subsequent consequences, partially because of this latency, changes rather emerge from the sum of all interactions. This “collective behavior” of each participant influences the music and video that is streamed to the website.

The second hurdle is how each participant knows how to interact on the website, also called User Experience Design. As the project moved online, all instructions for participating had to be a part of the presentation itself. Because the participants aren’t able to see each other during the performance, people aren’t able to imitate each other to figure out what is happening. Instead the instructions had to be clear for everyone and simple to understand. I decided to have a minimal amount of instructions in text form, I wanted to make the process clear without spelling it out in text, so people would feel less obliged to participate in specific ways. In the end this led to some confusion which I will reflect on later in this statement.

Chaos: An unpredictable process

The story of “and we continue” started with the water cycle: the system that moves water from the oceans to the land and back. Together with my collaborator

Meagan Woods who wrote the text for this project, I started working on how to shape this story and connect it with my research into complex systems.

After some trials and errors, I came up with the right idea for how to represent water in the music. I decided to focus in on the mutable or “fluid” character of water, a constantly changing substance that can take many forms. To translate this into music, I started creating my own digital instrument that would be able to create sounds that change in timbre over time. I would represent water with a drone like texture that would not change in pitch as much as it would change in timbre. The mutability became a central theme in the story of water casting the other characters to the background. Interestingly, in this case the reason why I wanted to use storytelling in the first place got reversed. Instead of the story providing structure to the music, the development of the music altered the structure of the story.

Almost all music that is used throughout “and we continue” is based upon a structured piano improvisation I did at home on an out of tune upright piano9. To create the various sounds for the first four parts of the project, I let the computer analyze the piano improvisation to extract the 32 most prominent frequency and amplitude pairs every 50 milliseconds or frame. This created the collection of pairs that would be used to drive 32 sine wave oscillators. The importance of this instrument is that it is able to control which pair is chosen and from which frame. For example, I could choose new frames with a minimum difference in amplitude, to secure a minimum difference in volume. The result of composing with frequencies and amplitudes for 32 oscillators created a texture that is on the border between hearing changes in pitch and hearing changes in timbre. Extending the metaphor of a complex system, the instrument let me deconstruct the improvisation into individual components consisting of frequency and amplitude pairs. By deconstructing the original piece, I was able to create new music that still consisted of the same frequencies as the improvisation.

Video became part of the project as I was looking for a way to show a change in perspective throughout the project. The shift from a local perspective of the individual, to the bird’s-eye view of the system at the end was translated into my project by creating my own interactive video device. This device would allow me to have control over which

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[9] I recorded a second version on a grand piano at school, but I found the richness in the sound of the upright piano to translate better into the project.

part of the background image is visible, composing with the position and scale of the visible part throughout the performance. The background image in question is a panorama of multiple images stitched together by visual artist Xinyue Liu. The panorama consists of NASA satellite images of the world's polar regions. These regions exhibit a broad range of different types of water, from glaciers and ice to clouds, rivers and oceans. These regions additionally symbolize the changing character of water, as global warming affects these areas disproportionally, changing the landscape more rapidly.[10]

Image 2 Video stream examples.
Note: beginning (left) and end (right).

In addition to the video that is streamed from my computer, there were graphics generated on the web browser of each participant, which is viewed as an additional layer on top of the streamed video. Everyone is given a token that represents their water particle. This token takes a different form for each participant, representing the various forms of water: Ocean, Ice, Aquifer, River, Cloud and Precipitation. Participants are able to click on the screen to move their token around. Each participants' position, clicks and relative position to others, are send to the other participants as well as to my computer. This communication enables the actions to influence both other participants as well as the music and video stream from my computer.[11]

Equifinality: The result

The final result is an online experience that involves music, video and text, each partially controlled by the audience. An experience about the complexity of water

[10] "Global Temperature Report for 2019."

[11] For a more technical description of the work, including the sound, video and communication with and between participants, please refer to Appendix C.

systems and the unpredictable consequences of individual actions within such systems. “and we continue” is structured in the following five parts that might look familiar:

I – Individuality. Where everyone follows their own journey, uninterrupted by others.
You – Interactions. Where the first interactions start to happen between participants.
Our – Influences. Where outside processes start influencing the participants actions in the system.
We – Chaos. Where all interactions and influences start creating unintended consequences beyond the control of the participants.
I – Equifinality. Where each participant comes together to become one collective system, once again.

The story starts off differently for every participant. The text is dependent on which type of token they get assigned at the beginning of the piece. It describes the type of water the token represents. When people click on the screen, the text changes, looping through the paragraph line by line. In the second part, the text is spoken and put through a vocoder, morphing it into the frequencies from the water character. Emphasis is put on the similarities between the participants’ tokens, as they can now see each other for the first time. For the third part, the text that is shown is the same for everyone. The placement is still different as it follows the placement of their token. This placement becomes centralized in part four, where it situates itself in the average position of each token. In the last part, the text starts filling the whole screen. This completes the journey from individual lines of text, to each line in the story coming together and appearing simultaneously as one.

The story is written from the perspective of water. It relates back to the human readers and listeners by making references to a difference in timescale. In part three and four of the text, the system and these timescales start to be influenced by humans. Everything moves faster and becomes more unpredictable, commenting on the discrepancy between natural cycles of climate change and the current path we as humans are on.

The video follows the story from individuality to system by expansion. The positions of each participants’ token are followed by the video device revealing the background image wherever that token is. As participants move closer to each other in part two, the amount of background image that is shown starts expanding, the closer a token is to all the others the bigger it gets. Influences start getting introduced in part three and four, pushing the tokens downwards and adding a force to make it harder for the participants to stay together. Actions no longer correspond to the position of the token, but tokens get drawn apart or directed downwards by forces indirectly controlled by the combined actions of all participants. For example, the more people move their token, the harder it becomes for them to get together in one place. Forces are reversed in the last part, drawing the tokens towards each other making the video grow to its full size, revealing most of the background image.

The digital instrument I created for this project generates most of the musical content throughout parts one to four. As described earlier, in general, the music represents the coming together of separate parts into a system. It does this by reversing the deconstruction of the piano improvisation over time. Each click action from the participants triggers a new frequency to be played by one of the 32 oscillators. The frequencies in the first part are all derived from the first frame in the improvisation, creating a texture on the same chord during this part. In the subsequent parts the frequencies start shifting and become more dissonant as frequencies from different frames are used. Participants moving closer together are represented by the sustain of each oscillator increasing. Participants moving closer together will hear each oscillator sustained after the initial attack and decay of the sound. Sound changes become faster in part three and four, more frequencies are triggered simultaneously leading to more and more dissonance. Short excerpts of the piano improvisation are added as a precursor to the final part. During the final part, the digital instrument briefly returns to the frequencies of the first part. Then the origin of all these sounds, that is the piano improvisation, is revealed as all participants come together forming the system.

To regulate the amount of action each participant can take, actions are taken in turn, where the click of one participant triggers the ability to click of a certain number of other participants. Throughout the presentation, this number changes, starting with only two, increasing until part four. In the last part the number goes down to zero ending the ability for the participants to take action as the system is at its final state.

and we continue: Reflections

“and we continue” went through various changes during the creation process. While I decided I wanted to create my project for an online audience early on, I ran into various problems working with this format. Notably, the lack of music creation possibilities on the web forced me to have a centralized audio system streamed to the audience instead of being able to create music for each participant individually. This in turn diminished the possibilities for real-time participant interaction with the system because of the aforementioned latency in streaming audio.

Looking back, I think I underestimated the need for clarity for the participants. Because most actions the participants took only returned with a latency of two to ten seconds in the music and video, many were uncertain that the actions they were taking were the right ones. Added to the confusion was that many actions only contributed to the system as a whole, and thus would only be noticed if many participants took the same action.

Another aspect that could have been made clearer to the participants was the choice to not participate. While I certainly wanted to encourage people to participate, the system wouldn’t break if a few people in the audience decided not to. For future showings I would make this clearer, so the audience doesn’t feel obliged to participate if they don’t want to, or if they don’t understand how to participate.

I am excited about the resulting text, video and sound in this project. While setting the parameters, I realized some parameters could have been set to more extreme ranges, to create a more varied sound and video experience, especially during part 2 and 3.[12] This includes parameters such as the sustain of each note, as well as the change in amount of background video that is shown.

Looking ahead, I want to expand the instrument I made for this project. I think it has more potential. In particular, I am interested in creating more options between the frequency oscillators and the whole sample. This will allow me to transform the sound more gradually from individual frequencies to the original sample.

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[12] Part 2: Interactions and Part 3: Influences.

I look forward to continuing collaborating with other artists. In line with my research about complex systems, I believe that no artist truly works alone. Throughout the last two years in this program, I realized we are always interacting within a system. While using tools from the online open-source community to create my work, I realized that even when I am working alone in my room due to the pandemic, I am still collaborating.

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Appendix A.

Participatory Systems: Composing Participation through rules of complexity

Introduction

> *"In spite of its great successes explaining the very large and very small, fundamental physics, and more generally, scientific reductionism, have been notably mute in explaining the complex phenomena closest to our human-scale concerns."*[1]

In the preface of Complexity: A guided tour, Melanie Mitchell explains that in the 20th century a new field of science emerged under the name of complexity science. Scientists started to study complex systems that showed behavior unexplainable by the usual reductive method of examining components in such systems. Complexity scientists hypothesized these behaviors emerged from the *interactions* between components.

Complex systems are defined by Mitchell as "a system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution."[2] In this paper, I use complex systems as described by complexity science as a framework to understand generative music as well as audience participation.

Drawing from examples of the experimental music movement started by John Cage as well as more recent examples from composers using computers to design a system, I ask in which ways the use of an interactive generative system shifts the practice of a composer making participatory music. Answering this question, I explore the interactions happening between the separate fields of complexity science, generative music, system design, game theory and speech as music.

After giving an overview of complex systems related to generative and interactive music, I focus on the interactions within a complex system to shift the view of interactivity

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[1] Melanie Mitchell, *Complexity: A Guided Tour* (Oxford University Press, 2009), x.

[2] Mitchell, 13.

from something that is added onto generative music to something that is inherent in such a system. Using this type of interaction as a framework I then discuss system design, using the concept of rules borrowed from game theory to describe how a composer can create Participatory Systems. Finally, I will argue for the use of speech in previously described systems by proposing speech as a musical ability that participants can use in their interactions.

An Interacting Complex System

Philip Galanter argues for a framework of complexity theory to be applied to generative art. He argues that “if we accept this paradigm, that generative art is defined by the use of systems, and that systems can be best understood in the context of complexity theory, we are lead to an unusually broad and inclusive understanding of what generative art really is.”[3] Galanter proposes a framework that broadly classifies various generative systems on a scale from order to disorder. Image A1 places various generative systems on a graph that shows the amount of complexity.

On the left side we have highly ordered or symmetrical systems. An example is Steve Reich’s It’s Gonna Rain (1965), a composition for 2 tape loops that slowly shift out of phase with each other. Reich describes this process as impersonal and precise: “there is nothing left to chance whatsoever. Once the process has been set up it inexorably works itself out.”[4] Note here that the generative system is implemented without the use of a computer. An important argument from Galanter’s paper is the observation that “you don't need a computer to create generative art, and that in fact generative art existed long before computers.”[5]

On the outer right side, we encounter systems that exhibit randomness. This is brought to its extreme in John Cage’s 4’33 (1952), in this famous composition the musicians are performing four minutes and thirty-three seconds of silence, 4’33 thus contains environmental sounds only. This openness to music that is not notated or planned in any way opens the path towards participation in music as anyone attending a

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[3] Philip Galanter, “What Is Generative Art? Complexity Theory as a Context for Art Theory,” in *GA2003–6th Generative Art Conference* (Milan, Italy, 2003), 12.

[4] Steve Reich, *Writings on Music, 1965-2000* (New York: Oxford University Press, 2002), 20.

[5] Galanter, “What Is Generative Art? Complexity Theory as a Context for Art Theory,” 13.

performance of 4’33 is consciously or unconsciously participating by making even the slightest of sound.

Towards the middle of this graph, we find increasingly complex systems, with genetic systems and artificial life as the most complex. Discussing evolutionary music Peter Todd and Gregory Werner note that this type of system is increasingly used in contemporary works attributing this to “new computer methods of simulating learning…and evolution”.[6] An example system that uses evolutionary methods is Haile, a xylophone playing robot. Haile improvises together with live musicians, listening and responding to their improvisations. To come up with novel responses, a genetic algorithm is used to modify phrases of the improvisations it hears.[7]

Moving towards the interaction in systems we can observe a relationship between the amount of complexity in a system and what type of interactions take place. In both ordered and unordered systems the interactions are linear in nature. If one were to replace the tape of It’s Gonna Rain the composition would change almost exactly in line with that change. Similarly, contributing to the environmental sounds in 4’33 results in similar changes in the soundscape. When a system becomes more complex non-linearity occurs within a system. Galanter states: “Local components [of a complex system] will interact in ‘nonlinear’ ways, meaning that the interactions do more than merely add up...they exponentiate.”[8] Because complex systems are made up of multiple interacting components, anything interacting with such a system sets into motion a chain of interactions resulting in an outcome that can’t be linked to the original interaction. This non-linearity can be observed in the way that Haile is responding to the musicians. The phrases of the musicians aren’t simply repeated back but first modified in various ways by the genetic algorithm.

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[6] Peter M Todd and Gregory M Werner, “Frankensteinian Methods for Evolutionary Music,” *Musical Networks: Parallel Distributed Perception and Performance*, 1999, 1.

[7] Gil Weinberg et al., “A Real-Time Genetic Algorithm in Human-Robot Musical Improvisation,” in *Computer Music Modeling and Retrieval. Sense of Sounds*, ed. Richard Kronland-Martinet, Sølvi Ystad, and Kristoffer Jensen, vol. 4969 (Berlin, Heidelberg: Springer Berlin Heidelberg, 2008), 351–59, https://doi.org/10.1007/978-3-540-85035-9_24.

[8] Galanter, “What Is Generative Art? Complexity Theory as a Context for Art Theory,” 5.

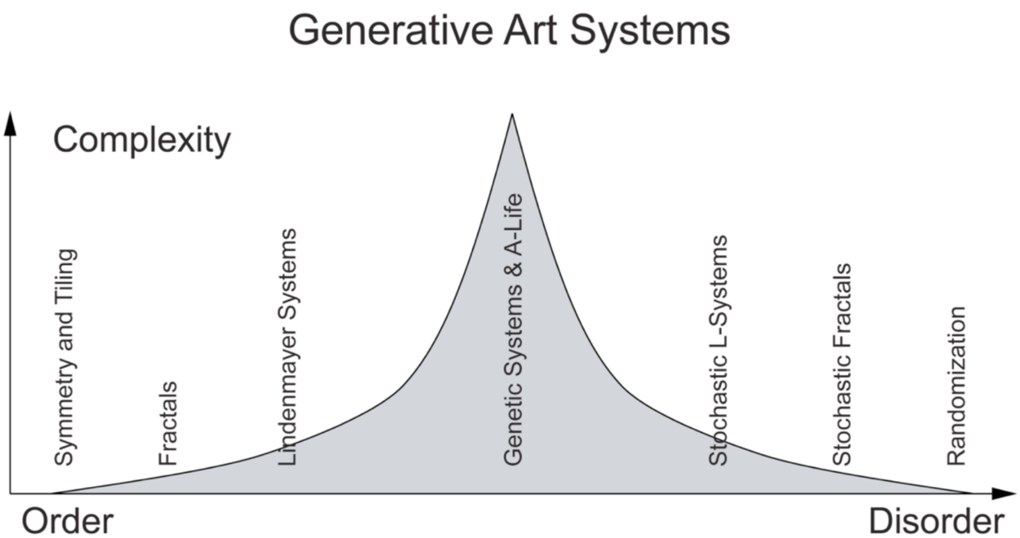

Image A1. Generative Art Systems from Philip Galanter, "What Is Generative Art? Complexity Theory as a Context for Art Theory," in GA2003–6th Generative Art Conference (Milan, Italy, 2003), 12.

Interaction within

Haile can be viewed as a complex system interacting with its environment, making it adaptable to the input it receives from the musicians it is playing with, similar to a lifeform adapting to its environment. This adaptation is beneficial for making music that can exhibit a wide variety of material as the musicians are able to come up with material that a non-interactive *Haile* would never come up with.

In this paper I ask how a music system can interact with audience members instead of musicians. A common issue in composing music with audience interaction is how a system can accommodate interactions from all audience members simultaneously. A common solution is given in *No Clergy*. In this composition, Kevin Baird lets the audience vote over a limited number of parameters.[9] These high-level parameters influence the music that is played. While this system can make the whole audience interact with the system at the same time, effective interactions get reduced to just the voting results for each parameter given.

[9] Kevin C. Baird, "Real-Time Generation of Music Notation via Audience Interaction Using Python and GNU Lilypond," in *Proceedings of the International Conference on New Interfaces for Musical Expression* (Vancouver, BC, Canada, 2005), 240–241, http://www.nime.org/proceedings/2005/nime2005_240.pdf.

The method I propose to tackle the problem of multiple interacting audience members is by re-situating actors from outside to inside the system. To understand this, I refer to the example of the Economy as a complex system given in Mitchell's book. "Economies are complex systems in which the 'simple, microscopic' components consist of people (or companies) buying and selling goods."[10] Because a person is a complex system as well[11], one can conclude that components of a complex system can be complex systems in and of themselves as well. This concept of recursive complex systems, and how complex systems can behave as components in a bigger complex system, leads to the mode of interaction I propose: Similar to people in an economy, we can view audience members as *components of a music system*. Such systems that are made up of interacting audience members are what I call Participatory Systems.

Framing the interaction as inherent to the system causes the audience to be central in the making of a generative system. The problem of multiple interacting audience members is now reversed. Having multiple participants creates benefit as more complexity is introduced into the system, opening the possibility of emergent behavior to arise from the sum of all interactions. Lower numbers of participants create a system that is less complex, impeding emergent behavior to occur.

So how do components within a system interact? Recalling the definition from Mitchell, she describes components of a system as having "no central control and simple rules of operation"[12]. Overall properties emerge from a system without supervision, however, there are simple limitations that determine the behavior of the components in a system. In an economy there is no ruler that determines how the economy behaves, but transactions are limited in various ways by law, culture and human behavior. We can thus identify that interactions are adapting to restrictions from its environment. As discussed earlier, a system that is adaptable to its environment can create a diverse or even infinite number of outcomes.

No central control, limitations and adaptability are all aspects of interaction within a system that can be considered when composing a system for audience interaction.

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[10] Mitchell, *Complexity: A Guided Tour*, 9.

[11] Melanie Mitchell also gives the human brain as an example of a complex system with neurons as the components.

[12] Mitchell, *Complexity: A Guided Tour*, 13.

Because these aspects become so important in the realization of Participatory Systems, it shifts the practice of a composer towards system design.

Interaction design or composing interactions

Composing Participatory Systems shifts the practice of a composer, David Kim-Boyle states: “The development of high-speed network communication protocols and other wireless and telecommunication technology has allowed composers to create musical environments that directly engage participants in the realization of new forms of musical expression. These environments often resituate the role of the composer to that of designer and transform the nature of performance to that of play.”[13]

By using a participatory system, the musical outcome is not dictated by the composer, the composer instead designs the system that will produce the outcome. However, one can still shape the outcome by actively limiting interactions in the system. If the system is adaptable, one can also “compose” the environment around the system to influence the musical outcome. Within a participatory system, this means to carefully consider the ways in which participants of a system interact as well as shaping the environment in such a way that these interactions become meaningful. Kim-Boyle argues for the importance of these design choices with regards to the relationships that are built between participants during the performance. He states that “…the composer or designer of that environment must also assume some responsibility for the quality of those relationships [between participants] that emerge.”[14]

In Max Neuhaus’s broadcast works we can find a good demonstration of how various system designs can create different outcomes for both the participants and the musical product. During *Public Supply I* (1966)[15] radio listeners are able to call the radio station to contribute any sound. These sounds are then mixed at the station and broadcast to all listeners. In *Radio Net* (1977) a more restrictive design is chosen where

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[13] David Kim-Boyle, “Network Musics: Play, Engagement and the Democratization of Performance,” *Contemporary Music Review* 28, no. 4–5 (August 1, 2009): 363, https://doi.org/10.1080/07494460903422198.

[14] Kim-Boyle, 372.

[15] Golo Föllmer, “Media Art Net | Neuhaus, Max: Public Supply I,” text, December 5, 2019, http://www.medienkunstnetz.de/works/public-supply-i/.

the callers are told to whistle one pitch until they are out of breath. Here the mixing is done automatically as each whistle is analyzed for its pitch and mixed accordingly.

Neuhaus states that in *Radio Net* the participants become more involved because of the imposed limitation to the sounds they can contribute. “In all the previous works I had left the nature of the sounds phoned in for each caller to decide. Here I wanted to provide an indication to try and move them past the ‘Listen, it's my voice on the radio’ stage and towards listening to one another.”[16] This gives us a hint that imposing restrictions on audience members paradoxically expands the creativity of the participants, while also creating more control in the musical output.

An intelligent example of restriction, while not in a participatory system, can be found in *Jambot* from Gifford and Brown, a “computational music agent that listens to an audio stream and produces improvised percussive accompaniment in real-time.”[17] The authors explain that the Jambot can take either imitative or intelligent actions as a response to the musicians it is interacting with, where intelligent means the agent creates his own response as opposed to imitating the incoming music. One of the strategies they propose is to use a measurement of confidence[18] to switch between the imitative and intelligent responses, effectively using confidence to choose when to restrict itself to just imitative actions. In the next section we learn that context-based restriction is one of the parameters essential to designing a complex system.

Interaction with rules

“To play a game is to follow its rules.”[19]

Another medium in which designed interactions take place is gaming. Rules as described in game theory can give us more insights how to design a system that can make the audience achieve more than what Liz Phillips and Paula Rabinowitz call the

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[16] Max Neuhaus, “UbuWeb Sound - Max Neuhaus: Radio Net,” accessed December 6, 2019, http://www.ubu.com/sound/neuhaus_radio.html.

[17] Toby Gifford and Andrew R Brown, “Beyond Reflexivity: Mediating between Imitative and Intelligent Actions in an Interactive Music System,” in *25th BCS Conference on Human-Computer Interaction* (Newcastle-upon-Tyne, UK, 2011), 1.

[18] How this confidence is measured is beyond the scope of this paper.

[19] Katie Salen and Eric Zimmerman, *Rules of Play* (Cambridge, Mass.: MIT Press, 2004), 117.

"'supermarket door process of interactivity': I walked up to it and it opened. I have power."[20] Phillips and Rabinowitz give a good insight in what can go wrong when you give the audience too much freedom. "[W]hen the audience expects instant response, asks the piece for self-affirmation, the effect closes down what the piece means to open up. Collaborative art asks for surrender and must elicit recognition, building from reflection. That moment of self-regard should then develop into more complex correspondences."[21] Limitations in the form of rules, as part of interaction design, thus need to restrict these initial expectations to open up the audience for listening and collaboration. As rules are essential to games, game theory has developed a comprehensive theory of rules.

Katie Salen and Eric Zimmerman discuss rules of games in relationship to meaningful play. "Meaningful play occurs when the relationships between actions and outcomes in a game are both discernable and integrated into the larger context of the game" (34). Here "discernable" signifies the player can perceive the result of its action, while the action being "integrated" forces it to have meaning beyond that direct result as well.

To create meaningful play, the creation of rules is essential. The authors first divide rules into three parts: Operational Rules, Constituative Rules and Implicit Rules. Constituative Rules are of most importance to the system designer as these constitute the "underlying formal structures that exist below the surface of the rules presented to players."[22] In Participatory Systems these rules are essential to create the sense of listening and collaboration described by Phillips and Rabinowitz. Operational rules can then be constructed from this underlying structure to guide the participants in specific ways while implicit rules are conventions brought by the participants and can't be designed.

Salen and Zimmerman argue that meaningful play can be viewed through the lens of complex systems, where emerging patterns are created through the players interactions. Meaningful play can occur as interactions are integrated; players actions do

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[20] Liz Phillips and Paula Rabinowitz, "On Collaborating with an Audience," *Collaborative Journal*, 2006, 31, http://lizphillips.net/w/wp-content/uploads/2012/02/oncollaborating.pdf.

[21] Phillips and Rabinowitz, 30.

[22] Salen and Zimmerman, *Rules of Play*, 130.

not only create direct results, but an emergent property of the system creates meaning beyond this direct result. This leads Salen and Zimmerman to state that "without complexity, the space of possibility of a game is not large enough to support meaningful play."[23]

But how can a rule-based system become complex and exhibit emergent properties? Here we revisit Melanie Mitchell's definition of complex systems again, where she states systems have "simple rules of operation."[24] A good example is the game of Go. This game has a very low number of simple rules[25], while applying these rules make complex patterns emerge on the board. Two other aspects of interactivity are important according to Salen and Zimmerman. One is the concept of "coupled interactions", components interactions in a system effect are linked. As well as context-dependent actions, which means that the surroundings of each component have to be taken into consideration for an entity to take action.

With such rules a composer making participatory art can imitate the usual composition process with rules. There are infinite ways a composer can create music, but there are a few common characteristics. Such characteristics, in my view, are choosing materials to work with, ordering them in time and applying alterations to the original materials. With operational rules we can instruct the participants to use certain materials. By designing constituative rules that result in coupled and context-dependent interactions we can loosely structure interactions in time as actions of players only happen after other actions have taken place. Finally, we can alter the actions that participants take based on different contexts the audience members might be in. Therefore, system design with rules can lead us back to the domain of composition again.

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[23] 21/02/2021 16:19:00

[24] Mitchell, *Complexity: A Guided Tour*, 13.

[25] "How to Play | British Go Association," accessed December 11, 2019, https://www.britgo.org/intro/intro2.html.

Interaction with speech

In this part of the paper I explain the use of speech as music, why using speech in a participatory system is beneficial as well as describing in what ways speech can be used in such systems.

The use of speech in music is intricately related to song. In a song, speech is usually altered to accommodate the music. Here, I adopt the concept of speech-as-music from Robert Ashley where speech in its natural form is viewed as musical. Kyle Gann writes: “[O]ne of Ashley’s guiding premises is that speech is itself music, that the melody of speech patterns can be composed.”[26] This notion is supported by a number of linguists explaining the similarities between prosody (the sounding aspects of speech) and music. Specifically, it is noted that like music, prosody is hierarchical. “From bottom up, syllables are combined to form feet, which are combined to form prosodic words, which in turn are combined to form minor and major intonational phrases” (Heffner and Slevc 3). This is similar to most music where notes are combined into motifs that in turn can form musical phrases.

Outside of the theoretical realm there are a number of compositions that show the musicality of speech. In Private Parts (1978) Robert Ashley writes the lines of his text in such a way that it can be spoken on top of a Tabla rhythm playing. The Tabla in turn adjusts to the speech of Ashley as well, creating almost common sounding speech within a musical environment.[27] We already encountered speech in *It’s Gonna Ra*in, where looping a recording of speech make the musical properties “emerge even more strongly.”[28] The exploration of musical speech is further developed in *Different Trains* (1988), where the rhythm and pitch of a spoken sentence is imitated by a string quartet, enhancing the musical quality in a different way.[29] These works all show ways in which music can incorporate or consist of speech, with compositional ‘rules’ guiding how this speech is used as music.

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[26] Kyle Gann, *Robert Ashley* (University of Illinois Press, 2012), 1.

[27] Gann, 54–55.

[28] Reich, *Writings on Music, 1965-2000*, 19.

[29] Reich, 151–52.

If we accept speech as a form of music, then most participants have a musical ability they can use within Participatory Systems. This ability is trained since birth, and while it is not meant to be used musically it can certainly be applied this way. In Max Neuhaus's *Radio Net* we already saw the benefit of participants using inherent musical abilities, in the form of whistling. Because speech is used as a means to communicate, it can even better accommodate interactions between participants. Speech is musical interaction.

Because many participants will be interacting, ways of combining speech is of significance in Participatory Systems. How can multiple speakers interact like musicians in an orchestra? *Different Trains* separate the speakers through time. Interactions between speakers thus only happen in chronological order. A different method than chronological ordering is used in Paul *Lansky's Idle Chatter* (1985), Lansky combines short speech fragments, phonemes, and arranges them rhythmically to create the perception of multiple persons chattering.[30] The use of short fragments is important as the meaning of the words become less perceivable. Short fragments of speech can be perceived as notes that can be stacked and arranged harmonically.

Participatory Systems involving speech need to have rules that can integrate multiple speakers to create an outcome similar to an orchestra, following the rules of a composition. The composer needs to regulate speakers in such a way that speech of a participant indirectly adds to the emerging musical outcome.

While the use of speech in a participatory system is not necessary, it creates ample opportunity for composers creating music from Participatory Systems. It would be hard to recreate the amount of musical opportunities for participants with anything other than speech.

Conclusion

The framework of complex systems guides us towards various insights into how a Participatory System can be designed. Considering participants as part of a complex system overcomes the multiple participants problem, making multiplicity a strength

[30] Denise Ondishko, "Six Fantasies on a Poem by Thomas Campion: Synthesis and Evolution of Paul Lansky's Music Compositions" (University of Rochester, 1990), 59.

rather than a weakness. At the same time this framework comes with new methods to deal with other problems in participatory music as well.

Investigating complex systems, we find that interactions among participants need to be restricted both to lead participants to interact beyond their intuition as well as to shape the musical outcome desired by the composer. Interaction can be shaped by rules for “meaningful play” to emerge. Shaping interactions so that actions become context dependent, linking interactions together and keeping the rules simple for the participants can create systems that show emergent behavior which integrates actions of participants to create meaning beyond direct response. This emergent behavior accommodates the composition of interesting musical outcomes as well.

In analogy to the way restrictions are set up for humans in an economy, restricting audience members in a Participatory System is beneficial as well. A restriction, that at the same time opens up an abundance of musical possibilities, is speech. As the ability to speak is mastered by nearly all participants, it can be used to create context based and linked interactions that lead to a Participatory System showing emergent behavior.

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Appendix B.

Video Documentation

Created by Casper Leerink
Music and Video - Casper Leerink
Text - Meagan Woods
Background Image - Xinyue Liu
Recording and editing - Casper Leerink

Description

Screen capture of the presentation of “and we continue” which was presented online on October 15th, 2020.

File Name

andwecontinue.mp4

Appendix C.

Technical Appendix

This appendix is an optional text, to be read in addition to the defense statement, explaining the technical background of the project.

“and we continue” consists of three key pieces of software, a virtual instrument build with Max for Live, an interactive video device realized in Max and the website where participants interact with each other and the instrument and video device. I will go into detail about each piece and explain how and what kind of communication is sent throughout the presentation. An overview of each component and communication between them is given in Image C1.

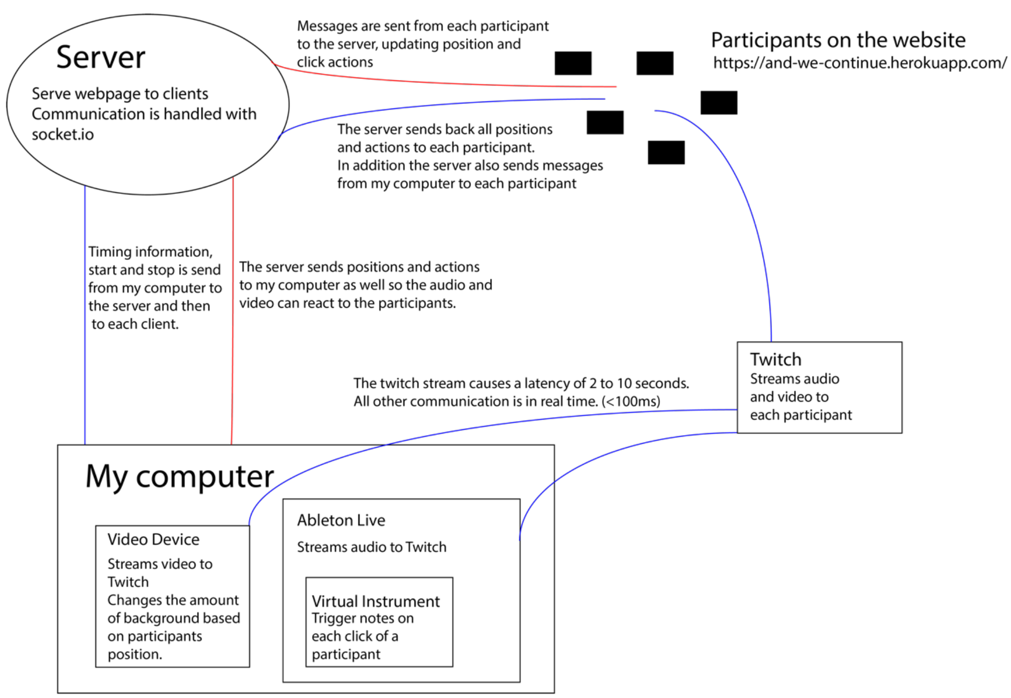

Image C1. **Blue lines are messages to the participants, red lines are messages from the participants.**

The website has the function of providing each participant with a token representing a type of water, see Image C2. Each token can be moved around by the participant by clicking on the screen. Text of the story is shown, first by clicking on the screen, and later based on a central timer that is sent from my computer to all participants. Drawing the tokens is done with the help of the p5.js JavaScript library[1]. Messages to and from the server are sent in real time with the help of web sockets. The position of each token in continually sent to the server, which updates the state and sends it out to each participant and my computer. In this way, the state of each participant is synchronized across every participant.

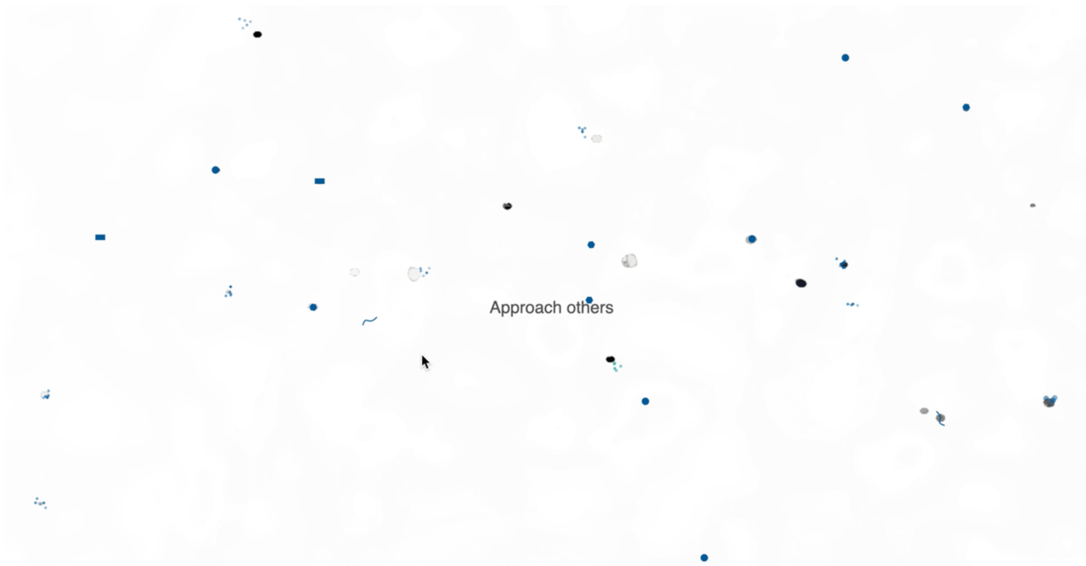

Image C2. Screenshot of a participant during the second part of the performance.

The ability to click is regulated by the actions and position of each participant. When a participant clicks, it enables the ability to click for a certain number of other participants that are near that participant on the screen. This number changes from two in the beginning, the number of participants divided by three in the middle to zero in the end. Because this number is zero in the end, no one will be able to click during the last part of the performance.

The virtual instrument I build in Max for Live has two functions: one is to record a sample of audio and analyze the 32 most prominent frequency and amplitude pairs each 50 milliseconds. The other is to use this information to drive 32 sine wave oscillators. To analyze the information from a sample, I used a frequency peak detector build by Mikhail Malt and Emmanuel Jourdan.[2] The detector provides a list of 32 pairs. Each 50

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[1] McCarthy, Lauren. P5 (version 1.1.9), 2020. https://p5js.org/.

[2] Malt, Mikhail, and Emmanuel Jourdan. Zsa.Descriptors. e--j, n.d. http://www.e--j.com/index.php/what-is-zsa-descriptors.

milliseconds, a new list is generated with new pairs of the sound at that time. The final data that is stored is a list of frames, where each frame is a list of the 32 pairs.

The pairs of frequency and amplitude are played back one by one in reaction to a click action from one of the participants on the website. Used in this way, a pair becomes very similar to a note played in a virtual instrument, except the information is in frequency and amplitude instead of pitch and velocity. The synthesis itself is very basic. There are 32 sine wave oscillators, one for each note in a frame, these are all directly connected to the sound output. The instrument can change the attack, decay and sustain[3] of each note as well as the panning, which changes based on the position of the participants click. For example, a click on the right side of the screen triggers a note with the panning to the right.

The core of the instrument is the capability to search for the next frame in various ways to have control over the amount of change between each frame. When all the pairs in a frame are played, a new frame needs to be chosen. For the purpose of this project, I wanted to have little change between each frame in the beginning and more towards the middle. I found that the best way to choose the frame with the least amount of audible change is to focus on the difference between amplitude for each pair in the frame. To have more change between the frames in the middle of the presentation, choosing the frame with the most difference in amplitude is used. Aside from the triggering of the notes, the sustain parameter is controlled by the participants. The closer the participants are to each other, the more the sustain will go up, the closeness of participants are calculated with the mean squared error of the distance between all participants.

Another important parameter build into the instrument is how many pairs are played before choosing a new frame. In each frame the pairs are sorted by frequency from low to high. If this parameter is a number below 32, then only the lowest frequencies up to that number are played. As the higher notes in the frequency peak detection are always softer than the lowest, this parameter works as a filter, removing the higher frequencies from the sound.

The device is used inside Ableton Live to apply compression and reverb to the audio signal coming from the device. Ableton Live is also used in the second part of the

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[3] The notes don’t have a duration, so the release parameter isn’t used.

presentation to trigger the spoken voice. The voice is altered by a vocoder that sources the carrier from the virtual instrument itself, creating a spoken voice that is similar in timbre and harmony to the sound from the instrument.

The video device I build for “and we continue” is made in Jitter, the video programming world inside of Max. The video mimics the positions of each participant, and it shows the background picture in those positions. First, circles are made at each position, if there are 20 participants, there are 20 circles. The size of each circle differs throughout the presentation and is influenced by how close together participants are on screen, the closer they are the bigger the circles. These circles are altered by a fractal generator to shift the shape continually throughout time. These altered circles then work as a mask for the background image. The whole screen is white, except for the positions of the circles.

The background image is a panorama photo, the left side of the picture connects to the right side, creating a loop. The image is placed on the inside of a cylinder, and then viewed from the center within that cylinder. As the camera rotates, different parts of the panorama become visible.

The resulting audio and video are sent to a program called Open Broadcasting Studio which streams the audio to Twitch. The Twitch stream is embedded on the website.