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DEPARTMENT: ART ON GRAPHICS

Nathan Selikoff: Explorations in Higher Dimensionality and Complexity

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While data scientists pursue new extremes of high-dimensional data, and data visualization professionals attempt to visualize within that space, Nathan Selikoff's work suggested a unique perspective on relationship among complexity, higher dimensions, and sensing what otherwise cannot be sensed. His long-tailed pursuit of visualizing complexity piqued our interest as we interviewed him for this article.

Francesca: Hello Nathan

Nathan: Hello

Bruce: We've been looking at your portfolio of work that you provide online at www.nathanselikoff.com and see a theme of dimensionality and mathematical algorithm embedded in your work.

F: Yes. Can you tell us about your journey up to when you worked on *Untiled Faces* (see Figure 1), which is work I find particularly engaging.

N: Sure. I started learning to code at age 6 or 7 on a Commodore 64 with the help of the "BASIC Training" column in 3-2-1 Contact magazine, plus the assistance of my dad who is a software engineer. Throughout childhood I was also exposed to many art classes and learnings from my mom who is an artist. Those two paths converged in high school as I spent lots of time learning computer graphics thanks to inspiring software, much of which contained algorithmic and procedural features and techniques that created fascinating visuals. I decided to go to the nearby University of Central Florida (UCF), as I had lived with my parents in Orlando since tenth grade. I started undergraduate studies in computer science and switched over to digital media for a semester or two, but the administration wasn't allowing digital media students in the fine art classes that I started getting excited about. That restriction was part of ongoing campus politics. So I said, "Fine. I will switch to art," and found my way by creating a degree across both disciplines anyway.

F: That set you up well for your journey from there.

B: Indeed. On your website, you mention being inspired by Clifford Pickover who I was unfamiliar with as I investigated his fascinating home page at pickover.com. His site resonates as I remember Christopher G. Langton's work resonating my interest in complexity and artificial life at an overlapping time.

N: I read *Chaos in Wonderland* in late 1998 and into 1999 and that book was certainly a pivotal inspiration for me. The book is a weird and wonderful mix of math, code, art, sci-fi, and philosophy, all of which have been interests of mine for a long time. He envisions a "Latöocarfian" civilization of creatures residing on Ganymede who dream of a system of equations and their outputs. It's a thin cover for sharing chaos theory and in particular, a set of equations in the form of an iterative function system which create beautiful strange attractors, the "dreams" of the creatures. These illustrate the book alongside many historical graphical references, and Pickover provides plenty of pseudocode for the reader to try making strange attractors on their own. I used that pseudocode to create many images, and was drawn into the infinite space of possibilities offered by such a simple set of equations.

F: And that inspired your art?

N: Yes, along with my classes and part-time jobs near the end of undergrad. I worked with a visual artist as a kind of artist assistant, and with a research lab affiliated with UCF that was doing mixed reality research — mostly what we



FIGURE 1. *Untiled Faces* suggests that to comprehend a complex system, it is often necessary to understand both the details and the big picture, and to jump back and forth between those levels of abstraction.

would call augmented reality today. The lab had their own game engine and we were doing applications for the Dept of Defense, and some educational experiences the lab brought to SIGGRAPH. I worked with them for two years and by that point I had experience with a lot of computer graphics stuff like 3d modeling and animation with tools like Maya and 3D Studio Max. That position let me dive more into the scripting side of things. The scripting was interesting but eventually they ran out of money and had to let folks go. So I transitioned into fine art pursuits that I balanced with freelance work for about a decade.

F: Ah yes. Can you talk about the art exhibitions?

N: Yes, for sure. The first ones were in the early to mid-2000s. I got my foot in the door at SIGGRAPH and a few juried exhibitions focused on digital art or mathematical art, including a conference called Bridges which is an inspiring community to be a part of for exploring mathematics and the arts. My work is at the intersection of math, art and computation, and eventually I started getting invited to group exhibitions by curators interested in that inter-

section. I continue to be inspired by the mathematics of complexity, chaos and fractals. I love being able to explore complex mathematical spaces interactively, pushing the envelope on rendering images with extremely high quality, and the physicality of turning them into beautiful prints and installations (see Figure 2). I love to express myself through code and leverage tech to create art, to pull on inspirational and motivational threads all the time, and to expand on ideas and see where they go.

B: Excellent. So let's share your work with our readers in this light. Do you think we can then take your thematic threads and point out how one inspiration inspired another inspiration through the process and practice of making art? I am interested in how one piece could not have been done without the effort put into a previous piece, if that describes your journey at all?

N: OK, yes, then we should start with the *Society of Stick People* (see figure 3), which had various iterations. The initial inspiration for the line of work that started it all in undergrad and beyond was simulating population dynam-

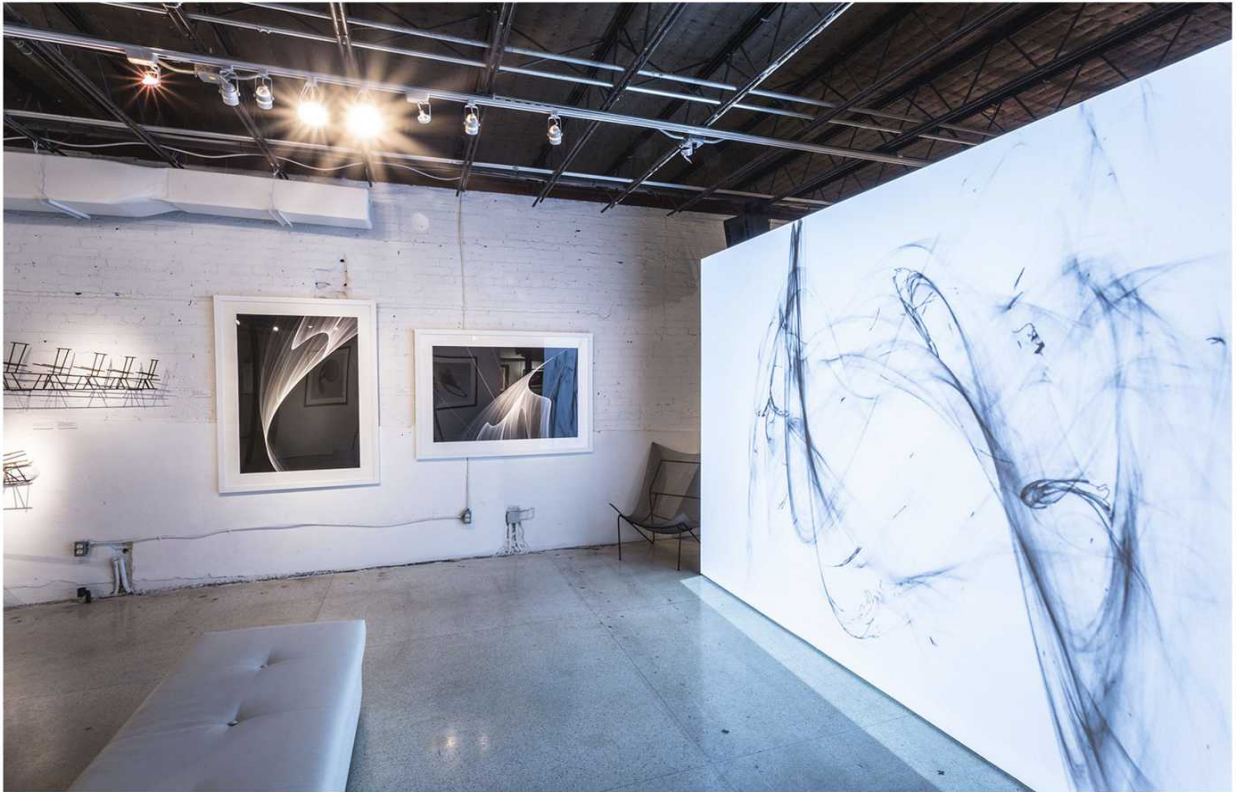


FIGURE 2. *Process Prints* and *Beautiful Chaos*, an interactive installation that allows the viewer to explore a chaotic dynamical system via gestural input. Installed at Snap! Space in Orlando, Florida. Photo courtesy Snap! Space and Tina Craig.

ics and exploring change over time where randomness and a sensitive response to initial conditions created a wide variety of outputs. Over time a primary question drove the work: *What if you could capture in one image the whole evolution of an ecosystem?* The work involves a simulation engine that takes the stick people through a life, from birth to death, where they are driven to gather resources while moving around a space and building things over time. What was interesting to me was keeping the virtual camera frame open to take a long-exposure image of the virtual system, to try and squish all that time, interactivity and change in evolution down to one frame. How could you capture in one frame the essence of the birth, life, and death that happened in that society. Every time the program runs it generates a different image, due to the slight randomness in the seeding of the initial parameters.

F: Now that's interesting to capture the different run of a simulation in a single frame with different parameters.

N: There's always been this interplay between the simulation itself and the outputs I am going for. I showed the prints in 2006 and didn't show the supporting animation until a few years later. There's a common thread to my work with strange attractors where I was primarily inter-

ested in generating the prints, using my internal interactive tools just for the creation of the final works. Eventually that progressed to where I was showing pieces of the

tools as the work itself. Basically I pulled back the curtain to let people see what was going on behind the scenes of the work — to show them the connection between what was happening in real-time and what resulted as exhibited work. That process worked very well in evolving from showing off mathematical prints, and eventually led to interactive installations based on those algorithms.

B: The interactive displays then change parameters mid-stream. I like the unique interactive experience your *Untiled Faces* work provides. Can you describe that work? You explore 4-D a lot, let go of the constraint where the fourth dimension is time. Certainly mathematically it doesn't have to be time, but with your stick people the fourth dimension is time, correct?

N: Yes, with the stick people the fourth dimension is time. But in *Untiled Faces*, with the interactive physical machine with three screens, the four dimensions are all parametric. You interact with two dimensions on the left joystick and two dimensions on the right joystick. Every re-

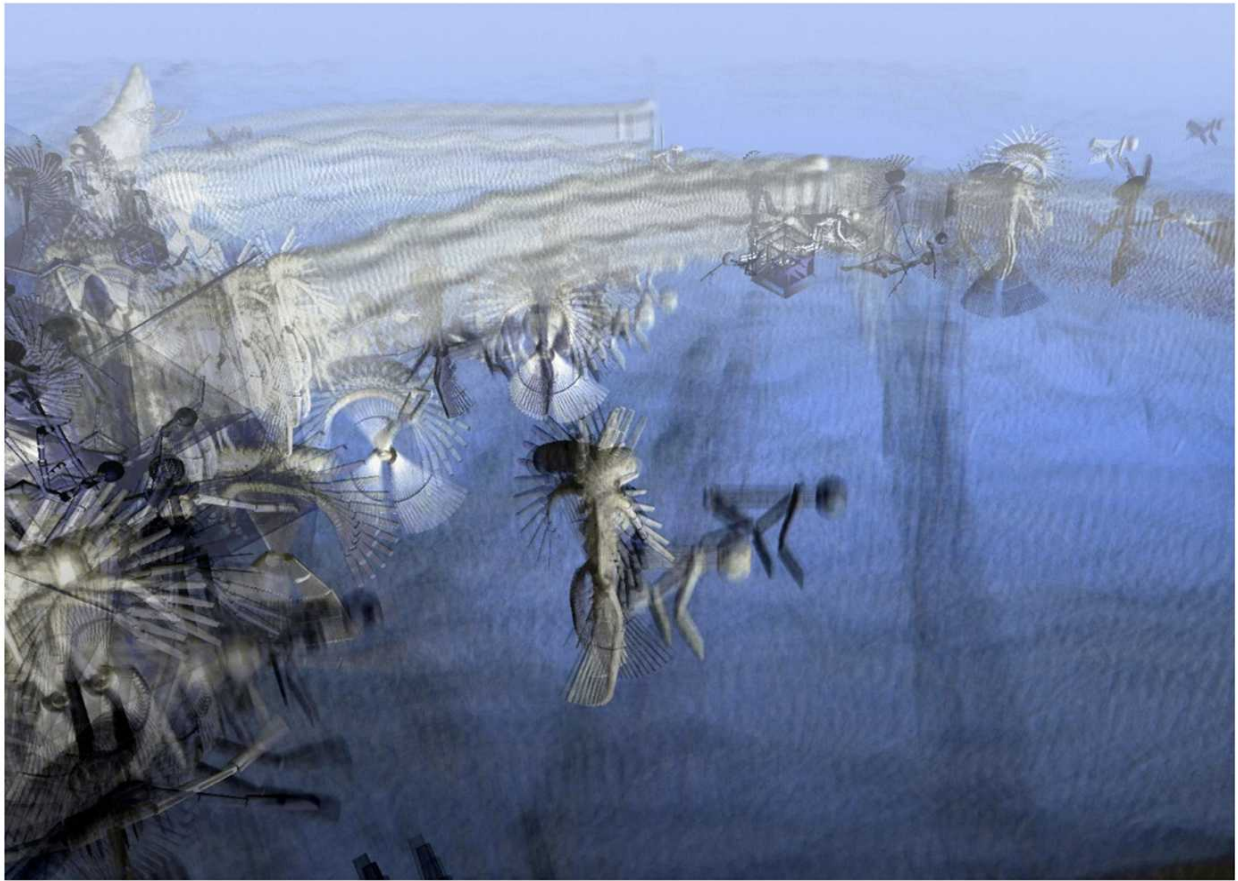


FIGURE 3. *Society of Stick People* suggests that manipulating the rendering style of a simulation to resemble digital chronophotography (a virtual long-exposure photograph), one can generate a wide variety of evocative results.

sultant image on the middle screen is a slice of a four-dimensional object that contributes to what is seen as an animation from one slice to the next in the center.

F: Can you explain that to be a little clearer to our readers?

N: Yea. When you draw you are working in two dimensions. When you sculpt you are working in three dimensions. We don't have such a way to work with or visualize four dimensions directly. Spacetime is a four-dimensional convention where you can think of time as a fourth dimension, but you can also think of a fourth spatial dimension. There is a branch of mathematics that deals with higher spatial dimensions: hypercubes, and other parametric spaces that exist in higher dimensions. For us to see them at all, they have to be dimensionally reduced to something we can perceive.

B: A slice of 4-D can become 3-D essentially?

N: Yes, it's helpful to think of a Pixar movie where they are rendering a 3-D world into a 2-D movie. There's a 3-D representation in there but it is presented on a 2-D screen.

We're seeing a projection or a shadow. I'm interested in the higher jump from four dimensions to three dimensions, which is highly challenging and motivating to visu-

alize because you have to try and think of a way to draw it back down to its lower-dimensional space we can perceive. So in *Untiled Faces*, I used a couple of techniques to do that. I sampled the 4-D parameter space twice. On the left screen, you see a grid of images, and the joystick moves you through that grid, controlling two parameters. On the right screen, you see a single image from that grid, and the joystick moves you through that image, controlling the other two parameters. Those four parameters are what are used to render the strange attractor in the middle screen. There's another layer too – given any parameterized attractor, you can compute something called the Lyapunov exponent to represent how chaotic it is. I use that value, mapped to a grayscale gradient, to color the images on the left and right. I found it ironic and serendipitous that this generated face-like images, since I was trying to discover the "face" or overall nature of the system.

F: What I find interesting is that it has crossover with some of the things that are happening today. You are generating an interactive system that then helps you, or an audience, generate work. So you focus on the underpinnings of the work, but this has resonance today with what is ongoing with generative Artificial Intelligence. Your work has not been that, but your work also connects to scientists who are trying to create simulations whereby they play with modeling parameters to see what comes out. There are reflections in those popular processes today too. To reflect upon the similarities among scientific processes that have similarities to artistic processes. I get how your work morphs into other work. I see this progression of moving from a specific storyline to more abstract visuals and experiences.

B: Are you still having emergent leaps of insight in that space or are you spent because you started off in 1999 and have been working in this space since then? Is it rare for you to have a flash of new insight? Do you still find value in taking all the insights you've had from the past and applying them in new and unique ways?

N: Well in the last few years there have been a couple of new insights. The first came from data visualization work I have been doing at Stitch Fix to visualize a 64-dimensional space that is used in a machine learning algorithm. I use a dimensional reduction technique called UMAP to create a 3-D galaxy fly through that represents what the machine algorithm is "seeing" in 64 dimensions. This has led to insight as to how data scientists think about dimensionality and how higher-dimensional spaces are integral to machine learning. I had a chance to speak about this work in more detail at SXSW last year.

B: Yea. That's a rich progression from previous work right there.

N: That's one example from work; an example of insight from life and being outdoors comes from a recent road trip I took from Orlando, Florida, to California and back. We stopped to spend some time in Antelope Canyon outside of Page, Arizona. The landscape features in these canyons, and in nearby formations like Horseshoe Bend, are all spatial representations of change over time. They are carved out of the landscape by erosive forces of water and winds that leave a record of what happens over time. Layers build up and break down and every slice traces a process. One of the features of a slot canyon is that it is continually undergoing change as well. When there is a big storm, there is forty to fifty feet of water rushing through the canyon that affects that tracing. It effects the overall sculpture where the whole thing might represent water traveling a path for the last hundreds of thousands of years, carving its way down, but that data embedded in the landscape is still undergoing change. It is never static.

N: What is being brought to people's attention more and more is that when we observe something we change it. There is no absolute objectivity or passive observation of a system, be it a computer system or a natural system, where the observer doesn't have some effect on it. Seeing or thinking about that dynamic system in a landscape, where it can tell us something but is also constantly undergoing change, has brought some insights for me as well.

F: That's interesting and I can see how the example from nature speaks to another dimension. You also work at translating between senses. Do you want to talk about that? N: Yes, because it ties into higher dimensionality as well. My work *Audiograph* shows off an audio environment by visualizing sound as a projected clock, as the sound is being captured by the microphone. So at any point in time you are looking at a representation of the last minute of sound that happened in that space (see Figure 4). It is constantly updating as the second hand goes around. The projection shows a frequency mapping with high frequencies on the inside and low frequencies on the outside. This one actually started as an interactive installation and then evolved into a print series, where instead of live audio I used field recordings from travels around the world to create prints via the same type of algorithm. Figure 5 shows a print of cicadas I captured on a trip to Seoul in 2016, which ended up looking like tree rings which I found fascinating.

B: That suggests the insects are making sounds at specific frequencies that are very consistent.

N: Yes, they are harmonics. Most natural sounds have overtones that appear across frequencies, while artificial sounds like sine waves won't have them. They exist in only one part of the spectrum. This ties to multidimensionality through the compression and remapping of time and the translation of audio frequencies to visual markers. We perceive sound over time, so it is unusual to present it in a format where we can perceive it all at once. It ties back to the imprint of the stick people's actions in compressed time. And to the canyon which encodes what happened in that space over time. There is an aspect of data compression and loss because you don't have access to the temporal data anymore, but you gain a visceral "all at once" sense of what happened over time.

B: This reminds me of how arbitrary a minute is such that there is no obvious way to extend it into 3-D to get an interesting form.

N: You start to think of a helix to get something that is more 3-D, or recording with a day or year time period.

F: Or making the time extent interactive, which ties to the next question I have. You've been moving between digital

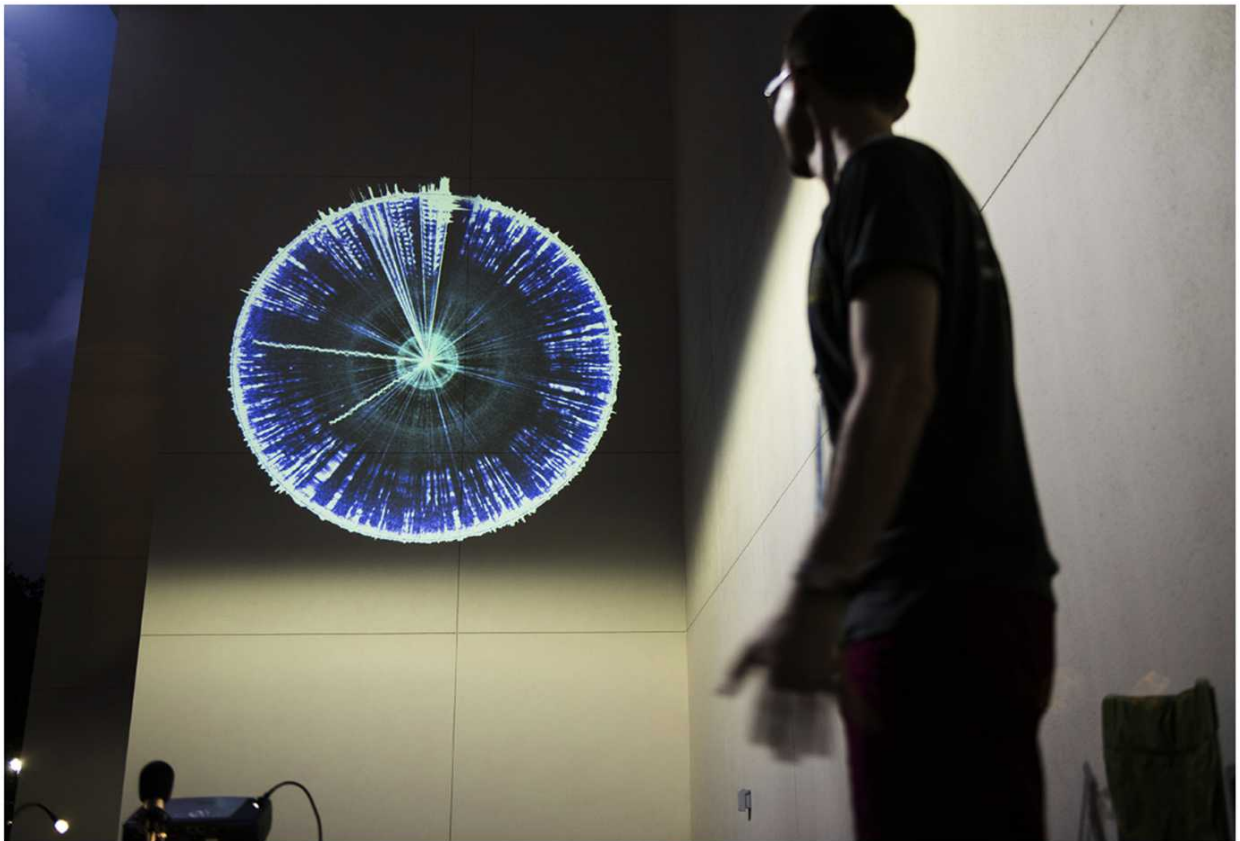


FIGURE 4. An example of the author's *Audiograph* interactive exhibit in action. Photo courtesy: Katie Kuykendall.

presentation and prints, but when you think of multidimensional space, you pursue 3-D space. Is there a conscious cycle you move between in choosing that?

N: When I do screen-based work, it isn't satisfying to have it displayed on a cell phone, or a computer screen. I want it to be projected on a seamless wall, or I want the screen to be so physical that it is part of an overall design. And if I work with a screen, I want to be able to change it, to go vertical for example.

F: You want the screen to be part of the physical environment?

N: Or to take it out of just being a screen. Not just a TV on the wall. *Untiled Faces* looks like it has three screens, but it's just a single monitor taken out of its case and framed in a way that divides it up and makes it unusual. I have another piece that animates buses over time and with that one I displayed the screen vertically and exposed the Raspberry Pi and cables that were leading to it.

N: I've gone through phases when I want to be in the real world building things with my hands, like the cardboard

works I have done. As I get older I find I don't want to be sitting at a computer for hours at a time.

F: I have spent time thinking about how we bridge a digital experience with our physical experience in the physical world. Especially when we are working with 64 dimensions trying to see data and print data at nano scales. There is something appealing about that which is made by hand, which is simple, and the other end of the complexity spectrum. It's like you are oscillating between the two. What do you see as the draw towards more traditional materials? Not so much in terms of the act of creating but in terms of insight and absorbing by an audience?

N: To me, to be honest, it is the act of creating that is satisfying for me. Especially when using your hands. It's probably a big part as to why people choose their media. But I agree that in terms of impact, there is a lot of potential there too, but I have only scratched the surface on that. There are artists who have worked extensively with data physicalization, where they bring data visualization into sculpture with various levels of abstraction. There's a lot of great work done in that space. My personal experience of work like that is that it really can be more impactful, see-

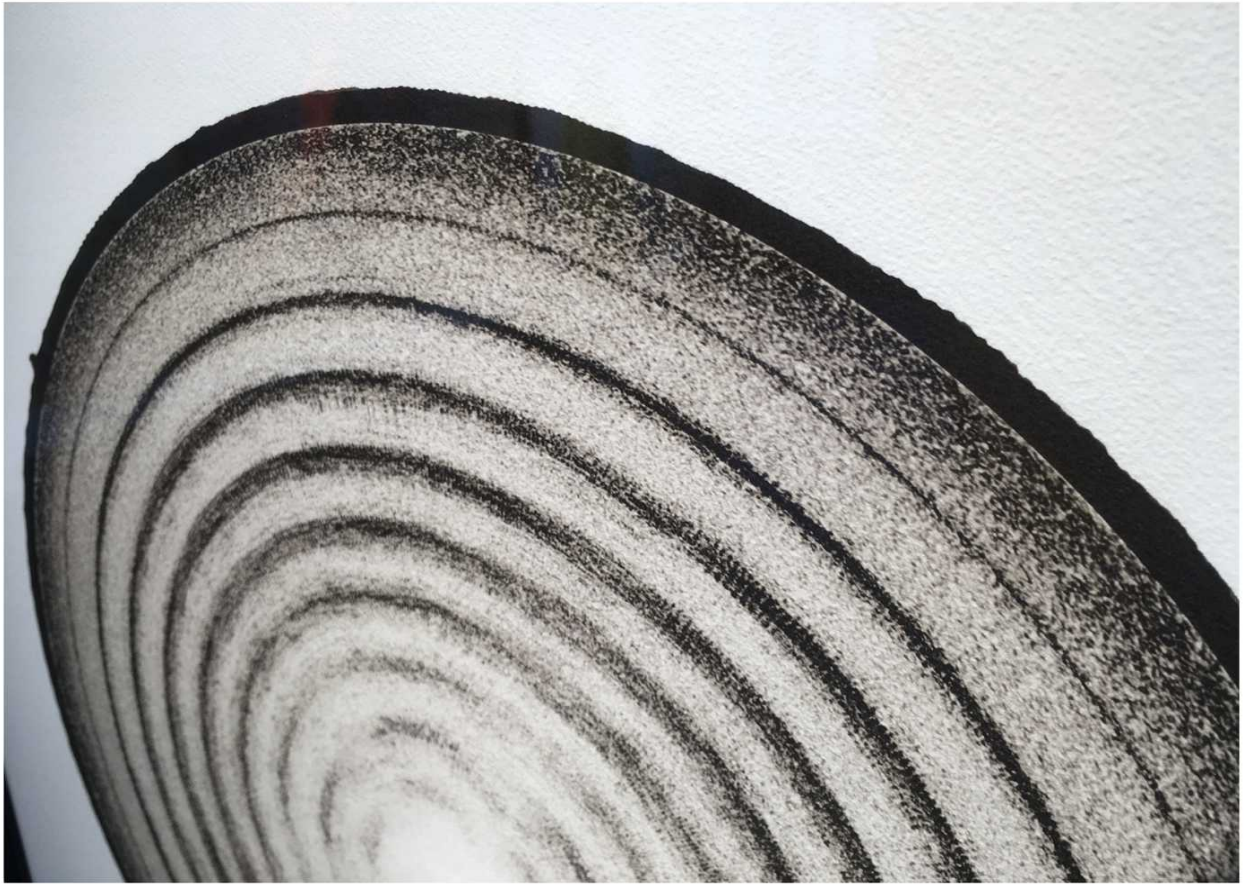


FIGURE 5. An Audiogram produced by capturing natural sounds in a field study and visualizing the audio recording using the artist's Audiograms algorithm.

ing the work in a large room where you can walk around it, see it from far away and really close up. That's where the AR/VR stuff is still not super-satisfying to me. But to be fair it has been a few years since I put on the latest headsets. I'd like to try them again, but I hope motion sickness isn't as bad as it was in the past. There's a way to go until it's seamless, though I know Apple just announced their new glasses. We'll see, but I haven't been drawn towards that tech yet.

F: I work in that space and find that to be a common response. But what inspired that thought was you were driving your 4-D chaos interaction with hand motions. That's like sculpting, but in a different way. When you are creating work by hand out of thin air.

N: Yes. Yes. That's when it becomes magical. You are not wearing gloves, and you are not wearing a headset, you aren't even touching anything but you are controlling gesturally with your hands. That can be done with the Leap Motion controller, or a Kinect controller to use the whole body. That has magical potential for sure.

F: So we haven't talked about the music?

N: Ah yes. I am a musician. I sing in a choir, and play violin, guitar, ukulele and a little bit of piano. It's a deep love and joy of mine. I have had a chance to work with composers to do some real-time visualization that goes with their pieces.

F: What's the interest to the connection and the visualization? What's the important part to you?

N: I did a piece at Full Sail with a composer locally, Keith Ley, and then one with Dmitri Tymoczko in Canada. Their pieces were both mathematically-oriented. One was focusing on four dimensions and the other, Dmitri's, was based on a geometric approach to music that is mathematically based. They created new work that they envisioned being accompanied by visualization, and invited me to collaborate. They compose the work and send me a simulated recording when it is close to finished, and I start to sketch and brainstorm with some of their input, the themes of the



FIGURE 6. A moment from a live musical performance investigating *The Thousand Faces of Form*.

music, or the mathematical aspects it is drawing from (see Figure 6). More so in Dmitri's case because he's written a whole book on the subject. For me that's a fun process of closing my eyes and thinking and visualizing what comes to mind to make it come alive on a screen. I keep everything real-time, using VJ-like tools where I can trigger different clips and perform the visuals along with the music.

F: So it is creation on site.

N: Yes.

F: Do you have any favorite pieces we can dive down into for a specific perspective? And 'no' is a fine answer that's OK too.

N: That's a tough one to answer.

F: Then we can end here and consider your process being more about the mix of work than what gets specifically materialized in the end.

B: There's plenty of richness in that. I can see how your career to date must influence the work you are doing with 64-dimensional space you provide for commercial use. And as you linger to think about it conceptually, it too will directly affect your artistic practice. Sixty-four dimensions seems like a big jump in the number of dimensions you want to reduce. I will like to see where you head from here.

N: That reminds me. One thing I wanted to bring into the

interview but haven't been able to do so, is James Bridal's book entitled *Ways of Being*. I finished it recently and it

was really inspiring. Towards the end he talks about the *Internet of Animals* which is a great evocative phrase. The things we're learning about animals and plants and their ways of being through various technologies and data can really open our eyes to the intelligences that have been surrounding us all along on this planet.

F: I can see how that would tie to your work and motivate your work.

N: I started taking timelapse photographs from my apartment about a year and a half ago. I took a Raspberry Pi computer and stuck it to the window, facing east on the ninth floor where I saw these beautiful sunrises. I learned about something called an analemma which is the shape that is formed by taking a picture of the sun from the same position at the same time of day for a year. Because of the tilt of the Earth's axis, the sun traces out a shape that looks like an infinity sign. I wanted to capture my own analemma from my own vantage point. I moved before I had a complete year's worth of images but what I am thinking about with that data set is that it, again, is multidimensional. Each photograph is two-dimensional, and you've got time as a dimension, but you've also got different cycles you can break down as dimensions. You have the time of day in a 24-hour cycle. You have time of year as a 365-day cycle. I want to interactively explore this time-lapse and day-lapse imagery. Our awareness of how much the

location of the setting sun changes from day to day is very gradual, but I'd like to create some new work that brings that change to the forefront. As I pay closer attention to what's happening outside my window, or around me as I walk the neighborhood, I'm thinking about the relativity of perception and the different layers and paces of change that exist in the world – animal, vegetal, mineral. To us, plants move slowly; maybe to plants, we move frantically. How might playing with point of view and compression or expansion of time and other dimensions help

us see and sense differently, more clearly, more humbly, more empathetically, particularly in the context of climate change?

F: That's a good place to end. We can thank you for sharing your inspirations with us and our readers.

B: Yes. Thank you

About the Authors

Nathan Selikoff produces art and tools that are inspired by the behavior of systems, science, nature, and music. He combines computer code, traditional materials, and future technology to bring new ideas to life. As people of all ages interact with his art, he hopes they experience the same curiosity and wonder that he does during the creative process.

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